E-ISSN: 2790-6094
P-ISSN: 2957-4587
Journal Biological And Allied Health Sciences

Development and nutritional quality assessment of multi-Grain and moringa leaf powder cookies to combat Malnutrition in children

Original Article

Roveeha Anjum[1], Hafiz Shahzad Muzammil[2], Tabeen Irfan[3], Ayeza Imtiaz[4]

ARTICLE INFORMATION

Corresponding Author:

- roveehachaudry20@gmail.com

Affiliations:

Faculty of Allied Health Sciences, Superior University, Lahore, Pakistan

Keywords: Malnutrition/prevention & control**,** Child Nutritional Physiological Phenomena**,** Nutritional Status**,** Moringa/chemistry**,** Food Fortification/methods

ABSTRACT

Introduction: Malnutrition affects children's growth, cognitive development, and immune function, especially in developing nations. MLP and multi-grain flour were used to cookies to assess their nutritional and sensory qualities as a functional diet to prevent child malnutrition.

Materials and Methods: The multi-grain cookies have 1, 2, and 3 grams of MLP and a wheat base. Our components were local, and moringa leaf drying and crushing produced MLP. The Superior University, Lahore culinary lab made the cookies. The cookies' diameter, thickness, spread ratio, and breaking force were measured. Moisture, ash, fiber, protein, fat, calcium, iron, and phenolic substances were tested chemically. Sensory evaluation assessed color, flavor, texture, and attractiveness using a 9-point hedonic scale.

Results: The study of chemical composition indicated that total carbs varied from 58.8 to 60 g/100g, moisture content ranged from 3.1 to 6.4 g/100g, total ash was between 1.4 and 1.7 g/100g, crude fiber fluctuated from 1.07 to 2.06 g/100g, crude protein spanned from 10.5 to 11.48 g/100g, and crude fat ranged from 21.5 to 25 g/100g. The calcium concentration ranged from 21 to 24 mg per 100g, iron from 2.5 to 2.66 mg per 100g, and total phenolic content from 110 to 138.78 mg of GAE per 100g. Sensory evaluation revealed elevated overall acceptability scores for cookies with 1 g of moringa leaf powder (8.9/9), whereas protein absorption peaked in T2, signifying enhanced nutritional enrichment. The research emphasizes the nutritional and sensory benefits of moringa leaf powder and multi-grain cookies in combating childhood malnutrition.

Conclusion: Moringa leaf powder contains protein, fiber, and minerals. It may increase biscuits' nutritional content (based on wheat flour weight) without affecting taste. Moringa leaf extract improved wheat flour biscuit technology and acceptance. The study highlights the potential of nutrient-dense, multi-grain, and moringa-fortified cookies as a cost-effective strategy to combat child malnutrition. Policymakers can integrate these cookies into school feeding programs, support local food production, and promote nutrition education for sustainable public health impact.

Introduction:

Worldwide, there are 165 million malnourished children under the age of five. Malnutrition causes as least half of all child deaths worldwide. Child malnutrition is mostly a problem in poor and under developed countries. Malnutrition is the leading cause of morbidity and mortality among children (1). Pakistan has one of the highest rates of child malnutrition when compared to other emerging countries. According to the National Nutrition Survey, 33% of all children are underweight, approximately 44% are stunted, 15% are wasted, 50% are anemic, and 33% are iron deficient. The prevalence of child malnutrition in Pakistan has decreased little during the previous two decades when compared to other developing countries (2).

Moringa (Moringa oleifera Lam.), commonly referred to as the Magic tree, and occasionally known as the Horseradish tree or Drumstick tree. The Moringaceae family is indigenous to the tropical and subtropical regions of Asia and Africa, but it is now cultivated globally, with significant production in Ghana, Senegal, and Malawi, and lower outputs in New Zealand. Recently, production has commenced in Nicaragua and Bolivia(3).

Moringa leaf powder is a particularly beneficial ingredient since it contains a significant amount of protein (27-30%), vitamins (C, A, and B-complex) and minerals (calcium, potassium, magnesium, phosphorus, iron, and beta-carotene), and other nutrients. In addition to being rich in antioxidants like flavonoids and polyphenols, which help fight free radicals, it also has a lot of dietary fiber, which helps with digestion (2, 4). Despite its low fat content, it is a good source of omega-3 and omega-6 fatty acids. Improved immunological function, higher nutrient absorption, and antioxidant protection are just a few of the many health benefits that may be achieved by integrating moringa leaf powder into one's diet (5).

The leaves of Moringa are regarded as a highly nutritious substance, including amounts of vitamin A, vitamin C, iron, calcium, and potassium comparable to those found in carrots, oranges, spinach, and bananas. It is also a commendable protein source when evaluated against its amino acid profiles and the FAO/WHO/UNO reference protein for children(4). Its protein composition exceeds that of eggs and soybeans and encompasses a diverse array of amino acids, including zeatin, glutamic acid, arginine, and aspartic acid. It also include carotenoid pigments, flavonoids, minerals, sterols, and some phenolic substances(5,6). Moringa leaves have demonstrated significant antioxidant activity, which may play a crucial role in cancer chemoprevention, decrease of protein oxidation, and control of lipid peroxidation(7). Moringa is beneficial for several health issues and ailments, including the treatment of abdominal tumours, hysteria, scurvy, paralysis, helminthic infections, prostate disorders, ulcers, skin infections, inflammation, as well as cardiovascular and liver diseases. Moringa also protects the body from arsenic-induced oxidative stress and reduces arsenic concentration(8,9). Moringa is regarded as an antihypercholesterolemic drug, a regulator of thyroid hormone levels, an anti-diabetic agent, an antipyretic, an antiepileptic, a treatment for gastric ulcers, an anticancer agent, and a hypotensive agent(10). Moringa leaf extracts function as an antimicrobial agent, serving as a potential inhibitor of various microorganisms, including bacteria (Escherichia coli, Staphylococcus aureus, Vibrio parahaemolyticus, Enterococcus faecalis, Pseudomonas aeruginosa, Salmonella enteritidis, and Aeromonas caviae) and fungi (Trichophyton rubrum, Trichophyton mentagrophytes, Epidermophyton floccosum, and Microsporum canis)(11,12).Health-promoting foods, especially cookies, have recently garnered significant attention from consumers, dietitians, specialists, and producers. Cookies are classed as widely marketed bakery items globally due to their ready-to-eat nature, affordability, nutritional richness, diverse flavours, and extended shelf life(13,14).

Moringa-fortified foods often face challenges like bitter taste, low nutrient bioavailability, short shelf life, limited large-scale adoption, and low consumer awareness. This study improves **taste acceptability** by blending moringa with multi-grain ingredients, making it more appealing to children. It enhances **nutrient absorption** by optimizing processing techniques to reduce anti-nutritional factors. The study also ensures **longer shelf life** through proper packaging and storage evaluation. By providing **scientific validation**

, it supports the large-scale integration of moringa-based foods into nutrition programs and public health policies.

The combination of Moringa leaf powder with multi-grain cookies can substantially improve children's nutritious intake. This method not only rectifies the immediate deficits of calcium and iron but also offers a wider array of important nutrients required for comprehensive growth and development. To develop nutrient-dense cookies incorporating multigrain flour and moringa leaf powder, and to evaluate their physical, chemical, sensory, and nutritional qualities as a means to help combat malnutrition.

Materials and Methods

The purpose of this experimental study was to create and assess nutritionally enhanced cookies using multigrain flour and moringa leaf powder. The study aimed to provide a thorough understanding of the nutritional, sensory, physical, and chemical characteristics of the cookies to combat malnutrition. This comprehensive approach sought to better comprehend the potential health advantages of these cookies. The goal of the study was to develop a snack that could improve dietary habits by combining moringa leaf powder, rich in antioxidants, vitamins, and minerals, with multigrain flour. The research was conducted over four months. All cookie formulations and baking operations were carried out at the Culinary Lab at Superior University in Lahore using standardized equipment and procedures to ensure consistency. Ingredients, including moringa leaves, multigrain flour, and other necessities, were procured from Lahore's local markets to ensure they were both easily accessible and freshly harvested.

Procurement of Raw Materials:

All ingredients, including sugar, multigrain flour, and other components, were sourced from local markets in Lahore. This local sourcing reflected the ingredients typically available to consumers while ensuring freshness and accessibility.

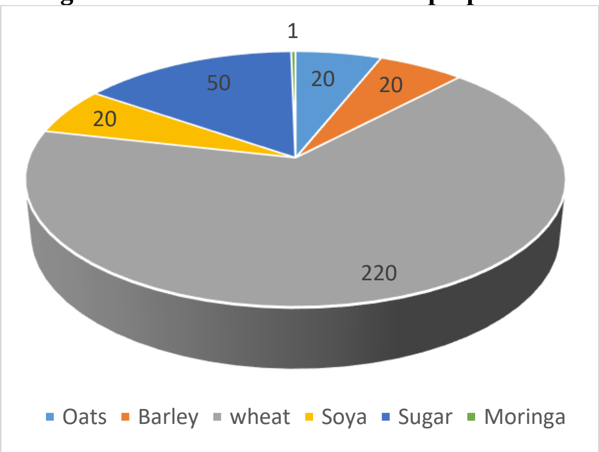
Gathering and Preparing Moringa Leaf Powder (MLP) Samples:

Freshly picked moringa leaves were carefully washed to remove dirt and impurities, ensuring a clean and healthy final product. The leaves were then dried in the shade for two days to reduce moisture while retaining their nutritional properties. Once dried, the leaves were ground into a fine powder to enhance the nutritional value of the cookies. All data were systematically collected, and standardized protocols were followed to ensure consistent and reliable analysis of the cookies' nutritional and sensory properties.

Development of Cookies:

According to the treatment plan, 175 grams of ingredients—90 grams of multigrain flour, 2.0 grams of yeast, 10 grams of margarine, 1.0 gram of salt, 12 grams of sugar, and 60 milliliters of water—were mixed to prepare the cookies. The dough was made by combining all the ingredients in a clean, dry bowl and allowing it to rest for two to three minutes. The dough was then rolled into uniformly sized rounds and baked at 180°C for 20 minutes in a preheated oven. After baking, the cookies were cooled to room temperature and stored in airtight glass containers to maintain freshness. Nutritional, sensory, physical, and chemical evaluations were performed on the cookies. Formula used in cookies preparation (AACC, 2002)

Figure 1. Formula used in cookies preparation



Course of treatment

How Moringa cookies affect the body's physiology:

Using the AOAC technique (2002), the study measured moisture, dietary fiber, protein, fat, carbohydrates, and ash in the multigrain cookies. For bioactive ingredients, the polyphenol content and total flavonoid content of moringa-enriched cookies were assessed using a spectrophotometric approach.

Physical Assessment:

The sensory attributes of the cookies were evaluated on a 9-point hedonic scale, focusing on color, flavor, texture, and overall appeal. Participants rated these attributes from 1 (strongly dislike) to 9 (strongly like), providing quantitative insights into consumer preferences. Additionally, a Honey Analyzer Type T was used for objective analysis of sweetness and texture, enhancing the understanding of how moringa leaf powder (MLP) and multigrain flour influenced the cookies' appearance and texture.

Treatments and Evaluation:

Four formulations of cookies were tested, each with varying levels of MLP. T0 (control) contained no MLP, while T1, T2, and T3 incorporated 1%, 2%, and 3% MLP, respectively. This incremental approach aimed to identify the optimal balance between nutritional benefits and sensory appeal. Nutritional and sensory properties were compared across the treatments to understand the impact of increasing MLP content on flavor, texture, and overall acceptability. The findings highlighted how MLP addition enhanced the bioactive properties while influencing sensory attributes, providing valuable insights into developing nutritionally enriched snacks.

Statistical Analysis:

The data collected during the study were analyzed using SPSS software version 26.0. Descriptive statistics were used to summarize variables such as nutritional composition, sensory scores, and physical characteristics of the cookies. Regression analysis was performed to evaluate the relationship between moringa leaf powder (MLP) concentration and key nutritional and sensory parameters, identifying significant predictors of overall acceptability. Differences between means were determined using the Least Significant Difference (LSD) test, with statistical significance set at $p < 0.05$. All measurements were conducted in triplicate to ensure accuracy and reliability of the results.

LSD was appropriate because it is a **sensitive pairwise comparison method**, useful for detecting small but meaningful variations in nutrient composition and sensory attributes. SPSS provided a reliable platform for data handling, ensuring **accurate, efficient analysis**, while ANOVA and LSD together enhanced the study's **statistical rigor**, allowing for informed conclusions on the best formulation for combating malnutrition.

Results

The nutritional analysis of the control cookie sample (T0), which contains no moringa leaf powder, revealed the following composition per 100 grams: 60 grams of total carbohydrates, 3 grams of moisture, and 1.5 grams of total ash. The crude fiber content was measured at 1 gram, with crude protein at 10.5 grams and crude fat at 24 grams. Mineral analysis showed calcium at 21 mg and iron at 2.5 mg, while the total phenolic content was recorded at 110 mg of gallic acid equivalents (GAE). Each parameter was determined using standardized methods, ensuring consistent and reliable measurements.

Table 2 Treatment 0 with no moringa

Sr no.	Parameters	UoM	Method	Specification	Results
1	Total Carbohydrates	g/100g	Chemical analysis of food by Pearson	Not Applicable	60
2	Moisture	g/100g	AOAC-925.10		3
3	Total Ash	g/100g	AOAC-923.03		1.5
4	Crude Fiber	g/100g	AOAC-962.09		1
5	Crude Protein	g/100g	AOAC-920.87		10.5
6	Crude Fat	g/100g	AOAC-2003.05		24
7	Calcium	Mg/100g	AOAC-999.10.11		21
8	Iron	Mg/100g	AOAC-999.10.11		2.5
9	Total Phenolic Contents	Mg of GAE/100g	AOAC-2023		110

The sample analysis revealed the following nutritional composition per 100 grams: 60 grams of total carbohydrates, 3.1 grams of moisture, and 1.7 grams of total ash. Crude fiber content was measured at 1.31 grams, while crude protein and crude fat were found to be 10.90 grams and 24.3 grams, respectively. The mineral analysis showed calcium at 22.8 mg and iron at 2.58 mg. Additionally, the total phenolic content was recorded at 112.13 mg of gallic acid equivalents (GAE). Each parameter was determined using established AOAC methods or the Chemical Analysis of Food by Pearson.

Table 3 Treatment 1 with 1 percent of moringa

Sr no.	parameters	UoM	method	specification	results
1	Total. Carbo…	g/100g	Chemical anylsis of food by pearson	Not Applicable	60
2	moisture	g/100g	AOAC-925.10ˆ		3.1
3	Total Ash	g/100g	AOAC-923.03 ˆ		1.7
4	Crude fiber	g/100g	AOAC-962.09 ˆ		1.31
5	Crude protien	g/100g	AOAC-920.87 ˆ		10.90
6	Crude fat	g/100g	AOAC-2003.05 ˆ		24.3
7	Calcium	Mg/100g	AOAC-999.10.11 ˆ		22.8
8	Iron	Mg/100g	AOAC-999.10.11 ˆ		2.58
9	Total phenolic contents	Mg of GAE/100g	AOAC-2023		112.13

The nutritional analysis of the sample per 100 grams indicated 58.8 grams of total carbohydrates, 3.7 grams of moisture, and 1.6 grams of total ash. Crude fiber content was measured at 1.07 grams, with crude protein at 10.87 grams and crude fat at 25 grams. Mineral analysis showed calcium at 21.8 mg and iron at 2.51 mg. The total phenolic content was recorded at 127.91 mg of gallic acid equivalents (GAE). Each measurement was conducted using established AOAC methods or Chemical Analysis of Food by Pearson.

Table 4. Treatment 2 with mg of moringa

Sr no.	parameters	UoM	method	specification	results
1	Total. Carbohydrate	g/100g	Chemical anylsis of food by pearson	Not Applicable	58.8
2	moisture	g/100g	AOAC-925.10ˆ		3.7
3	Total Ash	g/100g	AOAC-923.03 ˆ		1.6
4	Crude fiber	g/100g	AOAC-962.09 ˆ		1.07
5	Crude protien	g/100g	AOAC-920.87 ˆ		10.87
6	Crude fat	g/100g	AOAC-2003.05 ˆ		25
7	Calcium	Mg/100g	AOAC-999.10.11 ˆ		21.8
8	Iron	Mg/100g	AOAC-999.10.11 ˆ		2.51
9	Total phenolic contents	Mg of GAE/100g	AOAC-2023		127.91

The nutritional analysis of the sample cookies indicated a carbohydrate content of 59.2 g per 100 g, with moisture at 6.4 g per 100 g, reflecting the product's hydration level. The total ash level, indicative of the mineral residue, was quantified as 1.4 g/100g. The crude fibre, vital for digestive health, was 2.06 g per 100 g. The crude protein content, essential for bodily repair and growth, was notably high at 11.48 g/100g, whilst the crude fat was measured at 21.5 g/100g, enhancing the energy density of the cookies. The mineral composition included calcium at 24 mg/100g and iron at 2.66 mg/100g, so augmenting the nutritious value. The total phenolic content was measured at 138.78 mg of GAE per 100g, indicating possible antioxidant characteristics.

Table 5. Treatment 3 with 3 percent of moringa

Sr.no	parameters	UoM	method	specification	results
1	Total. Carbo…	g/100g	Chemical anylsis of food by pearson	Not Applicable	59.2
2	moisture	g/100g	AOAC-925.10ˆ		6.4
3	Total Ash	g/100g	AOAC-923.03 ˆ		1.4
4	Crude fiber	g/100g	AOAC-962.09 ˆ		2.06
5	Crude protien	g/100g	AOAC-920.87 ˆ		11.48
6	Crude fat	g/100g	AOAC-2003.05 ˆ		21.5
7	Calcium	Mg/100g	AOAC-999.10.11 ˆ		24
8	Iron	Mg/100g	AOAC-999.10.11 ˆ		2.66
9	Total phenolic contents	Mg of GAE/100g	AOAC-2023		138.78

The sensory assessment of cookies enriched with moringa leaf powder (MLP) demonstrated a significant trend in acceptance correlating with increasing MLP concentrations. The control cookies (0 grams MLP) achieved elevated scores in all sensory aspects, with color, taste, flavor, texture, and overall acceptability ranked near the maximum of 9. Cookies containing 1 gram of MLP exhibited great acceptability, with marginally superior flavor and overall acceptability scores relative to the control, indicating that minimal MLP fortification boosts sensory appeal. Nonetheless, cookies containing 2 grams of MLP exhibited a moderate reduction in color, taste, flavor, and texture, although overall acceptance remained very high. At 3 grams of MLP, sensory scores decreased further, with notable reductions in flavor and texture, suggesting that elevated MLP concentrations may diminish consumer attractiveness. The Least Significant Difference (L.S.D) values indicate that these sensory differences are statistically significant at the 0.05 level.

Table 6. Effect of MLP fortification on sensory evaluation of Moringa cookies

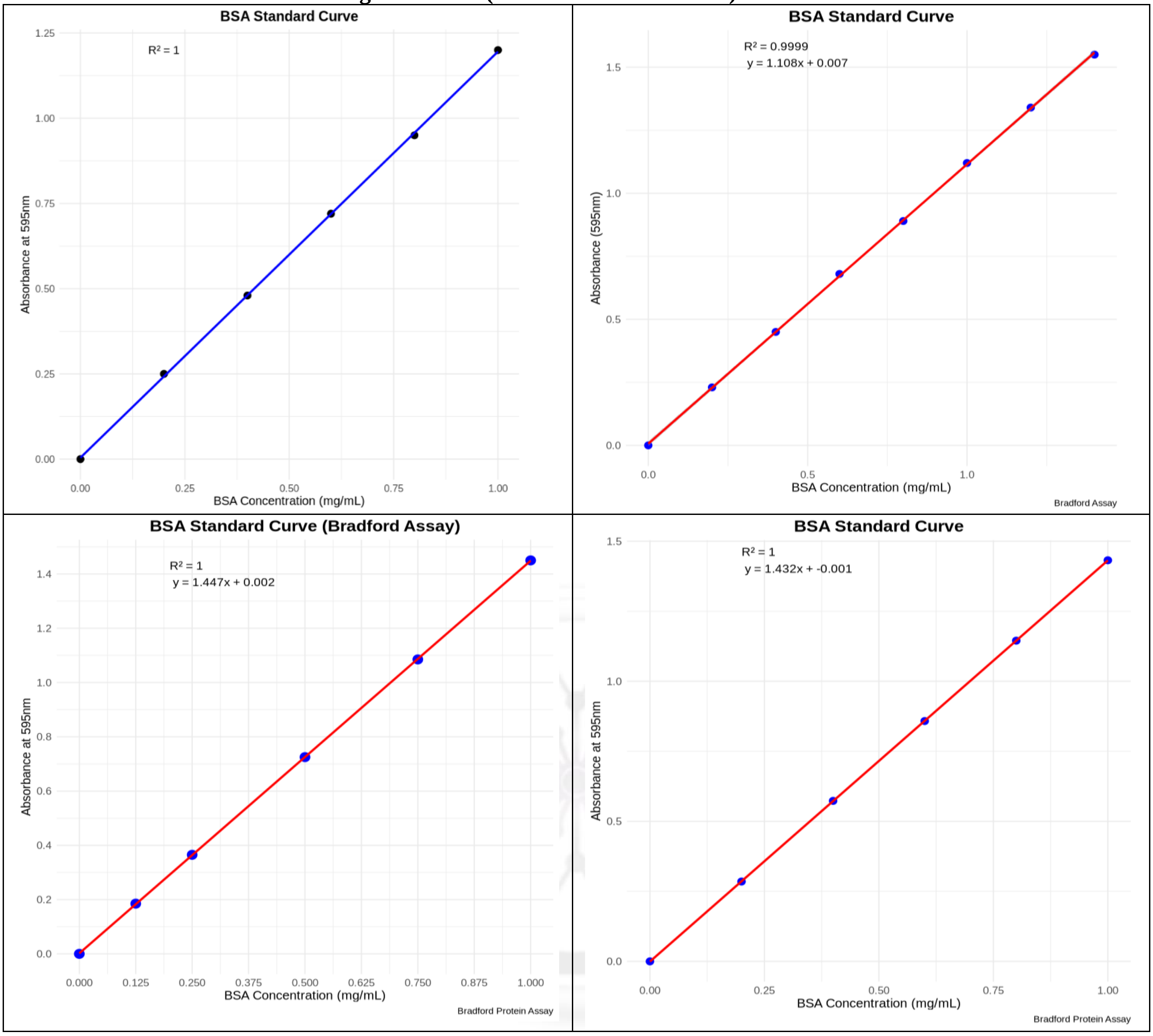
Samples	**Colour (9)**	**Taste (9)**	**Flavour (9)**	**Texture (9)**	**Overall Acceptability (9)**
Control	8.7 a	8.5 a	8.4 a	8.5 a	8.5 a
Cookies with 1gram MLP	8.6 a	8.7 a	8.8 a	8.6 a	8.9 a
Cookies with 2gram MLP	7.4 b	7.5 b	7.3 b	7.1 b	8.2 a
Cookies with 3gram MLP	6.5 c	6.9 b	6.7 c	6.8 b	7.1 b
L.S.D	1.05	1.1	1.2	1.3	0.9

The data shows that Treatment 2 (T2) received the highest scores across all sensory attributes, with taste at 8.29 ± 0.47, texture at 8.06 ± 0.47, color at 8.3 ± 0.35, appearance at 7.76 ± 0.64, and smell at 8.5 ± 0.4, suggesting it was the most preferred overall. Treatment 1 (T1) followed, with relatively high ratings in all categories but notably lower than T2, especially in appearance and smell. Treatment 3 (T3) had a moderate acceptance level, with scores lower than T2 and T1, particularly in texture. Treatment 0 (T0) consistently scored the lowest across all attributes, indicating the least favorable sensory profile. This analysis suggests that T2 offers the best combination of sensory qualities among the treatments tested.

Table 7. Sensory Evaluation among different Treatments

Treatment	Taste	Texture	Color	Appearance	Smell
T0	6.54 ± 0.48	6 ± 0.54	7.16 ± 0.27	6.44 ± 0.41	6.15 ± 0.64
T1	7.1 ± 0.52	7.61 ± 0.43	7.72 ± 0.53	7.02 ± 0.67	7.02 ± 0.44
T2	8.29 ± 0.47	8.06 ± 0.47	8.3 ± 0.35	7.76 ± 0.64	8.5 ± 0.4
T3	7.66 ± 0.26	6.82 ± 0.5	7.34 ± 0.37	7.06 ± 0.33	7.37 ± 0.52

Figure 1. BSA (Bovine Serum Albumin) Curves



Investigating the development and evaluation of moringa leaf powder and multi-grain cookies as a potential weapon against childhood malnutrition, the study compares the absorbance graphs of samples T0, T1, T2, and T3 at different BSA (Bovine Serum Albumin) concentrations, revealing notable variations in protein content. Increasing the quantity of BSA resulted in a consistent rise in absorbance across all samples, indicating an increase in the protein content, which is crucial for nutritional value. The absorbance values of T0 (control) were lower than those of T1, T2, and T3, suggesting that the inclusion of multi-grain and moringa leaf powder in these formulations increased protein levels. T2 stood out with its maximum absorbance, indicating the perfect combination for protein enrichment. Cookies made with moringa leaf powder and multi-grain flour have the makings of a healthy nutritional intervention for kids' diets, according to this trend.

Discussion

The high iron concentration was found in the 2g of DMLP included cookies but concern to acceptability of the customer 1.5g of DMLP integrated cookies was preferred by all the age group. Moringa oleifera leaves contain larger percentage of moisture, ash, fat, protein, fibre content when compared to the nutrient composition of sweet potato leaves(15). In addition, moringa dried leaves contains larger amount of iron content. So, eating of DMLP cookies helps to reduce the anemia and other iron deficiency associated diseases. The sensory features were examined to analyse the average preference of the evaluators to DMLP integrated biscuits. This examination also carried without any alteration of 9-point hedonic scale. The scores were awarded to each characteristic such as colour, look, texture, taste and aroma from highest point (like highly) to the lowest point 1 (dislike excessively) (12). This study also attempted to analyse the heterogeneity nature in the consumer preference(16). Moreover, DMLP included cookies preference to different age group was also examined by sensory analysis. This study studied the nutritive status of the DMLP cookies. The moringa leaves contains greater amount of essential amino acids like methionine and leucine. Dried Moringa Leaf Powder (DMLP) which is combined into cookies to provide huge health benefits from younger to elder and to manage malnutrition for upcoming generation(17,18).

Incorporating Moringa Leaf Powder (MLP) into multi-grain cookies offers potential long-term health benefits, supported by existing literature. Moringa oleifera is rich in antioxidants and bioactive compounds, contributing to its anti-inflammatory and hypoglycemic properties. Regular consumption may aid in managing blood glucose levels and reducing inflammation, which are crucial for preventing chronic diseases. Additionally, whole grains are associated with a lower risk of cardiovascular disease, type 2 diabetes, and obesity, due to their high fiber content and beneficial nutrients. Combining MLP with whole grains in cookies could synergistically enhance these health benefits, offering a functional food option to support long-term health. However, it's important to consider potential risks; some reports suggest that excessive intake of moringa supplements may pose health concerns, such as genetic damage and increased cancer risk. Therefore, moderation and further research are essential to ensure safety and efficacy.

The amount of protein in cookies

On average, moringa leaf powder (MLP) contains 290 g/kg of protein (Melesse et al., 2012). Table 2 displays the protein contents as a percentage. Protein content in moringa powder was 32.89%, which was greater than in the control cookie sample (9.37%). Protein content increased gradually to 10.35%, 11.35%, and 14.29% as a result of adding 3, 9, and 15% of MLP to the cookie, respectively. So, adding Moringa to the cookies significantly boosts their nutritional content.

Caloric input

You can find the calorie count of the baked cookies in Table 2. The caloric values are increased as the concentration of MLP is raised. The caloric value of cookies reinforced with 15% MLP was 411.9, whereas the caloric value of moringa leaves powder was 373.2. In comparison to the 401.3 kcal for the control group, the 3–9 and 15% groups came in at 407.1, 408.2, and 411.9 kcal, respectively, while the extract of Moringa leaves had a caloric value of 402.9.

Fiber contents

Table 1 shows that the fiber contents of the cookies ranged from 0.25 to 0.98%. Cookies made with moringa leaves extract got the same percentage as the control cookies, which had the lowest fiber level at 0.25 percent. This can be because neither polar nor organic solvents dissolve the fiber, and solvent extraction is the chosen method of extraction. The fiber concentrations in the cookie samples were increased to 0.48, 0.87, and 0.98% respectively at 3, 9, and 15% addition levels of MLP, after adding it to the cookie mix as a fiber rich ingredient (8.83%). Due to its relevance in promoting health, the production of foods rich in fiber is expanding rapidly (Ajila et al., 2008).

The elevated protein content seen in MOLP relative to maize meal (26.28% versus 9.88%) aligns with existing data. The findings indicate that MOLP may be utilised to combat protein and energy malnutrition (PEM) in impacted populations, particularly in rural areas such as those in KwaZulu-Natal, South Africa(19,20). The current investigation revealed a greater protein content in maize meal than previously reported results. The observed discrepancies may be attributed to environmental conditions and the processing procedures employed in the preparation of the maize meal samples among investigations. Crude protein is a crucial nutrient necessary for the construction and repair of damaged tissues, and it is vital for the development of muscle, skin, bone, and cartilage(21–23). Moringa is said to contain a majority of important nutrients, including key amino acids, prompting recommendations for regular usage. The fibre content in MOLP exceeded that of maize meal. Proper fibre consumption facilitates human digestion, diminishes plasma and LDL (low-density lipoprotein) cholesterol levels, enhances fat excretion, and reduces the risk of developing hypercholesterolaemia and cardiovascular illnesses. Fat content was markedly ($p < .05$) elevated in MOLP, with a mean value of 8.38%, in contrast to maize meal, which had a fat content of 4.16 ± 0.01%. This aligns with the findings of Madukwe and Fahey, who discovered that dried M. oleifera leaves are abundant in fatty acids(24). A prior study has demonstrated that M. oleifera leaves possess a significant concentration of polyunsaturated fatty acids and are therefore endorsed for human consumption. The polyunsaturated fatty acids included in moringa leaves encompass omega-3 and omega-6 fatty acids, both regarded as beneficial.

The Impact of MLP Reinforcement on the Texture and Dimension of Cookies

The force required to shatter and disperse cookies

The breaking power, spread ratio, thickness, and diameter of wheat flour cookies enriched with MLP are shown in Table 6. It was noted that the diameters of the cookies were progressively reduced when MLP was added. In contrast, the samples of cookies fortified with 3, 9, and 15% MLP measured 6.57, 6.41, and 6.31 cm in diameter, respectively, while the control group measured 6.73 cm. The addition of 1% Moringa leaves extract resulted in much larger cookies, measuring 6.92 cm in diameter.However, when comparing the control and 3% MLP-added cookie samples, the thickness of the former was 1.12 cm, while the latter showed no significant differences at 1.11 cm. In contrast, the samples of cookies with 9 and 15% MLP-added were thicker than the control, measuring 1.22 and 1.33 cm, respectively. Therefore, the spread ratios of the control and MLPadded cookie samples were higher, but the maximum spread was still achieved by the Moringa extracts, even when compared to the control samples. After the control cookies (which had a spread ratio of 6%), the cookies fortified with 3%, 9%, and 15% MLP had spread ratios of 5.86%, 5.22%, and 4.77%, respectively. The Moringa extract had the highest spread ratio. (27).

The results indicate that an increase in the proportion of MOLP correlates with a rise in the nutritional content of mahewu. The nutrient composition of the MOLP-supplemented mahewu, namely in terms of fat and fibre, was markedly elevated ($p < .05$) compared to traditional mahewu (control). The protein and ash concentrations in the mahewu samples exceeded those of the control. This indicates that moringa may improve the nutritional value of mahewu and comparable meals(28,29). This study is the first to document the nutrient profile of mahewu supplemented with moringa, despite the growing information on the incorporation of moringa in foods. Moringa powder has been documented to enhance the nutritional content of various starchy food products, including amala (a firm dough Nigerian dish) and ogi (a maize-based beverage). Nonetheless, the extent of the rise in nutritional levels was measured in the prior investigations. This study found that the fat content of mahewu increased by over 50% with the addition of MOLP, while the protein content rose by 11% when 4% MOLP was incorporated. M. oleifera is believed to be a significant source of monounsaturated and polyunsaturated fatty acids. It is widely acknowledged that the consumption of foods high in unsaturated fatty acids, particularly polyunsaturated fatty acids, diminishes the likelihood of elevated blood cholesterol levels and lowers the risk of stroke and cardiovascular disease(30–32).

The results of the sensory examination are presented in. A greater percentage of panellists reported that the control was more palatable than the MOLP-supplemented mahewu samples. The increased approval of the control may be attributed to the panellists' greater familiarity with regular mahewu compared to the MOLP-supplemented variant. The replacement of maize meal with MOLP altered the colour of mahewu from its typical creamy white to a subtle green(33–35). The colour acceptability of MOLP-supplemented mahewu was inferior to that of the control. The scent, mouthfeel, flavour, and general acceptability of the samples were adversely impacted by MOLP. This results parallels a result from the study conducted by, wherein consumers expressed a greater approval of regular mahewu compared to the provitamin A biofortified-supplemented mahewu samples(36–38). Of all the samples evaluated, mahewu augmented with 6% MOLP was the least palatable. The findings demonstrate that an increased proportion of moringa in mahewu samples leads to an unfavourable sensory characteristic of the beverage.

Conclusion

Moringa leaf powder is a natural source of minerals, fiber, and protein. It has the potential to increase the nutritional value of bakery products, such as biscuits, by up to 9% (based on the weight of wheat flour), without significantly affecting their sensory acceptability. The technological properties of wheat flour biscuits were improved by the addition of Moringa leaves extract, which also had a positive impact on their acceptability. Moringa-fortified multi-grain cookies have strong potential for integration into **government nutrition programs and school feeding initiatives** due to their high nutrient density, affordability, and ease of distribution. These cookies provide essential vitamins, minerals, and protein, making them an effective tool in combating childhood malnutrition, especially in low-income communities. Their long shelf life and convenient format make them suitable for large-scale implementation in **midday meal programs, food aid distributions, and maternal-child nutrition schemes.** By incorporating locally available ingredients like moringa and whole grains, these cookies also support **sustainable agriculture and local economies**. Policymakers can leverage this fortified food as a **cost-effective, scalable intervention** to improve child health and cognitive development, ultimately reducing the long-term burden of malnutrition-related diseases.

Limitations of the Study

When analyzing the findings, it is important to keep in mind that this study has several limitations. To begin, the results may not be applicable to a broader population due to the small sample size used for sensory evaluation and nutritional analysis. Secondly, the study did not examine the cookies' effects on children's nutritional status over the long term; instead, it concentrated on the short term evaluation of their nutritional quality. The third possible factor that affected the cookies' nutritional makeup is the wide range in ingredient quality and processing techniques. Also, things like cultural preferences, how well they taste, and how long they last in storage weren't well investigated. Finally, additional research is needed to determine whether the cookies are beneficial in addressing signs of childhood malnutrition, given this trial did not involve a clinical assessment.

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CONFLICT OF INTEREST
Authors declared no conflict of interest, whether financial or otherwise, that could influence the integrity, objectivity, or validity of their research work.

GRANT SUPPORT AND FINANCIAL DISCLOSURE
Authors declared no specific grant for this research from any funding agency in the public, commercial or non-profit sectors

DATA SHARING STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request

JBAHS web address: www.jbahs.pk
Email address: editor.jbajhs@superior.edu.pk