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Evaluation of Macronutrient and Selected Micronutrient Contents of Peanut Butter Fortified with Moringa Leaf Powder

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Authors' contributions

This work was carried out in collaboration among all authors. Authors OOB and IAD conceptualized and designed the study, performed the statistical analysis, and wrote the initial draft of the manuscript. Authors KPO and ORO contributed to the experimental procedures, managed data collection, and helped in interpreting the results. Author's FAO and TSO conducted literature searches, edited the manuscript, and ensured the manuscript met journal standards. All authors read and approved the final manuscript.

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ABSTRACT

Background to the Study: The increasing prevalence of malnutrition and micronutrient deficiencies, particularly in developing countries, necessitates the development of affordable, nutrient-dense foods.

Aim: This study aim to develop and evaluate the nutritional and sensory properties of peanut butter fortified with moringa leaf powder to enhance its macronutrient and micronutrient composition for addressing malnutrition.

Place and Duration of Study: Conducted in the dietetics kitchen of the Department of Human Nutrition and Dietetics, Lead City University, Ibadan, Oyo State, Nigeria, between February to May 2024

Methodology: Peanut butter was prepared using roasted groundnuts and fortified with varying levels of moringa leaf powder. A 70:30 ratio was applied for the peanut seeds and moringa powder respectively. The fortified peanut butter was prepared using standard methods, including sorting, roasting, de-hulling, grinding, and fortification. Nutritional analyses were conducted to determine proximate composition (protein, fat, fiber, ash, and carbohydrate) and micronutrient levels (iron, potassium, zinc, vitamin B6, and vitamin A). Sensory evaluation was performed using a 9-point hedonic scale to assess taste, texture, color, and overall acceptability. Data were analyzed using ANOVA with the Statistical Package for the Social Sciences (SPSS) Version 22.0, and differences between means were considered significant at $p < 0.05$.

Results: The results showed significant improvements in the nutritional composition of the fortified peanut butter compared to the control. Protein, fat, and fiber levels in the fortified product were 26.23 ± 0.08%, 52.66 ± 0.01%, and 4.87 ± 0.03%, respectively, compared to 24.84 ± 0.06%, 50.68 ± 0.01%, and 4.35 ± 0.01% in the control. Fortification also enhanced micronutrient levels, with iron and zinc increasing from 5.25 ± 0.02 mg/100 g and 3.24 ± 0.03 mg/100 g in the control to 7.14 ± 0.02 mg/100 g and 4.80 ± 0.03 mg/100 g in the fortified product. Sensory evaluation indicated higher scores for color but slightly lower scores for flavor and texture in the fortified samples ($p < 0.05$).

Conclusion: Fortifying peanut butter with moringa leaf powder significantly enhances its nutritional profile, particularly for iron, potassium, zinc, vitamin B6, and vitamin A. This fortified product presents a viable, cost-effective intervention for combating malnutrition in resource-limited regions. The study emphasizes the potential for large-scale production and highlights the need for further research on consumer acceptability and shelf stability.

Keywords: Peanut butter; moringa leaf powder; food fortification; malnutrition; nutritional composition; sensory evaluation; micronutrients; protein enrichment.

1. INTRODUCTION

The growing recognition of medicinal plants as both dietary and therapeutic resources highlights their significant role in improving human health and well-being (Davis & Choisy, 2024). Beyond their use as food, plant-based products contribute essential macro- and micronutrients and bioactive compounds, supporting the prevention and management of chronic diseases such as cancer, diabetes, and cardiovascular disorders (Haver & Cronise, 2017). Among these, dark green leafy vegetables stand out for their rich nutrient profiles, providing iron, calcium, zinc, provitamin A carotenoids, vitamin C, and folic acid, all of which are critical for human nutrition (Melse-Boonstra 2020).

Moringa oleifera, known as the "miracle tree," is a prime example of such plants. Native to the Sub-Himalayan tracts of India and Africa, moringa is a powerhouse of nutrients, boasting more vitamin A than carrots, more calcium than milk, and more protein than eggs (Islam et al., 2021). Its leaves have been widely used in Africa and Asia to combat malnutrition, particularly among children, and to enhance the nutritional value of processed foods like bread, biscuits, and spreads (Ferreira et al., 2023). The fortification of traditional diets with moringa is gaining popularity as a cost-effective strategy to address micronutrient deficiencies in resource-limited settings.

Malnutrition remains a pervasive issue in many developing countries, including Nigeria, where high rates of wasting and underweight children under five years old highlight the inadequacy of staple-based diets. These diets, primarily composed of starchy foods, lack diversity and are deficient in essential nutrients like protein, iron, and zinc (John et al., 2024). While peanut butter is a highly cherished food spread in these regions due to its affordability and rich protein content, it falls short in providing sufficient micronutrients required for optimal health (Arya et al., 2016). To address these challenges, fortifying peanut butter with moringa leaf powder offers a practical and sustainable solution. Moringa's exceptional nutrient density, including its high iron, calcium, and vitamin content, can complement the macronutrient-rich profile of peanut butter (Islam et al., 2021). This combination has the potential to enhance dietary diversity and provide a fortified product capable of alleviating malnutrition in vulnerable populations.

Studies have shown that food fortification is a cost-effective strategy to address nutrient deficiencies, particularly in children (Olson et al., 2021). Studies on moringa have demonstrated its efficacy in improving the nutritional content of various foods, including maize-based porridge, cookies, and yogurts (Oyeyinka & Oyeyinka, 2018). Additionally, peanut butter, with its high levels of protein and unsaturated fats, has been successfully used in therapeutic feeding programs to combat severe malnutrition (Abubakar, 2022). The integration of moringa leaf powder into peanut butter production represents an innovative approach to create a nutrient-dense, culturally acceptable, and economically viable product. The importance of leveraging plant-based foods for addressing malnutrition is well-documented. Dark green leafy vegetables, like moringa, are highlighted in numerous studies for their superior nutrient density and role in combating micronutrient deficiencies (Glover-Amengor et al., 2016). Studies reveal that moringa leaves contain 25 times more iron than spinach, 17 times more calcium than milk, and 9 times more protein than yogurt, making it a potent candidate for combating malnutrition (Islam et al., 2021). Furthermore, moringa's ability to retain nutrients during drying and processing enhances its utility as a fortifying agent in food products.

Fortified peanut butter has been a cornerstone in therapeutic feeding programs in regions with high rates of malnutrition. A study by Bai et al. (2022) demonstrated the efficacy of fortified peanut-based ready-to-use therapeutic foods (RUTFs) in reducing wasting among children under five. However, while these products excel in macronutrient content, their micronutrient profiles are often suboptimal. Incorporating moringa leaf powder into such spreads addresses this gap, as shown in studies where moringa significantly improved the iron and zinc levels of baked goods and cereals. Research has emphasized the critical role of iron and zinc fortification in reducing anemia and promoting cognitive development in children (Mamun et al., 2017). A study demonstrated that diets fortified with moringa leaf powder enhanced the bioavailability of these minerals, helping to reduce anemia by up to 40% among school-aged children (Shija et al., 2019). Similarly, zinc fortification has been linked to improved immune function, particularly in malnourished populations.

From a global perspective, the integration of moringa into staple food systems aligns with sustainable development goals (SDG 2: Zero Hunger). Studies in Ethiopia and Malawi show that adding moringa to food systems significantly improved community nutrition while promoting agricultural sustainability. Moringa's adaptability to arid climates and its high yield per hectare further underscore its potential as a scalable solution to malnutrition.

The sensory and acceptability aspects of moringa-fortified foods have also been explored extensively. Chinma et al. (2014) investigated the fortification of cookies with moringa powder and observed high consumer acceptance despite initial skepticism about the taste and texture. This highlights the potential for integrating moringa into culturally familiar foods like peanut butter. Furthermore, the ability of peanut butter to mask the strong flavor of moringa increases its feasibility for widespread adoption.

This study focuses on producing peanut butter fortified with moringa leaf powder, determining its macronutrient and selected micronutrient composition, and evaluating its sensory acceptability. Conducted in the dietetics kitchen of Lead City University, Ibadan, this research aims to contribute to the development of affordable, nutrient-enriched food spreads that can improve the nutritional status of populations in developing countries. By enhancing the micronutrient profile of peanut butter, this study seeks to provide a scalable solution to address the persistent issue of malnutrition in resource-limited settings.

2. METHODOLOGY

2.1 Materials Procurement

Peanuts, peanut oil, moringa powder, sugar, and salt were purchased from Orita Market, New

Garage, Ibadan, Oyo State, Nigeria. Additional equipment, including water, bowls, spoons, pans, and a blender, were supplied by the Department of Human Nutrition and Dietetics, Lead City University, Ibadan, Oyo State.

2.2 Preparation of Peanut Butter Fortified with Moringa Leaf Powder

2.2.1 Sorting and pre-processing

Peanuts (2400 g) were sorted to remove dirt and damaged nuts. The sorted peanuts were soaked with 100 g of salt in 5 liters of water for 20 minutes. After soaking, the peanuts were drained and spread on a tray to dry.

2.2.2 Roasting

Salt was heated in a pan, and the dried peanuts were roasted with continuous stirring for 10 minutes at 100°C. During the roasting process, the peanut skins changed from bright red to dull red, and the nuts themselves turned light brown.

2.2.3 Cooling and de-hulling

The roasted peanuts were allowed to cool on a tray to halt the cooking process. Skins were removed by rubbing the peanuts between palms, and discolored nuts were discarded.

2.2.4 Blending and fortification

The cleaned peanuts were ground using an electric blender. During the blending process, sugar and moringa powder were incorporated at a fortification ratio of 30% moringa powder and 70% peanut butter, to produce fortified peanut butter.

2.2.5 Packaging

The final product was packaged in airtight glass containers and stored at ambient temperature.

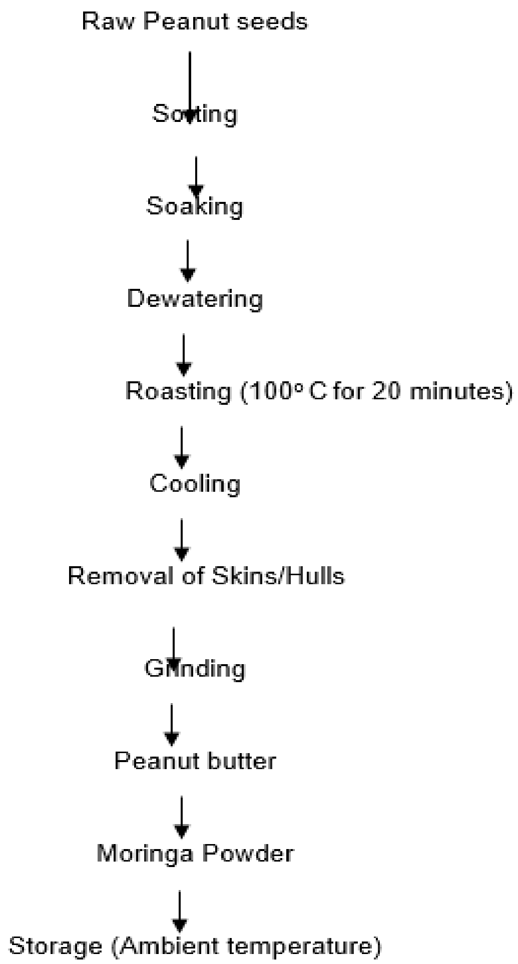

Fig. 1. Flowchart for peanut butter fortification

2.3 Proximate Analysis

2.3.1 Crude protein determination

The semi-micro Kjeldahl method was employed for determining crude protein. This involved digestion, distillation, and titration processes to measure nitrogen content. The protein content was calculated by multiplying the nitrogen percentage by a conversion factor of 5.46 (FAO, 2003).

2.3.2 Crude fat determination

Fat content was measured using a Soxhlet extraction method with petroleum ether as the solvent. The percentage of fat was calculated based on the weight of extracted oil relative to the initial sample weight (Geeth et al., 2020).

2.3.3 Carbohydrate determination

Carbohydrate content was determined by difference. This was achieved by subtracting the sum of moisture, protein, fat, and ash percentages from 100 (AOAC, 1990).

2.3.4 Moisture and ash content

Moisture content was assessed by oven-drying, while ash content was determined by incinerating the sample in a muffle furnace.

2.4 Micronutrient Analysis

Selected micronutrients, including iron, zinc, calcium, and vitamins, were analyzed using atomic absorption spectrophotometry (AAS) and spectrophotometric methods following established protocols (Namik and Yavuz, 2006).

2.5 Sensory Evaluation

A sensory evaluation was conducted with a panel of untrained testers. Attributes such as taste, texture, aroma, and overall acceptability were assessed using a 9-point hedonic scale (Kemp et al., 2013).

2.6 Statistical Analysis

All experiments were conducted in triplicate. Data were analyzed using ANOVA with the Statistical Package for the Social Sciences (SPSS) Version 22.0, and differences between means were considered significant at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Proximate composition of peanut butter with moringa

The proximate composition of the peanut butter samples is summarized in Table 1. The moisture, protein, fat, fiber, and ash contents were significantly higher ($p<0.05$) in peanut butter fortified with moringa (2.12 ± 0.01%, 26.23 ± 0.08%, 52.66 ± 0.01%, 4.87 ± 0.03% and 3.26 ± 0.02%, respectively) compare to the peanut butter (2.05 ± 0.01%, 24.84 ± 0.06%, 50.68 ± 0.01%, 4.35 ± 0.01% and 2.53 ± 0.02%, respectively). However, the carbohydrate content was significantly higher in peanut butter (15.56 ± 0.03%) compare to peanut butter fortified with moringa (10.87 ± 0.04%).

3.2 Micronutrient Content of Peanut Butter with Moringa

Micronutrient analysis revealed that peanut butter with moringa had higher iron (7.14 ± 0.02 mg/100 g), potassium (405.70 ± 0.14 mg/100 g), and zinc (4.80 ± 0.03 mg/100 g) levels compared to peanut butter (5.25 ± 0.02 mg/100 g, 389.25 ± 0.21 mg/100 g, and 3.24 ± 0.03 mg/100 g, respectively). Vitamin B6 and vitamin A contents were also higher in peanut butter with moringa, at 0.45 ± 0.00 mg/100 g and 395.84 ± 0.03 mg/100 g, respectively, compared to 0.44 ± 0.00 mg/100 g and 378.71 ± 0.02 mg/100 g in peanut butter.

Table 1. Proximate composition of peanut butter with moringa, (%)

Samples	Moisture	Protein	Fat	Fibre	Ash	Cho
A	2.05±0.01^b	24.84±0.06^b	50.68±0.01^b	4.35±0.01^b	2.53±0.02^b	15.56±0.03^a
B	2.12±0.01^a	26.23±0.08^a	52.66±0.01^a	4.87±0.03^a	3.26±0.02^a	10.87±0.04^b

A- peanut butter, B- peanut butter with moringa; Data are mean values of duplicate determinations; a,b: means with different superscripts in the same row were significantly different ($p≤0.05$). CHO- carbohydrate. The standard deviation of means is presented as '±' in the table.

Table 2. Micronutrient content of peanut butter with moringa, (mg/100g)

Samples	Iron	Potassium	Zinc	Vitamin B6	Vitamin A
A	5.25±0.02[b]	389.25±0.21[b]	3.24±0.03[b]	0.44±0.00[b]	378.71±0.02[b]
B	7.14±0.02[a]	405.70±0.14[a]	4.80±0.03[a]	0.45±0.00[a]	395.84±0.03[a]

A- peanut butter, B- peanut butter with moringa; Data are mean values of duplicate determinations; a,b: means with different superscripts in the same row were significantly different (p≤0.05). CHO- carbohydrate. The standard deviation of means is presented as '±' in the table.

3.3 Sensory Evaluation

The sensory evaluation results, presented in Table 3, show that peanut butter with moringa scored significantly higher for color (2.90 ± 0.32) compared to peanut butter (1.70 ± 0.48). However, peanut butter received slightly higher scores for texture (1.70 ± 0.48) and flavor (1.00 ± 0.00) than peanut butter with moringa (1.40 ± 0.52 and 1.10 ± 0.32, respectively). Both samples received similar ratings for taste.

3.4 Acceptability

Table 4 summarizes the overall acceptability of the samples. Peanut butter scored higher for taste (4.30 ± 0.48), color (4.80 ± 0.63), and aroma (4.30 ± 0.68) compared to peanut butter with moringa. peanut butter with moringa had a slightly higher score for texture (4.10 ± 0.88) than peanut butter (4.00 ± 0.47).

4. DISCUSSION

The study's micronutrient analysis of peanut butter and its moringa-fortified counterpart highlights significant nutritional differences that align with established research. Control peanut butter demonstrated the lowest moisture content (2.05 ± 0.01%), whereas peanut butter fortified with moringa exhibited a slightly higher moisture content (2.12 ± 0.01%). This increase in moisture content aligns with studies on moringa-fortified foods such as cakes and maize-ogi, where similar increases were observed with greater moringa inclusion (Kolawole et al., 2013). Comparable trends were noted in bread fortified with moringa seed powder, further supporting the present findings (Bolarinwa et al., 2017). Additionally, the moisture levels observed in the peanut butter samples correspond with previous data from studies on the proximate composition of retail peanut butter in Côte d’Ivoire (Zamble-Boli et al., 2013, Zamblé et al. 2013).

Peanut butter with moringa exhibited significantly higher protein, fat, fiber, and ash content than the control. These findings are consistent with previous research demonstrating that fortification with moringa leaf powder increases macronutrient levels in primary foods (Abioye and Aka, 2015; Moyo et al., 2011). The high protein content of moringa leaves (approximately 28-30%) contributes to this enhancement. Fortification transforms peanut butter into a more nutritious snack by enriching its protein profile, contrasting with carbohydrate-dominant options like cake flour. Meanwhile, peanut butter (control) retained a higher carbohydrate content, consistent with previous studies that reported lower carbohydrate levels in moringa-fortified products like bread (Bolarinwa et al., 2017).

Table 3. Sensory evaluation of peanut butter with moringa, (mg/100g)

Samples	Taste	Color	Texture	Flavor
A	2.90±0.31[a]	1.70±0.48[b]	1.70±0.48[a]	1.00±0.00[a]
B	2.90±0.32[a]	2.90±0.32[a]	1.40±0.52[b]	1.10±0.32[a]

A- peanut butter, B- peanut butter with moringa; Data are mean values of duplicate determinations; a,b: means with different superscripts in the same row were significantly different (p≤0.05). CHO- carbohydrate. The standard deviation of means is presented as '±' in the table.

Table 4. Acceptability of peanut butter with moringa

Samples	Taste	Color	Texture	Aroma
A	4.30±0.48[a]	4.80±0.63[a]	4.00±0.47[a]	4.30±0.68[a]
B	3.90±0.88[a]	3.50±1.58[b]	4.10±0.88[a]	4.10±0.74[a]

A- peanut butter, B- peanut butter with moringa; Data are mean values of duplicate determinations; a,b: means with different superscripts in the same row were significantly different (p≤0.05). CHO- carbohydrate. The standard deviation of means is presented as '±' in the table.

Regarding mineral content, peanut butter with moringa contained significantly higher levels of iron, zinc, calcium, and potassium compared to the control. This outcome reflects moringa's exceptional mineral density, known to surpass milk in calcium, bananas in potassium, and spinach in iron content (Khawaja et al., 2010). The elevated mineral levels underscore moringa's potential as a fortificant to combat micronutrient deficiencies, especially in malnourished populations.

In terms of vitamins, the fortified peanut butter displayed significantly higher vitamin A and B6 levels than the control. Vitamin A is essential for vision, immune function, and overall metabolic health, and its deficiency is a major public health issue in developing nations (Amadi, 2017). The substantial increase in vitamin A aligns with reports of moringa containing 4-10 times more vitamin A than carrots (Islam et al., 2021) and findings from studies on vitamin A-enhanced cookies fortified with moringa (Uchendu et al., 2012). Similarly, the elevated vitamin B6 content in the fortified peanut butter reflects moringa's natural abundance of this nutrient, which is critical for brain function, immunity, and preventing conditions like anemia and neurological disorders (Stach et al., 2021).

Sensory evaluation revealed no significant differences ($p>0.05$) in taste, flavor, and mouthfeel between the control and fortified samples. However, differences in color, texture, and appearance were observed, with the fortified sample receiving slightly lower acceptability ratings in these categories. These findings are consistent with studies on peanut pastes and moringa-fortified cookies, which report minor sensory deviations while maintaining overall acceptability (Manobanda-Nandez et al., 2022; Uchendu et al., 2012). Despite these variations, the fortified product demonstrated a favorable balance between nutritional enhancement and sensory appeal, making it suitable for broader consumer acceptance.

5. CONCLUSION

This study demonstrated that fortifying peanut butter with moringa leaf powder significantly enhances its nutritional value, increasing protein, fat, fiber, and essential micronutrient levels, including iron, calcium, potassium, vitamin A, and vitamin B6. These improvements make the fortified peanut butter a nutrient-dense and effective food option for addressing malnutrition and micronutrient deficiencies, particularly in resource-limited settings. Sensory evaluation showed that the fortified product maintained acceptable taste, flavor, and mouthfeel, though minor differences in texture and appearance were noted. The results indicate that moringa-fortified peanut butter has the potential to be well-received by consumers while delivering substantial nutritional benefits.

Beyond its nutritional value, this fortified peanut butter offers a cost-effective and scalable solution for addressing malnutrition in regions with limited resources. The use of locally available and affordable ingredients, combined with a straightforward production process, makes large-scale implementation feasible. The long shelf life and cultural acceptability of peanut butter further enhance its practicality as a dietary intervention. Future research should explore consumer acceptability in diverse populations, storage stability, and economic feasibility to facilitate the integration of fortified peanut butter into broader nutrition intervention programs aimed at combating malnutrition globally.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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