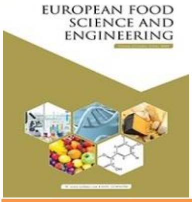

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Effect of fortification of defatted *moringa oleifera* seed flour on consumers acceptability and nutritional characteristics of wheat bread

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ABSTRACT

Bread was enhanced with defatted moringa seed flour in various quantities (0-7.5%) in this investigation. Results of the proximate analysis showed that defatted moringa seed flour addition significantly ($P<0.05$) increased the protein (13.82–15.39%), fat (1.25–1.56%), ash (1.51–1.61%) and fibre content (0.13–0.18%) of the bread samples, while the moisture (7.85–7.60%), carbohydrates content (75.44–72.88%) and pH (8.05-7.8%) of the bread decreased. Addition of defatted moringa seed flour significantly ($P<0.05$) decreased the loaf heights from 10.50 to 6.90 (cm), loaf weights from 133.1 to 118.0 (g), loaf volumes from 1148 to 671(cm^3), and the specific volumes from 9.05 to 5.55 (g/cm^3). The mineral contents (calcium, iron, sodium, potassium, and phosphorus) of the moringa fortified bread also increased significantly as the proportion of defatted moringa seed flour. Results of the sensory evaluation indicated that the 5% defatted moringa fortified bread was not significantly different from the bread produced from 100% wheat flour in terms of most of the quality attributes evaluated in this study. In conclusion, fortification of bread with defatted moringa seed flour increased both the micro and macronutrient of conventional bread and was acceptable to consumers at a 5% fortification level.

1. Introduction

Much of the discussion on food security is centered on feeding the world's population, which is expected to reach 8.4-8.7 billion by 2030, 9.4-10.2 billion by 2050, and 13.2 billion by 2100 (Eke & Elechi, 2021). These have resulted in the development of food production and processing technologies that are wreaking havoc on human and planetary health and obliterating the planet's safe operating zone (Leeuwis *et al.*, 2021; Elechi *et al.*, 2022). The present food processing system appears to be to blame for the growing availability of ultra-processed meals rich in calories, sugar, and salt, as well as nutrient-poor foods, greenhouse gas emissions that harm the environment, and increased food safety and health concerns (Elechi *et al.*, 2022). Diet-related hazards are now the world's third greatest cause of mortality, and malnutrition is a prominent cause of lost years of healthy life (Elechi *et al.*, 2022, GBD, 2020). These issues necessitate a transition in how we produce and process food toward a more sustainable system that incorporates innovations for healthy diets, responsible consumption, and carbon footprint reduction (Elechi *et al.*, 2022). As a result of the drive for a sustainable food system and healthy food design, food production systems that safeguard planetary and human health are to be adopted.

Poor dietary diversity is one of the primary causes of chronic malnutrition (poor quality and limited variety of foods in the diet). In country-level agri-food systems, there is also a clear link between over-reliance on a few staple commodities, insufficient dietary variety, and malnutrition. Food and production variety must be addressed from a food system viewpoint to prevent malnutrition. Plants that are *'lesser-known species'*, *'neglected crops'*, *'underutilized crops'*, *'marginal crops', poor men's crops', 'crops for the future'* with known economic value, as well as much good food and nutrient sources, are understudied and can be referred to as hidden treasures that offer enormous opportunities to combat poverty, hunger, and malnutrition (FAO, 2018). *Moringa oleifera*, sometimes known as the "*wonder plant" or "tree of life,"* is a highly nutritious plant whose leaves, roots, seeds, flowers, wood, and bark are utilized for nutritional, health, and pharmaceutical purposes all over the world (Otokpa *et al.*, 2019; Bolarinwa *et al.*, 2017). It is reported to contain over ninety antioxidants and to give more than 100% of the daily intake of B_{12}, riboflavin B_2, and thiamine B_1, all of which are essential nutrients for celiac disease sufferers (Otokpa *et al.*, 2019). *Moringa oleifera* also has anti-inflammatory, antispasmodic, antihypertensive, anticancer, antioxidant,

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antiulcer, antiepileptic, diuretic, cholesterol-lowering, renal, antidiabetic (Paliwal *et al.*, 2011), and hepatoprotective properties that work together for optimal iron absorption. Skin infections, anemia, anxiety, asthma, blackheads, blood impurities, bronchitis, catarrh, congested chest, cholera, and a variety of other ailments have all been treated with it (Mahmood *et al.*, 2010).

Bread is a fermented confectionary product created mostly from wheat flour, water, yeast, and salt through a number of procedures that include mixing, kneading, rising, shaping, and baking (Dewettinck *et al.*, 2008; Ochelle *et al.*, 2019). Bread is one of Nigeria's most essential staple foods and the country's most popular non-indigenous cuisine (Shittu *et al.*, 2007). It is a favorite of both youngsters and adults from all socioeconomic backgrounds. Bread may be served in a variety of ways; it can be eaten as a snack or used as a component in other dishes (Bolarinwa *et al.*, 2017). Mixed flour is suggested for bread preparation due to the high cost of wheat, which raises the cost of bread (Olaoye *et al.*, 2006). Furthermore, bread is a high-energy diet that is high in carbohydrates and fat (Ameh *et al.*, 2013) but lacking in other nutrients including protein, minerals, and vitamins (Young, 2001). Many researchers have looked at the possibility of substituting wheat flour with other forms of flour to improve the nutritional content of bread (Adeleke & Odedeji, 2010; Olaoye *et al.*, 2006; Sanful and Darko, 2010; Abdelghafor *et al.*, 2011; Onuegbu *et al.*, 2013; Udoa *et al.*, 2013; Igbabul *et al.*, 2014; Nwosu *et al.*, 2014; Elechi *et al.*, 2020). Otokpa *et al.*, (2019) and Bolarinwa *et al.*, (2017) examined the acceptability and other features of the moringa seed-wheat bread combination; however, the nutritional efficacy of fortification with defatted *Moringa oleifera* seed flour and consumer acceptability of bread fortified with defatted *Moringa oleifera* seed bread has yet to be determined. This is becoming more important as consumer awareness of the link between food, health, and nutrition grows, and the creation of foods needs the inclusion of functional ingredients with a lower fat content from plant sources such as *Moringa oleifera.*

The adding of nutrients to food, whether or not the nutrients were previously present in the food, is known as a fortification. It is a method of enhancing a population's nutritional status. As a result, food fortification will remain an essential tool for treating and preventing specific nutritional deficiencies, as well as promoting general well-being in certain demographic groups and perhaps preventing certain chronic illnesses (Elechi *et al.*, 2020). Technological and scientific problems include identifying and developing fortifying agents that ensure product quality and bioavailability (Karmes *et al.*, 2006). According to Naghii (2007), fortified foods assist to maintain appropriate nutritional status and reduce the risk of iron deficiency, and fortified ready-to-eat cereals area popular technique. Identifying affordable, easily available foods with abundant nutrient sources will be a high complement for the food industry, especially in developing nations where the number of people living below the poverty line is significant (Hekmat *et al.*, 2015). The usage of this plant as a functional food component has expanded in recent years. The goal of this study was to examine how adding defatted *Moringa oleifera* seed meal to bread affected its nutritional value and customer appeal.

2. Materials and methods

2.1. Procurement of materials

The raw materials used in this research are *Moringa oleifera* seed flour and Wheat flour. Moringa oleifera seeds fruit pods were purchased from Mararaba market-a border between Nasarawa state and FCT-Abuja, while wheat flour and all other ingredients for baking (sugar, salt, fat, and yeast) were purchased from North bank market in Makurdi-Nigeria.

2.2. Sample preparation

Preparation of moringa seed flour

The *Moringa* seeds fruits pods were opened along the cracks and the seeds were collected and cleaned. The dried seeds were subjected to one treatment i.e. soaking in water at room temperature for 72 h. The soaked seeds were drained and oven-dried for 8 h at 60 ºC. The dried seeds were milled and the oil was extracted to obtain defatted cake. The defatted cake was further milled and sieved to obtain a fine powder. The flour sample was then packed in a plastic container sealed with nylon foil and stored in low-density polyethylene bags of ambient temperature prior to analysis.

Blends formulation and recipe for the production of bread

The composite flour blend and the recipe for the production of defatted moringa seed flour are shown in Table 1. The doughs from the flour blends were baked using the baking formula of 500 g of the flour blend, 10 g of yeast, 2 g of salt (NaCl), 20 g of sugar (sucrose), and 20 g of margarine, and approximately 250 mL of water.

Bread production process

A sieve with a mesh size of 500 µm was used to sift the wheat flour and moringa flour. The various formulas were precisely weighed and properly combined in clean bowls to produce the dough using the direct dough method, as stated in Table 1. The dough was hand-kneaded for around 40 minutes, using a floured surface to avoid pallets in the dough, until the gluten expanded, making the dough elastic. The dough was allowed to be proof for 30 min and kneaded again. The kneaded dough was transferred to the baking molds, which were greased before proving to prevent the dough from sticking together during baking. The dough was left to ferment in the baking pans covered with polyethylene bags for 45 min at room temperature, resulting in gassing and gluten development. The leavened dough was placed in the oven and baked for 30 minutes at 250 °C. The baked bread was taken out of the oven and placed on cooling racks. For examination, the bread samples were sealed in polythene bags and stored in a dry location.

2.3. Analyses

Determination of functional properties of defatted moringa flour

The bulk density (BD), reconstitution index, oil absorption capacity (OAC), solubility and water absorption capacity (WAC), swelling index (SI), and viscosity of defatted moringa seed flour were determined according to Fagbemi *et al.* (2005).

Determination of proximate composition

The moisture, raw protein, raw fiber, ash, fat, and carbohydrate of the moringa fortified bread samples and 100% wheat bread (control) were determined using a standard analytical method. The moisture, raw protein, raw fiber, fat, and ash were determined by using AOAC (2012). Carbohydrate was determined by difference (i.e. 100 -% protein, % moisture, % fiber, % fat, % ash).

Table 1. Blends formulation and recipe for the production of bread

Product code	Wheat flour (%)	Moringa Seed flour (%)	Salt (g)	Sugar (g)	Yeast (g)	Margarine (g)	Water (ml)
A	100	0	2	20	10	20	250
B	97.5	2.5	2	20	10	20	250
C	95	5	2	20	10	20	250
D	92.5	7.5	2	20	10	20	250

2.4. Evaluation of physical properties of bread

Determination of loaf weight

Bread weight was determined by the method described by (AOAC, 2012). Weights were recorded with an electronic balance (0.00)

Determination of loaf height

This was gotten using a meter rule to take the loaf height measurement. The meter rule was placed down beside the loaf until it reached the bottom. The height was then read off the meter rule.

Determination of loaf volume

The loaf volume of bread was determined by the seed displacement method (Penfield & Campbell, 1990). A 3000 mL graduated container was filled with millet seeds and poured into a measuring cylinder to note the volume of the rectangular box after filling with millet seeds to a flat level. The loaf was then placed in an empty container and filled to an equivalent height of the container with the millet seeds. The millet seeds were measured by using a measuring cylinder to note the volume of millet seeds displaced which is equivalent to a bread sample in the container.

Determination of specific loaf volume

The specific volume (cm3/g) of the bread was determined using the method of Penfield & Campbell (1990). The specific loaf volume was calculated by dividing the individual loaf volume of the bread by the weight of the bread.

$$Specific\ loaf\ volume\ (cm3/g) = \frac{loaf\ volume}{loaf\ weight}$$

Determination of mineral content

Mineral composition (iron, calcium, potassium, and phosphorus) was determined by acid digestion. Ash obtained after incineration at 600 °C was digested into a solution by wet digestion using a mixture of concentrated nitric, perchloric and sulphuric acids in the ratio of 9:2:1 respectively. Fe and Ca were determined by Atomic Absorption Spectrophotometer (AAS) (UNICAM 960 series). While K was determined using an atomic emission spectrometer (200-A model, Buck Scientific Ltd UK), and colorimetric method was used to determine Phosphorus (AOAC, 2000).

Consumer acceptability test

The moringa fortified bread samples were coded and served to thirty-five (35) untrained consumers and randomly selected judges using the method described by Ihekoronye & Ngoddy (1985). Consumers were recruited from the students and staff of the Federal University of Agriculture, Makurdi, Nigeria. The judges were asked to score the bread samples for color, shape, texture, sweetness, flavor, mouth feels, and overall acceptability, using a nine (9) point hedonic scale, where 1 to 9 represented dislikes extremely and like extremely, respectively. To unify the conditions of the evaluation, all samples were prepared in disposable plastic plates coded with a three-digit number, evaluated by each panellist in a monadic order, following a balanced-incomplete box design (Stone *et al.*, 2020). The samples were served in three sessions consisting of 3–4 samples for each round and served in random order to each panellist. During the test, the panellists were asked to pause between the samples and cleanse their palates with prepared tap water at room temperature (Samakradhamrongthai *et al.*, 2021). The evaluation was performed in individual booths under white light at the Sensory Evaluation and Consumer Testing Unit (Department of Food Science and Technology, College of Food Technology and Human Ecology, University of Agriculture, Makurdi, Nigeria).

2.5. Statistical analyses

All analytical determinations were conducted in 3 replications. Means and standard deviations were calculated. Data obtained were subjected to analysis of variance (ANOVA). Duncan's new multiple range tests (DNMRT) were used to compare the treatment means. Statistical significance was accepted at ($P<0.05$).

3. Results and Discussion

3.1. Functional properties of the defatted moringa seed flour

The result of the functional properties of the defatted Moringa seed flour is presented in Table 2. The functional properties of the defatted moringa seed flour showed bulk density (0.75g/ml), oil absorption capacity (88.45%), reconstitution index (76.28%), swelling index (8.25 g/vol), solubility (8.63%), viscosity (342.60 cp), and water absorption capacity (82.45%). The application of food materials in new product development is dependent on their functionality. The functional properties recorded in this study agree with the findings of Elechi & Sule (2021) for pumpkin seed flour; and Makinde & Joel (2019) for cashew flour.

3.2. Proximate composition of bread samples

Figure 1 shows that there were significant differences ($P<0.05$) in the proximate composition of the various samples of defatted moringa-wheat bread as compared to the control. An increase in the protein content from 13.83 to 15.39% was observed with an increase in the level of defatted moringa seed flour addition. The increment in the protein content of the fortified bread could be due to the high protein content of moringa seed used as fortifier. Moringa seed flour and moringa cake flour have been reported to contain 28% and 50.8% raw protein, respectively (Abiodun *et al.*, 2012). The protein content (13.83–15.39%) of the moringa fortified bread produced in this study is within the range of protein content (10.6–18%) of bread fortified with (5–20%) tilapia fish flour

Table 2. Functional properties of Moringa Oleifera Seed Flour Fundamental Behaviour of the flour.

Bulk Density (g/ml)	Oil Absorption Capacity (%)	Reconstitution index (%)	Swelling index (g/vol)	Solubility (%)	Viscosity (cp)	Water Absorption Capacity (%)
0.75	88.45	76.28	8.25	8.63	342.60	82.45

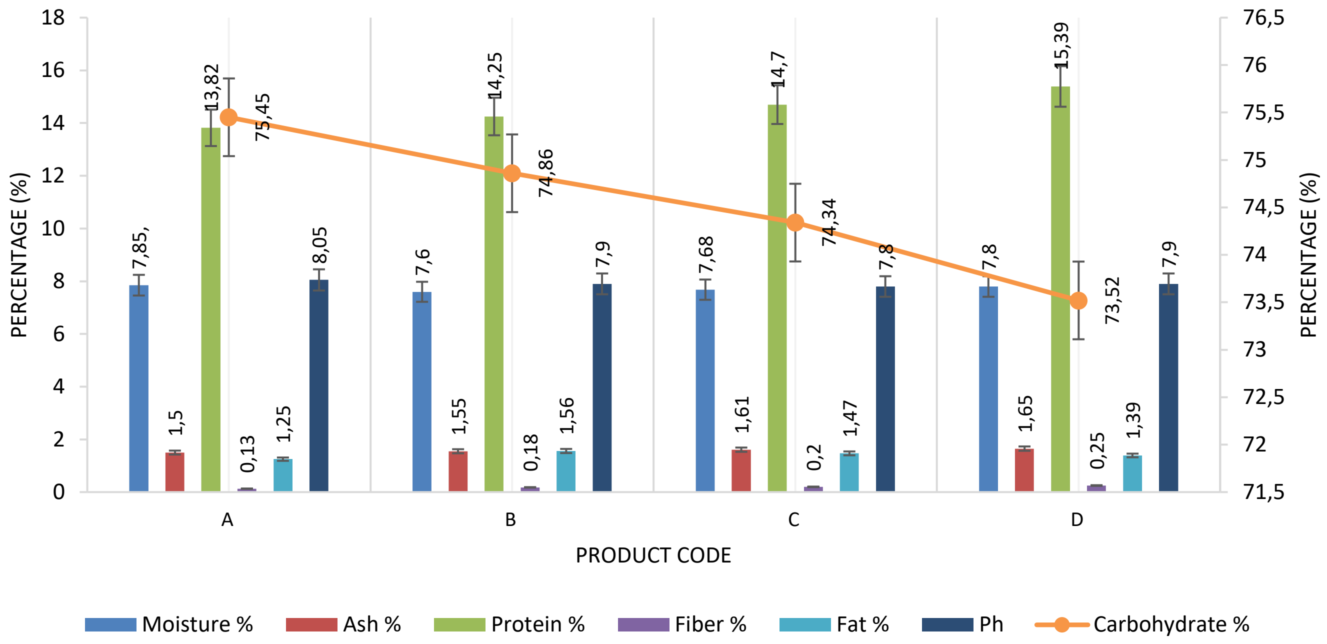

Figure 1. Proximate composition of bread samples

(Adeleke & Odedeji, 2010), (14–21%) of potato bread fortified with (30–70%) whole soy flour (Gomes Natal *et al*., 2013). The protein content of the defatted moringa fortified bread reported in this study is higher than that reported by Otokpa *et al*., (2019) and Bolarinwa *et al*. (2017) for moringa seed flour bread probably due to variations in the dough formulation and in the effect of defatting that produced concentrated protein Moringa cake.

There was no significant difference (P>0.05) in moisture contents (7.85 to 7.6%) of the bread samples compared to the control. The moisture content of this study was lower than that reported by Otokpa *et al*., (2019) and Bolarinwa *et al*. (2017) for bread fortified with moringa seed flour. The variation in the moisture contents of the bread samples could be due to variations in the chemical composition of ingredients, levels of fortification, and method of baking. However, the defatted moringa fortified bread in this study would have longer shelf life due to its relatively low moisture content (Bolarinwa *et al*., 2017).

The raw fiber contents (0.13-0.25%) of the bread samples also increased significantly (P<0.05) due to the fortification of wheat flour with moringa seed flour in the bread formulation. This is within the range (0.08–0.62%) reported by Bolarinwa *et al*. (2017) for moringa seed flour fortified bread but higher than (0.02-0.06%) reported by Otokpa *et al*. (2019) for moringa seed flour fortified bread and 0.03-0.14% report of Olaoye *et al*. (2006) for bread produced from composite flour of wheat, plantain, and soybeans. This could imply that defatting increases the fiber quality and quantity of food.

The relatively low-fat content (1.25-1.56%) of the defatted moringa fortified bread indicated that bread will have extended life and is suitable for fat-conscious consumers. The fat content (1.25–1.56%) of the moringa fortified bread samples reported in this study is lower than the fat content (19.43 to 23.66%) of Otokpa *et al*. (2019) and (7.3–15.8%) of Bolarinwa *et al*. (2017) for moringa fortified bread and (3.52–5.50%) of composite bread produced from wheat, maize and orange fleshed sweet potato flour as reported by Igbabul *et al*. (2014). This could be attributed to the effect of defatting of moringa seed.

Ash is an index of the mineral content of food. The increment (1.5–1.65%) in the ash content of the bread samples could probably be due to the higher ash content (4.1%) of moringa seed powder (Abiodun *et al*., 2012). The ash content (1.5–1.65%) obtained in this study is in line with the ash content (0.63–1.8%) and (1.41 to 1.63%) for bread fortified with moringa seed flour reported by Bolarinwa *et al*. (2017) and Otokpa *et al*. (2019) respectively. The ash content is also in agreement with the ash content (2.85–2.88%) of maize powder substituted with 20% soy powder (Edema *et al*., 2005) and the ash content (1.7–2.6%) of cookies fortified with dried moringa leaves (Haneen, 2015).

The carbohydrate content (75.45–73.53%) of the moringa fortified bread samples decreases as the substitution of moringa seed powder increases in the blend. Un-fortified bread had the highest carbohydrate content (75.45%) while 7.5% moringa fortified bread had the least carbohydrate content (73.53%). This observation was in line with other studies (Otokpa *et al*., 2019; Bolarinwa *et al*., 2017) that also reported a decreased in the level of the carbohydrate content of bread from moringa fortified bread. Sanful & Darko (2010) also reported a decrease of 36–39% in the carbohydrate content of bread produced from wheat and soy flour blends. The pH content (8.0-7.8%) of the fortified bread decreases with an increase in defatted moringa seed flour. A similar finding was reported by Eke & Elechi (2020) for meat pies sold in Nigeria.

3.3. Physical properties of bread samples

The results of the physical properties of the bread are presented in Figure 2. The loaf weight of the samples A, B, C,

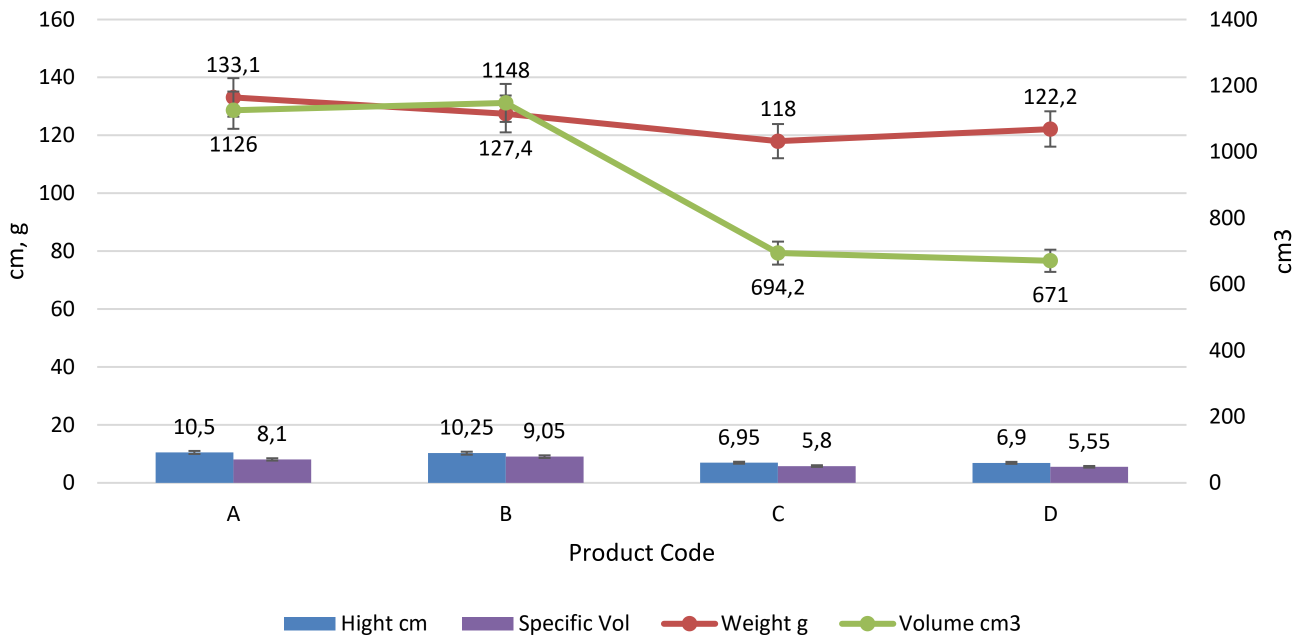

Figure 2. Physical properties of wheat bread fortified with defatted *Moringa oliefera* seed flour

and D decreased significantly (P<0.05). This disagrees with the findings of Ochelle *et al.* (2019) and Otokpa *et al.* (2019) who reported an increase in loaf weight as a result of relatively high moisture, and carbon dioxide diffusion, the nature of carbohydrates, and high bulk density of flour. However, the finding of this study agrees with Elechi *et al.* (2022) for carrot-mango fortified doughnut, Chong & Noor Aziah (2008) for a banana doughnut, Oke *et al.* (2018) for breadfruits doughnut and Satish *et al.* (2018) for millet doughnut. The loaf height and volume of the bread decreased from 10.5 cm to 6.9 cm and 1126 cm^3 to 671 cm^3 leading also to a general decrease in specific volume. But an increased volume and specific volume was observed from sample B which contained 95% Wheat flour, and 5% defatted moringa seed flour. The decrease in weight, height, volume, and specific volume could be attributed to the lower gluten content with an increase in non-gluten flour which could not be properly stretched by carbon dioxide (CO_2) gas during fermentation and proofing. Gluten is an important component in protein which gives a firmer dough matrix and manages to trap air cells to produce bread with greater volume. Elleuch *et al.* (2011) reported that the decrease may be due to the high fiber content of the moringa seed. A similar trend was observed by Dewettinck *et al.* (2008) and Ochelle *et al.* (2019).

3.4. Minerals content of fortified breads

Generally, the mineral contents of the moringa fortified bread increased as the substitution level of moringa seed powder increased in the flour blend as presented in Figure 3. The relatively high level of minerals in the fortified bread compared to the un-fortified bread could be due to the high contents of essential minerals in the moringa plant. Moringa leaves and seed has been reported to be rich in minerals that are essential for human development and growth (Mahmood et al., 2010). The calcium content of moringa powder is more than two times that of milk, and its iron content is more than that of spinach (Gopalakrishnan *et al.*, 2016). The calcium content (51.27-67.82 mg/100 g) of the defatted moringa fortified bread reported in this study was similar to (54–84 mg/100 g) of potato bread fortified with soybeans flour (Gomes Natal *et al.*, 2013) and higher than (0.002-0.065 mg/g) of Otokpa *et al.* (2019) but lower than the calcium content (563–826 mg/100 g) of Bolarinwa *et al.* (2017) for moringa seed flour fortified bread.

The iron content (1.57-2.66 mg/100 g) was also similar to the iron content (1.99 mg/100 g) of the bread of composite bread produced from wheat, maize, and orange-fleshed sweet potato flour (Igbabul *et al.*, 2014) and higher than 0.03 to 0.06 mg/kg of Otokpa *et al.* (2019) but lower than the iron content (19.4–26.4 mg/100 g) of Bolarinwa *et al.* (2017). Potassium and phosphorus are important components of cell and body fluids that help control heart beat rate and blood pressure. The potassium content (421.8-458.7 mg/100 g) reported in this study was higher than the potassium content (272.5–327 mg/100 g) of the moringa fortified bread reported by Bolarinwa *et al.* (2017) and potassium content (110.4–188.2 mg/100 g) of wheat bread supplemented with stabilized un-defatted rice bran (Ameh *et al.*, 2013). The phosphorus content (122.4-173.5 mg/100 g) was higher than (23.5–28.9 mg/100 g) of the moringa fortified bread (Bolarinwa *et al.*, 2017). The Sodium content of the bread sample increased from 332.5 to 374.9 mg/g.

3.5. Sensory attributes of the moringa fortified bread

The mean sensory scores of the moringa fortified bread a represented in Table 3. The scores of almost all the sensory attributes of the un-fortified bread were not significantly (P>0.05) different from the mean sensory scores of the wheat bread fortified with defatted moringa seed powder. The value for the aroma increased from sample B (2.5% moringa) which had the highest score of 7.23 to sample A with a value of 6.77. Then there was a reduction in the value of sample B C5.08 which was the lowest. While sample D had a value of 5.92. The aroma was based on the smell appeal; and the panelist showed a preference for sample A (100% wheat), Sample B (2.5% moringa), and sample D (92.5% Wheat flour, 7.5% Moringa seed flour). The taste of the bread did not show a significant difference (P<0.05) between samples A and B. There was a decrease in the value across the sample with Sample C and D with sample C (95% wheat flour, 5% moringa seed flour) having the lowest value of 5.08.

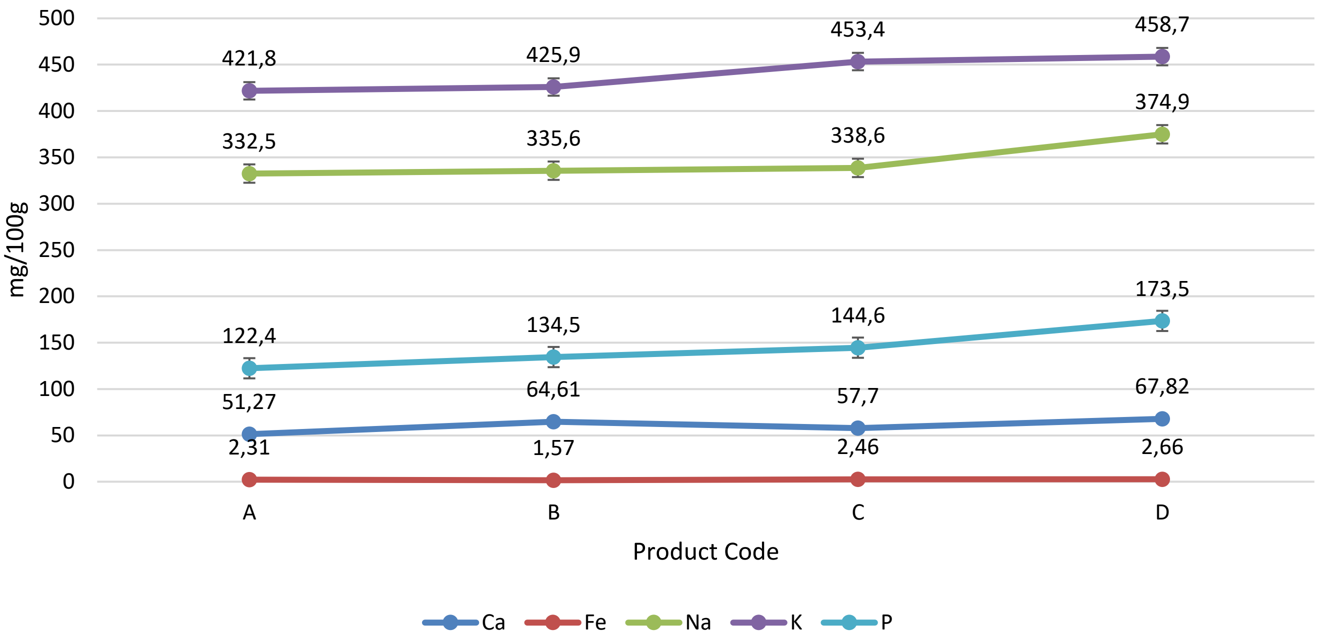

Figure 3. Mineral contents of bread samples (Key: Ca: Calcium, Fe: Iron, Na: Sodium, K: Potassium, P: Phosphorous)

Table 3. Consumer acceptability scores of bread samples

Parameter	Sample Code			
	A	B	C	D
Appearance (Crust)	6.69^{ab}	7.46^{a}	6.08^{b}	6.92^{ab}
Taste	6.54^{a}	7.15^{a}	5.08^{b}	5.51^{b}
Aroma	6.77^{a}	7.23^{a}	5.08^{b}	5.92^{ab}
Crust Texture	6.77^{a}	6.85^{a}	5.69^{b}	6.38^{ab}
Crumb Texture	7.08^{a}	7.23^{a}	5.85^{c}	6.48^{ab}
Crumb Colour	7.00^{ab}	7.38^{a}	6.08^{b}	7.08^{ab}
Overall Acceptability	7.31^{a}	7.54^{a}	5.77^{b}	5.85^{b}

Values on the row with different superscripts are significantly different (P<0.05)

The color was based on the color appeal. The panelists showed a preference for the brown color of sample B. Browning in the bread samples could have been due to Maillard-type reactions (Potter & Hotchkiss, 2006) resulting from the presence of reducing sugars, proteins, and amino acids and caramelization due to the effect of severe heating during processing (Mannay & Shadaksharaswany, 2005). The scores for the texture (softness and smoothness) of the bread sample were not significantly changed across the sample ranging from 7.23 (sample B) to 5.83 (sample C). Crumb that was associated with increased fiber was probably, mellowed by the oil contents. The baking conditions (temperature and time variables), the state of the bread constituents such as fiber, starch, and protein; and the amount of water absorbed during dough mixing will all contribute to the outcome of the overall acceptability (Bakke & Vickers, 2007). All the samples were generally accepted by the consumers having achieved a mean score above 5. According to Knuckles *et al.* (1997), in sensory evaluation, products with a score value of more than 5 for overall acceptability can be considered a good quality product. This, indicate the feasibility of adding moringa seed powder to bread. This result suggests the potential of using moringa seed powder as a food fortifier. Similar results were obtained by Otokpa *et al.* (2019) and Bolarinwa *et al.* (2017) for moringa seed flour fortified bread.

3. Conclusions

The enriched bread has higher amounts of carbohydrates, minerals, and vitamin A after being supplemented with defatted moringa seed powder. Consumers overwhelmingly approved of all samples, with a pass average score of more than 5. The bread with 2.5 percent moringa seeds powder, on the other hand, had the finest sensory attributes. This study found that fortifying wheat bread with moringa seed powder resulted in a significant increase in the bread's protein content, which might be of tremendous nutritional value to impoverished nations where many high-protein meals are prohibitively expensive. Due to the high mineral content of fortified bread, defatted moringa-enriched bread may be able to aid in the reduction of hidden hunger in underdeveloped nations.

Availability of data and material

Data included in the article/supplementary material/referenced in the article.

Ethics approval and consent to participate

The researchers applied the principle of voluntary participation confidentiality and anonymity in the study to ensure that the rights of the panelists were respected. Letter of approval for the study was obtained from Department of Food Science and Technology, Federal University of Agriculture, Makurdi, Nigeria and informed consent (verbal) was obtained from each of the panelists before the sensory evaluation was conducted

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Disclosure statement

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References

Abdelghafor, R. F., Mustafa, A. I., Ibrahim, A. M. H., & Krishnan, P. G. (2011). Quality of bread from composite flour of sorghum and hard white winter wheat. *Advance Journal of Food Science and Technology*, *3*(1), 9-15.

Adeleke, R. O., & Odedeji, J. O. (2010). Acceptability studies on bread fortified with tilapia fish flour. *Pakistan Journal of Nutrition*, *9*(6), 531-534.

Ameh, M. O., Gernah, D. I., & Igbabul, B. D. (2013). Physico-chemical and sensory evaluation of wheat bread supplemented with stabilized undefatted rice bran. *Food and Nutrition Sciences*, *4*(09), 43.

AOAC. (2012). Official Methods of Analysis. 18th Edition, Association of Official Analytical Chemists, Arlington.

Bakke, A., & Vickers, Z. (2007). Consumer liking of refined and whole wheat breads. *Journal of food science*, *72*(7), 473-480. Doi:10.1111/j.1750-3841.2007.00440.x

Chong, L. C., & Noor Aziah, A. A. (2008). Influence of partial substitution of wheat flour with banana (Musa paradisiaca var. Awak) flour on the physico-chemical and sensory characteristics of doughnuts. *International Food Research Journal*, *15*(2), 119-124.

Dewettinck K., Bockstaele, F.V., Kuhne, B., Van-de, W., Courtens, T., & Gellynck, X. (2008). Nutritional value of bread; influence of processing, food interaction and consumer perception. Review. *Journal of Cereal Science*, *48*, 243-257.

Edema, M. O., Sanni, L. O., & Sanni, A. I. (2005). Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria. *African Journal of Biotechnology*, *4*(9), 911-918.

Eke, M. O., & Elechi, J. O. (2021). Food safety and quality evaluation of street vended meat pies sold in Lafia Metropolis, Nasarawa state, Nigeria. *International Journal of Scientific Research in Biological Sciences*, *8*(1), 88-98.

Elechi, J. O. G., Nwiyi, I. U., & Adamu, C. S. (2022). Global Food System Transformation for Resilience. In A. I. Ribeiro-Barros, D Tevera, L.F. Goulao and L.D Tivana (Eds). Food Systems Resilience. IntechOpen Limited. London. United Kingdom. Doi:10.5772/intechopen.102749

Jasper, E., Cornelius, A., & Salam, S.B. (2020). Quality Evaluation of Bread Fortified with Pumpkin (Cucurbitapepo) Seed Milk. *Global Scientific Journal*, *8*(2), 4778-4795.

Elechi, J.O.G., & Sule, J. I. (2021). Influence of Traditional Food Processing Systems on Food Safety, Chemical Compositions and Functional Properties of Pumpkin (Cucurbita pepo L) Seed Flour. Journal of Nutrition and Food Security. (INPRESS)

Elechi, J.O.G, Sampson Eno-Obong Abia, Adamu Cornelius S, Nzuta Rimancwe A and Adejoh Benjamin Joseph (2022) Product Development, Nutritional Characteristics and Consumers Acceptability Studies of Doughnut Partially Substituted with Carrot *(Daucus carota)* and Mango *(Mangifera indica L)* Flour Fortified with Date (*Phoenix dactylifera L*) Fruits Syrup as Sweetener. Food and Applied Bioscience Journal. (INPRESS).

Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C., & Attia, H. (2011). Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review. *Food chemistry*, *124*(2), 411-421. doi:10.1016/j.foodchem.2010.06.077

Fagbemi, T.N, Oshodi, A.A., & Ipinmoroti, K.O. (2005). Effects of processing on the functional properties of full fatted and defatted fluted pumpkin (*Telfairia occidentalis*) seed flour. *Journal of Food Technology,* 3(3), 370-377.

FAO. (2018). Future Smart Food Rediscovering hidden treasures of neglected and underutilized species for Zero Hunger in Asia, Executive summary, Bangkok.

Gopalakrishnan, L., Doriya, K., & Kumar, D.S., (2016). Moringa oleifera: a review on nutritive importance and its medicinal application. *Food Science and Human Wellness*, *5*, 49–56. doi:10.1016/j.fshw.2016.04.001

GBD (Global Burden of Disease Study) (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990– 2019: A systematic analysis for the global burden of disease study 2019. The Lancet. 396:1204-1222

Mouminah, H.H.S. (2015). Effect of dried Moringa oleifera leaves on the nutritional and organoleptic characteristics of cookies. *Alexandria Science Exchange Journal*, *36*, 297-302. doi: 10.21608/asejaiqjsae.2015.2934

Hekmat, S., Morgan, K., Soltani, M., & Gough, R. (2015). Sensory evaluation of locally-grown fruit purees and inulin fibre on probiotic yogurt in Mwanza, Tanzania and the microbial analysis of probiotic yogurt fortified with Moringa oleifera. *Journal of Health, Population, and Nutrition*, *33*(1), 60-70.

Igbabul, B., Num, G., & Amove, J. (2014). Quality evaluation of composite bread produced from wheat, maize and orange fleshed sweet potato flours. *American Journal of Food Science and Technology, 2*(4), 109–115.

Ihekoronye A.I., & Ngoddy, P.O. (1985). Integrated food science and technology for the tropics. Macmillan Publisher LTD, London.

Bolarinwa, I. F., Aruna, T. E., & Raji, A. O. (2019). Nutritive value and acceptability of bread fortified with moringa seed powder. *Journal of the Saudi Society of Agricultural Sciences*, *18*(2), 195-200. Doi:10.1016/j.jssas.2017.05.002

Mahmood, K. T., Mugal, T., & Haq, I. U. (2010). Moringa oleifera: a natural gift-A review. *Journal of Pharmaceutical Sciences and Research*, *2*(11), 775.

Knuckles, B. E., Hudson, C. A., Chiu, M. M., & Sayre, R. N. (1997). Effect of β-glucan barley fractions in high-fiber bread and pasta. *Cereal Foods World*, *42*(2), 94-99.

Leeuwis, C., Boogaard, B. K., & Atta-Krah, K. (2021). How food systems change (or not): Governance implications for system transformation processes. *Food Security*, *13*(4), 761-780. Doi:10.1007/s12571-021-01178-4

Maria, M. F., & Hannah, J. I. (2019). The impact of processing methods on chemical composition, mineral bioavailability and functional properties of Nigerian-grown cashew flour. *International Journal of Food Studies*, *8*(1). Doi:10.7455/ijfs/8.1.2019.a1

Mannay S., & Shadaksharaswany, C. M. (2005) Foods: facts and principles. (2nd ed.). New Age International Ltd. Publishers. New Delhi, India.

Gomes Natal, D. I., Souza Dantas, M. I. D., Teixeira Ribeiro Vidigal, M. C., Machado Rocha Ribeiro, S., Ribeiro Silva, R., & Stampini Duarte Martino, H. (2013). Physical and sensorial properties of potato breads fortified with whole soybean flour. *Revista Chilena de Nutrición*, *40*(1), 62-70.

Nwosu, J.N., Owuamanam, C.I., Omeire, G.C., & Eke, C.C. (2014). Quality parameters of bread produced from substitution of wheat flour with cassava flour using soybean as an improver. *American Journal of Research Communication*, *2*(3), 99–180.

Ochelle P.O., Ikya, J.K., Ameh, C.O. & Gbaa, S.T. (2019). Quality assessment of bread from wheat, water yam and soybean flours. *Asian Food Science Journal*, *10*, 2581-7752.

Oke, E. K., Tijani, A. O., Abiola, O. T., Adeoye, A. K., & Odumosu, B. O. (2018). Effects of partial substitution of wheat flour with breadfruit flour on quality attributes of fried doughnut. *Journal of Agricultural Sciences*, *13*(1), 72-80. Doi: 10.4038/jas.vl3il.8302

Olaoye, O. A., Onilude, A. A., & Idowu, O. A. (2006). Quality characteristics of bread produced from composite flours of wheat, plantain and soybeans. *African journal of Biotechnology*, *5*(11), 1102-1106.

Onuegbu, N.C., Ihediohanma, N.C., Odunze, O.F., Ojukwu, M., (2013). Efficiency of wheat: maize composite flour as affected by baking method in bread and cake production. *Sky Journal of Food Science*, *2*(8), 5-13.

Otokpa Edu Comfort, Ochelle Paul Ohini, Ikala Gloria Ulenya, Akor Isaac Ahangba (2019) Physio-chemical and sensory properties of wheat bread fortified with moringa oleifera seed flour. *Noble International Journal of Agriculture and Food Technology*, *1*(1), 01-12.

Paliwal, R., Sharma, V., & Sharma, S. (2011). Elucidation of free radical scavenging and antioxidant activity of aqueous and hydro-ethanolic extracts of Moringa oleifera pods. *Research Journal of Pharmacy and Technology*, *4*(4), 566-571.

Penfield, M.P., & Campbell, A. M. (1990). Experimental Food Science, 3rd ed., 541 pp., Academic Press, Orlando, FL.

Potter, N., & Hotchkiss, J. (2006). Food Science. 5th ed. CBS Publishers and distributors. Daryangaji, New Delhi, India,

Samakradhamrongthai, R. S., Jannu, T., & Renaldi, G. (2021). Physicochemical properties and sensory evaluation of high energy cereal bar and its consumer acceptability. *Heliyon*, *7*(8), e07776. Doi:10.1016/j.heliyon.2021.e07776.

Sanful, R. E., & Darko, S. (2010). Utilization of soybean flour in the production of bread. *Pakistan Journal of Nutrition*, *9*(8), 815-818.

Shittu, T.A., Raji, A.O., & Sanni, L.O., (2007). Bread from composite cassava wheat powder: I. Effect of bakingtime and temperature on some physical properties of bread loaf. *Food Research International, 40*, 280–290. Doi:10.1016/j.foodres.2006.10.012

Stone, H., Bleibuam, R.N., & Thomas, H.A. (2020). Sensory Evaluation Practices, 5th ed. Academic Press.

Udofia, P. G., Udoudo, P. J., & Eyen, N. O. (2013). Sensory evaluation of wheat-cassava-soybean composite flour (WCS) bread by the mixture experiment design. *African Journal of Food Science*, *7*(10), 368-374.

Young, J. (2001). Functional bakery products: current directions and future opportunities. *Leatherhead Food Ra Rood Industry Journal*, *4*, 136-144.