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DEVELOPMENT OF FUNCTIONAL COOKIES FORTIFIED WITH MORINGA OLEIFERA LEAF POWDER AND THEIR QUALITY EVALUATION

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Abstract

Healthy foods with added nutritional and functional value have been widely pursued by consumers. The objective of this research study was to fortify cookies with various amounts of Moringa oleifera leaf powder and assess their physical, nutritional, and sensory characteristics. The shade dried moringa leaves were powdered and added to a cookie formulation at 0%, 5%, 10% and 15% replacement for wheat flour. Standard analytical methods were used to assess the physical properties, proximate values & sensory acceptability of developed cookies. The results indicated that the ash, protein, and crude fiber contents were significantly improved with increased moringa incorporation while the carbohydrate content was significantly decreased. Physical properties were affected by fortification, with increased cookie thickness and weight and decreased diameter and spread ratio. Sensory evaluation showed that all the treatments were acceptable, but the sensory scores decreased with the increasing fortification levels because of the increased herbal characteristics. Fortified cookies made with moringa leaf powder (5%) had the best optimum level between nutritional fortification and consumer acceptability of all fortified treatments. The results indicate that M. oleifera leaf powder can be used as a functional content in formulation of nutrient enhanced bakery products.

INTRODUCTION

Healthy foods with added nutritional and functional value have been widely pursued by consumers and the food industry owing to the rapid increase in prevalence of lifestyle-related disorders and micronutrient deficiencies. The concept of functional foods i.e., foods which influence health in a beneficial way in addition to the effect of nutrients, are increasingly capturing attention throughout the globe (Temple, 2022). Incorporation of bioactive components into widely consumed food products is a significant approach to enhancing the dietary quality and addressing nutritional issues (Bürck et al., 2024). The most consumed snack foods are bakery products, especially cookies, because they are convenient, have a long shelf life, inexpensive, and

acceptable to consumers. Traditional cookies, however, tend to be high in carbohydrates and fats and low in dietary fiber, vitamins, minerals and the content of antioxidant compounds (Krajewska & Dziki, 2023). Therefore, fortification of bakery products with beneficial plant compounds in order to improve nutrient value of food products without compromising taste/texture characteristics is of recent interest.

Proteins, dietary fibre, minerals and phytochemicals derived from plants have been increasingly used to produce functional bakery products. Fortification of bakery products is an effective strategy to enhance the micronutrient content for various population segments, especially in developing countries, where micronutrient deficiencies continue to be a public health issue (Chakraborty, & Chakraborty, 2023). Moringa is one of the most suitable functional ingredients, because of its high nutritional value and rich bioactive compound profile (Trigo et al.). According to Milla et al. (2021), moringa leaves in powdered form could be incorporated into bakery products to improve their nutritive values and provide a source of antioxidants which may also improve the consumer's health. Thus, the preparation and testing of moringa fortified cookies is an emerging research field in the area of food technology. The leaves, seeds, pods, flowers and roots of the plant are all edible and/or medicinal with the leaves being the most nutritious part and widely used in food fortification initiatives (Grosshagauer et al., 2021). Based on its nutritional profile, leaf powder (of moringa) is a potential functional product in the creation of value-added bakery products (Ariani et al., 2023). Incorporation in cookies could be of great value to create nutritious snacks that could help enhance dietary intake and consumer health (Fapetu et al., 2022).

M. oleifera leaf powder has been getting traction in the bakery industry because of its remarkable nutritional and functional qualities (Khalid et al., 2023). Some research has demonstrated cookies, biscuits, bread, and other baked goods can be fortified with moringa leaf powder to enhance their protein, dietary fiber, mineral, and antioxidant levels (Fapetu et al., 2022; Trigo et al., 2023). Although the results are encouraging, the diverse formulations, processing conditions, and incorporation levels have led to inconsistent results in terms of product quality and consumer acceptance (Espinal-Carrión et al., 2023).

Previous studies have mainly concentrated on the nutritional improvements of bakery products fortified with moringa with very few studies testing the nutritional value and sensory properties at the same time in the same experimental design (Ferreira et al., 2023). Furthermore, there is a vast level of acceptable moringa incorporation levels across different studies, which hinders the determination of an optimum fortification level that balances the nutritional benefits with taste, color, texture and overall acceptability (Ilyas et al., 2023). Consumer acceptance is also an important criterion for the commercial success of functional food products, and additional studies are necessary to find formulations with enhanced nutritional and antioxidant properties that have desirable sensory characteristics (Giuberti et al., 2021).

Therefore, the objective of the present research was to formulate bakery products (i.e. cookies) with different concentrations of Moringa oleifera leaf powder & assess their nutritional profile, physical properties, and sensory acceptance. The results of this research are likely to support the formulation of value-added functional bakery products and supply scientific proof of the effective use of moringa as a natural source of super nutrients in food systems.

MATERIALS & METHODS

2.1 Study Area

This study was conducted at IFNS Laboratory, Arid Agriculture University Rawalpindi, Pakistan. Food laboratory at IFNS lab is equipped with all sorts of food processing, proximate analysis and sensory evaluation of foods. The laboratory study consisted of 3 main steps which included moringa leaf powder preparation, moringa leaf powder cookies preparation at varied proportion and assessment of their nutritional, physical, and

sensor properties. All experiments were designed and conducted in laboratory conditions.

2.2 Procurement of Raw Materials

Fresh Moringa oleifera leaves were collected from healthy and mature plants growing in the vicinity of Rawalpindi/Islamabad, Pakistan. The material for cookies included wheat flour (refined), sugar, eggs, butter, baking powder, & other ingredients required for cookie preparation were purchased from a local supermarket in Rawalpindi, Pakistan. The chemicals are of analytical grades that were used and stored according to the manufacturers' recommendations until use. Dry ingredients were kept in full airtight containers at ambient temperature, while other perishable ingredients including eggs were refrigerated until required for cookie formulation (Drabik et al., 2021).

2.3 Preparation of Moringa Leaf Powder

Fresh Moringa oleifera leaves were sorted to exclude the damaged, undesirable materials, and cleaned in tap water then in distilled water. The cleaned leaves were shed Dried at room temperature 25 to 30°C for 4-5 days till obtaining a constant weight for preventing loss of the heat labile antioxidants and other nutrients. Powdering was conducted of dried leaves and 60-mesh screen applied for getting a fine moringa leaf powder and filled in airtight polyethylene bags. Stored in cool, dry, and dark conditions inside airtight container (Ramarao et al., 2022; Fapetu et al., 2022).

2.4 Treatment Plan

Table 2.1: Treatment Formulations

Treatment	Wheat Flour (%)	Moringa Leaf Powder (%)
T0 (Control)	100	0
T1	95	5
T2	90	10
T3	85	15

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2.5 Preparation of Cookies

The preparation of cookies follows the normal creaming method, and few adjustments are being made to utilize various concentrations of Moringa oleifera leaf powder. Cookies formulation prepared by replacement of wheat flour partially with moringa leaf powder following the treatments outlined in the following Table (Table 2.1).

Table 2.2: Ingredients Used for Cookie Preparation

Ingredient	Quantity (g)
Wheat Flour	100
Butter	50
Powdered Sugar	40
Egg	25
Baking Powder	1.5
Vanilla Essence	1 mL
Moringa Leaf Powder	As per treatment

2.6 Procedure for Preparation of Cookies



Butter & powdered sugar were mixed until smooth and light using a planetary mixer and then egg & vanilla essence were incorporated and cream mixed until smooth. Wheat flour, moringa leaf powder and baking powder were mixed individually and then added to the cream mixture one by one to make a uniform dough. The dough was allowed to rest for approximately 10 minutes, then rolled out into approximately 5 mm thickness, and cut into round pieces and placed on baking trays lined with baking paper. They were placed into an electric oven and baked at 180 ± 5 °C for 12-15 min and left to cool at room temperature for about 30 min. The cooled cookies were put into hermetically sealed polyethylene containers and kept at ambient temperature for physical, chemical, antioxidant and sensory analyses (Riaz et al., 2022).

2.8 Proximate of Moringa Leaf Powder

Proximate composition of the prepared Moringa oleifera leaf powder was determined for moisture, ash, crude protein, crude fat, crude fibre and carbohydrate contents. All analysis was performed three times in accordance with the standard methods of the Association of Official Analytical Chemists (2023). The results were presented in percentages, based on dry weight.

2.9 Physical Characteristics of Cookies

Physical characteristics of the cookies were determined following baking and cooling them to

25° C. Weight, Diameter, Thickness and Spread ratio were measured. All the above parameters were selected as test parameters to study the effect of Moringa oleifera leaf powder incorporation on the physical quality of the developed cookies (Agrawal et al., 2022). Three trials were performed for each measurement, and the mean values were reported.

2.10 Proximate Composition of Cookies

The proximate composition of the cookie samples was analyzed to assess the nutritional effect of Moringa oleifera leaf powder for cookies. Analyses performed were moisture, ash, crude protein, crude fat, crude fiber, total carbohydrates and energy value. The determinations were repeated three times following the standard procedure of the Association of Official Analytical Chemists (AOAC, 2023) and presented as percentages.

2.11 Sensory Assessment

The evaluation was carried out by a panel of 25 semi-trained members comprising students and faculty members. The panelists were chosen for their volunteer interest and knowledge of bakery products. To eliminate bias in the panelists, the samples of cookies were allotted three-digit random numbers for coding and presented to the panelists in a random order. The panelists tested the cookie samples by judging on the different sensory attributes. The attributes were rated on a hedonic scale from 1 (dislike extremely) to 9 (like extremely), as suggested by Peryam and Pilgrim, (1957).

2.12 Statistical Analysis

Experiment was conducted with four treatments and three replications. All analytical determinations, including physical properties, proximate composition, and sensory evaluation, were performed in three replications, and results were analyzed using SPSS and expressed as mean value ± standard deviation (Steel et al., 1997).

RESULTS AND DISCUSSION

3.1 Proximate Analysis of Moringa Powder

The proximate analysis of M. *oleifera* powder is presented in Table 3.1. The analysis revealed that moringa leaf powder possessed considerable nutritional profile, particularly in protein, mineral content and dietary fiber. These nutritional characteristics support its utilization as a functional composition in bakery products and other fortified foods.

Table 3.1: Proximate Analysis of Moringa Powder

Parameter	Value (%)
Moisture	7.85 ± 0.21
Ash	9.42 ± 0.18
Crude Protein	27.60 ± 0.35
Crude Fat	5.18 ± 0.14
Crude Fiber	10.75 ± 0.28
Carbohydrates	39.20 ± 0.41

The proximate composition of M. oleifera leaf powder showed it to be good nutritional functional food ingredient (Table 3.1). The moisture content was found to be 7.85 ± 0.21% which was comparatively low, suggesting good degree of moisture removal and the storage stability will be enhanced due to low microbial growth and enzymatic degradation. Similarly, Tafu and Jideani (2022) reported a similar low moisture content and highlighted that moringa leaf powder with proper drying has better shelf stability and food fortification potential.

The ash content (9.42 ± 0.18%) indicated that moringa leaf powder has a high mineral content. Similarly, Oyeyinka et al (2022) found significant mineral content in moringa leaves, such as

calcium, potassium, magnesium and iron. Variations in ash content across studies could be due to environmental conditions, soil fertility, plant maturity, location of growth, and post-harvest processing.

The crude protein content (27.60 ± 0.35%) showed that moringa powder is a good source of plant-based nutrient which can be used in the nutritional enrichment of bakery products. The same protein concentration has been studied by Qadir et al., (2022) who showed that Moringa leaves have high protein content, as well as essential amino acids and antioxidant components. The different protein levels found between investigations may be due to different cultivars, stage of harvest, farm management, and/or drying methods.

The crude fat content (5.18 ± 0.14%) was relatively low and this is a good attribute of moringa leaf powder that it can be used as a food fortifier without adding a significant amount of fat to the end product. Tafu and Jideani (2022) reported similar results, stating that moringa leaf powder has moderate amount of lipids and good nutritional composition.

The crude fibre content (10.75 ± 0.28%) was relatively high, suggesting the potential of moringa leaf powder to enhance dietary fibre intake. A high dietary fibre intake is linked to better gastrointestinal function, greater satiety, and a decreased risk of metabolic disorders. Sokombela et al. (2022) reported similar fiber content in moringa leaves, which they showed to be significant depending on cultivation practices and nutrient management.

Carbohydrates constituted the largest proportion (39.20 ± 0.41%) of the moringa leaf powder, providing an additional source of energy while complementing its protein, mineral, and fiber contents. Overall, the current findings are similar with the previous study reported by Oyeyinka et al. (2022), confirming that *M. oleifera* powder possesses a balanced nutritional composition and is a suitable ingredient for improving the nutritional profile of functional bakery products.

3.2 Physical Characteristics of Cookies

The physical properties of the cookies that were made using different concentrations of Moringa oleifera leaf powder are displayed in Table 3.2. These are physical properties, which affect consumer perception and acceptability of bakery products, such as weight, diameter, thickness and spread ratio. These parameters were affected to varying extents because of the high fibre content and water absorbing property of moringa leaf powder.

Table 3.2: Physical characteristics of cookies fortified with different levels

Treatment	Weight (g)	Diameter (cm)	Thickness (cm)	Spread Ratio
T0 0%	12.45 ± 0.12	5.82 ± 0.08	0.72 ± 0.02	8.08 ± 0.15
T1 5%	12.68 ± 0.10	5.70 ± 0.06	0.75 ± 0.01	7.60 ± 0.12
T2 10%	12.91 ± 0.14	5.55 ± 0.07	0.79 ± 0.02	7.03 ± 0.14
T3 15%	13.16 ± 0.16	5.36 ± 0.09	0.84 ± 0.02	6.38 ± 0.18

Values are expressed as mean ± standard deviation (n = 3).

The physical properties of cookies developed were significantly influenced by the fortification of M. oleifera powder (Table 3.2). The weight of cookies increased gradually with increasing levels of fortification, ranging from 12.45 ± 0.12 g in the control treatment up to 13.16 ± 0.16 g for the highest fortification level. The weight gain could be due to its water holding capacity, which improved water retention in dough during baking. The hydrophilic nature of moringa leaf constituents led to similar increases in cookie weights after moringa incorporation as reported by Nimbalkar et al. (2022).

As the moringa leaf powder increased, there was a gradual decrease in the diameter of the cookies (5.82 ± 0.08 to 5.36 ± 0.09 cm). At the same time,

the thickness of cookies also increased significantly from 0.72 ± 0.02 to 0.84 ± 0.02 cm, with a corresponding decrease in the spread ratio from 8.08 ± 0.15 to 6.38 ± 0.18 as shown in Figure 3.1. These changes suggest that moringa leaf powder has a thickening effect on dough and caused the water absorption to rise, which in turn slowed down dough flow during baking and resulted in thicker cookies with lower spread. Agrawal et al. (2022) also investigated likewise decrease in the spread ratio in cookies with moringa seed flour, which was attributed to disruption of gluten matrix and higher water absorption during baking.

In contrast, Fapetu et al. (2022) reported the increase trend in cookies' diameter & spread ratio together while a reduction in thickness as the level of moringa powder fortification level increased. The difference observed between the present results and those reported by Fapetu et al. might be due to variations in the formulation of cookies, substitution level, particle size of moringa powder, flour characteristics, consistency of dough, mixing method and baking conditions, which are known to affect the geometry and spread of cookies during baking.

The dimensional changes, although noticeable, did not affect the structural integrity and the appearance of all treatments, thus highlighting the possibility of using Moringa oleifera leaf powder in cookies. The baking properties were significantly affected, however, by increased fortification levels, indicating the need for optimization of incorporation level to achieve a desirable balance between nutritional benefits and baking properties.

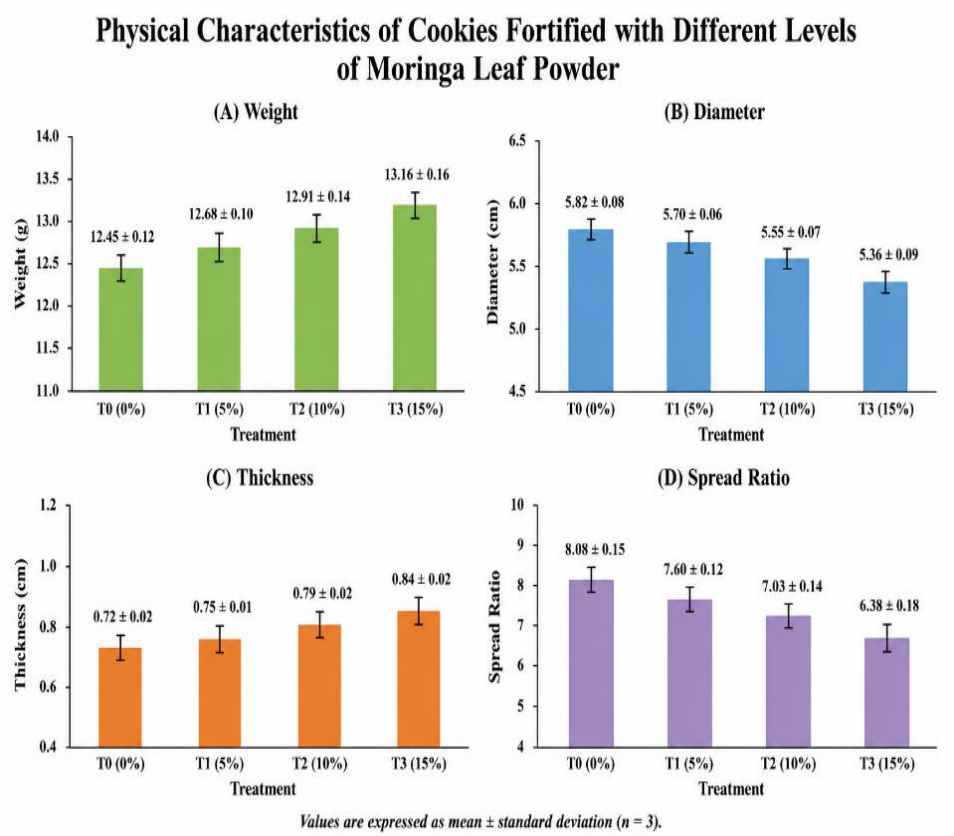


Figure 3.1: Physical characteristics of cookies with different fortification level

3.3 Proximate Composition of Cookies

The proximate analysis of cookies fortified with 4 levels of M. oleifera powder is shown in Figure 3.2. The findings demonstrated that moringa fortification progressively improved nutritional profile of cookies. Increases in protein, ash, and

crude fiber were seen with high levels of moringa leaf powder, while carbohydrate content showed a decreasing trend.

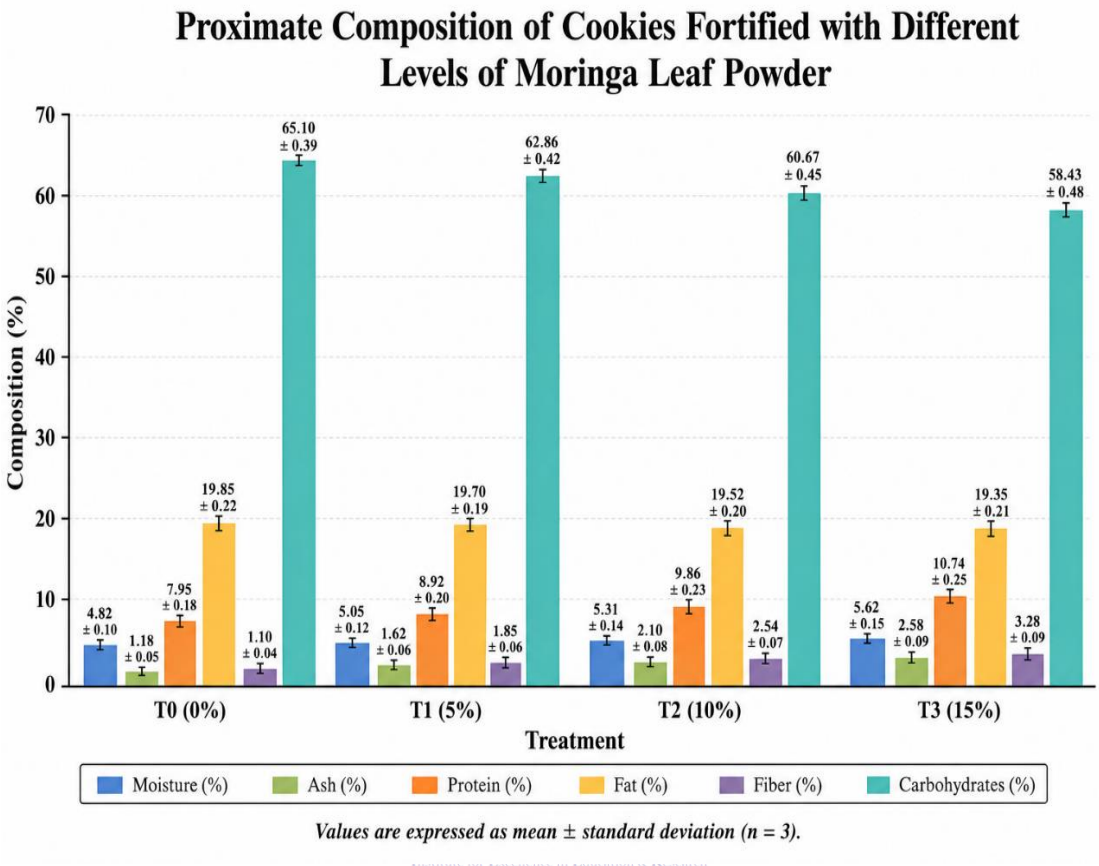


Figure 3.2. Proximate analysis of cookies fortified with different levels of moringa powder

The fortification of M. oleifera leaf powder had a positive effect on nutritional profile of cookies (Figure 3.2). The highest fortified treatment had a moisture content that was slightly higher than the control at 5.62% compared to 4.82%. The increase is due to high water absorption and water-holding potential of dietary fibre content of moringa leaves that help in retaining water during the baking process. Fapetu et al. (2022) also observed similar moisture levels when moringa leaf powder was incorporated into cookies, which they attributed to the moringa leaf's hygroscopic property.

The ash composition of fortified cookies also showed a significant rise (1.18% to 2.58%) with the increase in moringa incorporation, which results in increased mineral content of the cookies. Similar results were investigated by Saleem et al. (2023) when the ash content increased significantly after the fortification of M. oleifera leaf powder. This rise is mainly due to the naturally high levels of calcium, potassium, iron, magnesium & other important minerals in moringa leaves. Some variations between studies might be due to the cultivar of moringa, geographical origin, substitution rates, and baking conditions.

The protein content was found to increase gradually from 7.95% up to 10.74%, which depicts the functionality of moringa powder as a protein rich fortifying ingredient. Fapetu et al. (2022) reported similar increases in protein level of moringa added cookies, and Riaz et al. (2022) in moringa fortified biscuits. The rise of protein is due to the nutritional value of bakery products based on high protein content & balanced amino acid profile of moringa leaves.

The fat content had only slight variation, from 19.95% to 19.35%. The results are likewise to those studied by Riaz et al. (2022) who noted that the relatively low-fat composition found naturally in moringa leaves. This means that there was a lower impact of moringa leaf powder on the lipid profile. Thus, it is concluded that small portion of wheat flour replacement with moringa leaf powder was beneficial for the nutritional profile and did not significantly affect the contribution of energy from fat.

The crude fiber content also significantly increased from 1.10% to 3.28%, highlighting the contribution of dietary fiber in moringa leaf powder. In similar research, Saleem et al. (2023) found that cookies prepared with higher quantities of moringa had higher fiber content. The increased fiber content could be beneficial for digestive health, satiety, glycemic regulation and cardiovascular disease prevention.

As the level of fortification of moringa increased, the carbohydrate content declined gradually from 65.10% to 58.43%. Fapetu et al. (2022) also noted similar reductions with an increase in carbohydrate reduction as wheat flour, which has a high starch content, was gradually substituted by moringa leaf powder with relatively high protein, dietary fibre and mineral concentrations. This change in composition led to a nutritionally balanced product.

Overall, the present results show that Moringa oleifera leaf powder (MOLP) can be used as a improving ingredient to increase the nutritional profile of cookies. The higher levels of protein, fiber and mineral content as well as the lower level of carbohydrates are in line with the results of earlier studies on bakery products fortified with moringa seeds (Fapetu et al., 2022; Saleem et al., 2023; Riaz et al., 2022). However, as the nutritional quality increased with fortification, the level of fortification needs to be optimized to keep a optimum level between the nutritional value & consumer acceptability.

3.4 Sensory Assessment of Cookies

Fortification effect on consumer acceptability of cookies was assessed by sensory evaluation of cookies fortified with different concentrations of Moringa oleifera leaf powder. The sensory attributes evaluated were color, aroma, taste, texture and overall acceptability. The mean sensory scores obtained from the panelists are presented in Table 3.3.

Table 3.3: Sensory Scores of Cookies Fortified with Different Levels of Moringa Leaf Powder

Treatment	Color	Aroma	Taste	Texture	Overall Acceptability
T0 (0%)	8.40 ± 0.35	8.20 ± 0.42	8.35 ± 0.38	8.10 ± 0.40	8.30 ± 0.34
T1 (5%)	8.05 ± 0.40	7.95 ± 0.45	8.00 ± 0.43	7.95 ± 0.39	8.05 ± 0.36
T2 (10%)	7.35 ± 0.48	7.20 ± 0.52	7.15 ± 0.50	7.40 ± 0.44	7.30 ± 0.42
T3 (15%)	6.40 ± 0.55	6.25 ± 0.60	6.10 ± 0.58	6.70 ± 0.53	6.30 ± 0.55

Values are expressed as mean ± standard deviation (n = 25 panelists).

Sensory evaluation showed that addition of M. oleifera leaf powder in different concentrations had a progressive effect on the organoleptic properties of cookies. The color scores gradually decreased as moringa was incorporated. Fortified cookies developed a darker greenish-brown color while the control treatment had the highest color scores, due to the natural chlorophyll pigments found in moringa leaves. Agba et al. (2024) reported similar findings, noting that green color in the moringa powder was responsible for lower color acceptability of moringa-enriched cookies, and proposed discoloration as a means to enhance consumer acceptance.

There were minor differences between treatments in aroma score. The presence of moringa powder in cookies at 5–10% fortification level preserved the desirable aroma characteristic, while the higher fortification levels resulted in an increased herbaceous aroma, which was less preferred by the

panelists. The trend is in accordance with the results of Oh and Kang (2025) who found that low incorporation of moringa maintained desirable aroma and flavour scores while higher levels affected the scores.

The taste scores reduced significantly as moringa leaf powder was added. The control cookies had the highest taste score followed by the 30% moringa cookies and then moringa at the lowest score with 15%. The moringa cookies with 15% moringa content were the least desirable while the control cookies were the most desirable in terms of taste. The reduction in taste preference may be due to the presence of phenolic compounds and Glucosinolates in moringa leaves that impart a characteristic herbal and slightly bitter taste to the leaves. In the same way, Oh and Kang (2025) found that taste scores decreased significantly with increasing moringa leaf powder concentration.

Texture was satisfactory for all treatments. The moderate fortification of cookies with moringa enhanced the firmness and structural integrity of the cookies while the excessive fortification led to slightly hard cookies due to their high dietary fiber content and water absorption capacity. In a similar study, Oh and Kang (2025) reported significant increases in hardness, gumminess and chewiness as moringa supplementation increased.

Overall acceptability is the result of the overall perception of all the sensory attributes. The present study showed that cookies formulated with moringa leaf powder at 5% (T1) had the highest overall acceptability compared to the other fortified treatments. Likewise, Oh and Kang (2025) found that the best formulation was low level moringa incorporation, and Agba et al. (2024) determined that the acceptability of the moringa fortified cookies was enhanced by decreasing green color produced by moringa.

In conclusion, present study showed that mid-level of fortification of M. oleifera powder could be fortified in cookies without significantly altering the acceptability of the cookies by consumers. However, the high fortification levels negatively influenced color, taste, aroma, and overall acceptability, highlighting the need for optimization of incorporation level for commercially viable functional bakery products.

4. Conclusion and Recommendations

The present study successfully developed cookies fortified with *M. oleifera* leaf powder and evaluated their physical, nutritional, & sensory characteristics. Moringa incorporation progressively improved the nutritional quality of cookies by rising protein, ash, and crude fiber contents while reducing carbohydrate levels. Physical characteristics were also affected, with increased thickness and weight and decreased diameter and spread ratio as the level of moringa increased, mainly due to its high fiber and water-holding capacity.

Sensory evaluation showed that all treatments were acceptable; however, sensory scores declined with higher levels of fortification. Among the fortified treatments, 5% moringa incorporation (T1) provided the best optimum level between nutritional improvement & sensory acceptability. Overall, the results suggest that *Moringa oleifera* leaf powder can be effectively used as a functional ingredient in cookie production, particularly at moderate levels, to develop nutrient-enriched products with good consumer acceptance. Food industries and bakery enterprises may utilize moringa leaf powder as a natural source of plant-based protein, dietary fibre, and minerals in bakery products. The future research should be focused on shelf-life stability, nutrient bioavailability, mineral and vitamin composition, and the application of moringa in other food products. Additionally, larger consumer acceptance studies and optimization of flavor and color characteristics are recommended to further improve the market potential of moringa-fortified products.

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All authors contribute to this article equally.

CONFLICT OF INTEREST

There is no conflict of interest among all authors.

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