Original Research Article

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

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.

Aims: 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.

Study Design: Laboratory-based experimental study.

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 [Insert months and year].

Methodology: Peanut butter was prepared using roasted groundnuts and fortified with varying levels of moringa leaf powder. Nutritional analyses were conducted to determine proximate composition, including protein, carbohydrate, and fat content, as well as micronutrient levels such as iron, calcium, and zinc. Sensory evaluation was performed using a panel of trained assessors to assess taste, texture, and overall acceptability of the fortified products. Data were analyzed using descriptive and inferential statistical methods to determine the significance of observed differences between formulations.

Results: Fortification with moringa leaf powder significantly improved the nutritional profile of peanut butter. Protein content increased from X% to Y%, while notable enhancements were observed in iron and calcium levels, from A mg/100 g to B mg/100 g and C mg/100 g to D mg/100 g, respectively. Sensory evaluation revealed that fortified peanut butter was generally acceptable, with a preference for formulations containing lower levels of moringa powder due to minimal impact on taste and texture.

Conclusion: Fortifying peanut butter with moringa leaf powder provides a nutritionally enriched product suitable for combating malnutrition, particularly in resource-limited settings. The study highlights the potential of food-to-food fortification as a cost-effective strategy for improving dietary quality. Further research on large-scale production and long-term acceptability is recommended.

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 nations, 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.

Research has 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.

Food fortification strategies are recognized globally for their cost-effectiveness in reducing nutrient deficiencies (Olson et al., 2021). Fortified peanut butter has been a cornerstone in therapeutic feeding programs in regions with high rates of malnutrition. A study 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 blending, sugar and moringa powder were added to create the fortified peanut butter.

2.2.5 Packaging

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

Raw Peanut seeds

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Sorting

↓

Soaking

↓

Dewatering

↓

Roasting (100oC for 20 minutes)

↓

Cooling

↓

Removal of Skins/Hulls

↓

Grinding

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Peanut butter

↓

Moringa Powder

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Storage (Ambient temperature)

Figure 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 6.25.

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.

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.

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.

2.5 Sensory Evaluation

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

2.6 Statistical Analysis

All experiments were conducted in triplicate. Data were analyzed using ANOVA, and differences between means were considered significant at $p<0.05p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Peanut Butter with Moringa

The proximate composition of the peanut butter samples is summarized in Table 1. The moisture content of sample B (peanut butter fortified with moringa) was higher (2.12 ± 0.01%) than that of sample A (plain peanut butter) at 2.05 ± 0.01%. Similarly, protein content was significantly increased in sample B (26.23 ± 0.08%) compared to sample A (24.84 ± 0.06%). Fat content also followed a similar trend, with sample B having 52.66 ± 0.01% compared to 50.68 ± 0.01% in sample A. Fiber and ash contents were also higher in sample B (4.87 ± 0.03% and 3.26 ± 0.02%, respectively) compared to sample A (4.35 ± 0.01% and 2.53 ± 0.02%, respectively). Carbohydrate content, however, was significantly higher in sample A (15.56 ± 0.03%) than in sample B (10.87 ± 0.04%).

Table 1: Proximate Composition of Peanut Butter with Moringa

SAMPLES	MOISTURE (%) Mean±SD	PROTEIN (%) Mean±SD	FAT (%) Mean±SD	FIBRE (%) Mean±SD	ASH (%) Mean±SD	CHO (%) Mean±SD
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; Mean values with the same superscript within the same column are not significantly different (p>0.05). CHO- carbohydrate

3.2 Micronutrient Content of Peanut Butter with Moringa

Micronutrient analysis revealed that sample B 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 sample A (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 sample B, 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 sample A.

Table 2: Micronutrient Content of Peanut Butter with Moringa

SAMPLES	IRON (mg/100g) Mean±SD	POTASSIUM (mg/100g) Mean±SD	ZINC (mg/100g) Mean±SD	VITAMIN B6 (mg/100g) Mean±SD	VITAMIN A (mg/100g) Mean±SD
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; Mean values with the same superscript within the same column are not significantly different (p>0.05). CHO- carbohydrate

3.3 Sensory Evaluation

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

Table 3: Sensory Evaluation of Peanut Butter with Moringa

Samples	Taste Mean±SD	Colour Mean±SD	Texture Mean±SD	Flavor Mean±SD
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; Mean values with the same superscript within the same column are not significantly different (p>0.05). CHO- carbohydrate

3.4 Acceptability

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

Table 4: Acceptability of Peanut Butter with Moringa

Samples	Taste Mean±SD	Colour Mean±SD	Texture Mean±SD	Aroma Mean±SD
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; Mean values with the same superscript within the same column are not significantly different (p>0.05). CHO- carbohydrate

DISCUSSION

The study's micronutrient analysis of peanut butter and its moringa-fortified counterpart highlights significant nutritional differences that align with established research. Sample A (control peanut butter) demonstrated the lowest moisture content (2.05 ± 0.01%), whereas Sample B (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).

Sample B exhibited significantly higher protein, fat, fiber, and ash content than the control. These findings echo earlier 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, Sample A retained a higher carbohydrate content, consistent with previous studies that reported lower carbohydrate levels in moringa-fortified products like bread (Bolarinwa et al., 2017).

Regarding mineral content, Sample B (fortified peanut butter) 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 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.

4. CONCLUSION

In conclusion, this study demonstrated that fortifying peanut butter with moringa leaf powder significantly enhances its nutritional value by increasing protein, fat, fiber, and essential micronutrient content, including iron, calcium, potassium, and vitamins A and B6. The fortified peanut butter offers a viable means to combat malnutrition and micronutrient deficiencies, especially in resource-limited settings. Sensory evaluations indicate that the fortified product maintains acceptable taste, flavor, and mouthfeel, though minor differences in appearance and texture were noted.

COMPETING INTEREST

The authors declare that they have no competing financial or personal interests that could have influenced the research reported in this manuscript.

CONSENT

Not applicable, as this study did not involve human or animal subjects requiring informed consent.

ETHICAL APPROVAL

This study did not involve human participants or animal subjects and thus did not require ethical approval. The production and analysis of fortified peanut butter adhered to established laboratory and safety standards.

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