

Research Article	Pak-Euro Journal of Medical and Life Sciences	
DOI: 10.31580/pjmls.v8i1.3246	Copyright © 2025 All rights are reserved by Corresponding Author	
Vol. 8 No. 1, 2025: pp. 197-204		
www.readersinsight.net/pjmls	Revised: March 21, 2025	Accepted: March 25, 2025
Submission: January 03, 2025	Published Online: March 31, 2025	

PREPARATION AND QUALITY EVALUATION OF MORINGA (*MORINGA OLEIFERA* L.) FORTIFIED BREAD

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Abstract

The present study was conducted to develop and evaluate the physicochemical and sensory properties of moringa (*Moringa oleifera* L.) fortified bread. The aim of this study is to develop fortified bread by incorporating moringa leaf powder (MLP). The bread samples were prepared by the incorporation of 0, 5, 10, 15, 20 g of moringa powder by following the bread recipe. The samples were prepared, baked and analyzed for physico-chemical and sensorial analysis for moisture content, ash content, protein content, total carbohydrates, weight before and after baking, bread height, and sensory attributes. The results obtained for T4 bread sample showed statistically highest values for ash 2.5%, fat 3.7%, protein 33%, sodium 4.8 mg/100 g, phosphorus 0.54 mg/100 g, and potassium 0.95 mg/100 g followed by T0 had the highest moisture content 25.25% and total carbohydrates 56.22%. Sensory evaluation indicated that T2 received the highest color score, 8.5, T1 had the highest aroma score, 7.4, T3 exhibited superior texture, 7.9, and T3 was rated highest in overall acceptability, 8.6. Based on these findings, T2 and T4, containing 10 g and 20 g of moringa leaf powder, respectively, demonstrated enhanced nutritional value and acceptable sensory characteristics. It is concluded from this study that the potential of moringa-fortified bread in addressing malnutrition challenges, particularly in Pakistan, is promising due to its high nutritional value and local availability.

Keywords: Fortified bread, Malnutrition alleviation, *Moringa oleifera*, Nutritional value, Sensory evaluation

INTRODUCTION

Moringa (*Moringa oleifera* L.) is a nutrient-rich plant widely cultivated in India and later introduced to various Asian and African countries, including China, Egypt, and Pakistan. Due to its exceptional nutritional profile, moringa has gained significant attention as a functional food ingredient. Different parts of the plant, including leaves, seeds, and flowers, are used in various culinary and medicinal applications (1). The leaves, in particular, are a rich source of proteins, iron, antioxidants, and essential vitamins such as A, B, and C. The incorporation of moringa leaf powder (MLP) into staple foods has been explored as a strategy to enhance their nutritional value, making it a potential solution for combating malnutrition (2).

Moringa leaf powder has been extensively studied for its ability to enhance the nutritional quality of food products. Studies have shown that processed bread formulated with wheat flour and MLP exhibits higher crude fiber, protein, fat, minerals, and β -carotene content, although some formulations have shown compromised physical properties and reduced acceptability (3). The World Health Organization (WHO) has recognized *Moringa oleifera* as an alternative dietary source to address malnutrition (4). Furthermore, studies investigating moringa-fortified baked products, such as cookies and gluten-free bread, have reported improvements in protein content, amino acid composition, and mineral levels (5, 6).

One of the key nutritional concerns globally, particularly in developing countries like Pakistan, is protein-energy malnutrition (PEM), which can lead to growth retardation, weakened immunity, and impaired cognitive development (2). Moringa is a rich source of 16–19 amino acids, including 10 essential amino acids required for human health (7). Its high content of micronutrients such as folic acid, pyridoxine, nicotinic acid, and provitamin A makes it an effective dietary supplement for vulnerable populations,

including women of childbearing age and children under five (8). In particular, vitamin A deficiency remains a major public health issue in South Asia and sub-Saharan Africa, affecting vision, growth, and immune function (9). Recent research highlights the growing importance of moringa in food fortification efforts. The incorporation of MLP into wheat-based bread and other bakery products has been proposed as a viable strategy to enhance the nutritional value of staple foods. It is demonstrated by Sengev *et al.*, 2013, that moringa-fortified bread provides significant amounts of protein, minerals, and phenolic compounds, which are essential for maintaining overall health (10). The development of moringa-fortified bread in Pakistan, particularly for populations in regions such as the Thar Desert, has the potential to address both malnutrition and food security challenges. Keeping in view the aim of this study is to prepare moringa-fortified bread with varying levels of moringa powder and assess its physicochemical and sensory properties.

MATERIALS AND METHODS

Fresh leaves of *Moringa oleifera* were collected from the garden of Sindh Agriculture University, Tandojam, Pakistan. The leaves were thoroughly washed, shade-dried at room temperature until completely moisture-free, and then ground into a fine powder. The powder was sieved and stored in airtight jars for subsequent use in bread formulation (11).

Bread was prepared using a standard formulation consisting of wheat flour, dry yeast, bread improver, butter/oil, salt, sugar, and distilled water. The *Moringa* leaf powder was incorporated into the dough at varying concentrations: T0 (control, 0 g), T1 (5 g), T2 (10 g), T3 (15 g), and T4 (20 g).

Physicochemical properties of the bread samples were evaluated using standard procedures as described by Sengev *et al.*, 2013 (11), bread diameter (cm) was measured by placing bread slices edge to edge using a standard ruler. Bread volume (cm³) was assessed with a digital vernier caliper with 0.01 mm precision. Ash content (%) was determined by incinerating pre-weighed samples in crucibles and recording the residual weight. Moisture content (%) was assessed by drying 5 g of bread sample at 65–70°C for 4–4.5 hours, followed by cooling in a desiccator and reweighing. Protein content (%) was analyzed using the micro-Kjeldahl method and nitrogen content was converted to protein using a factor of 6.25 (James, 1995). Total carbohydrate (%) was calculated by difference using the formula:

Total carbohydrates (%) = 100 – (% Ash + % Moisture + % Fat + % Protein + % Fiber).

Fat content (%) was measured using the Mojonnier extraction method.

Mineral analysis for sodium (Na), phosphorus (P), and potassium (K) was carried out using Flame Atomic Absorption Spectrophotometry (FAAS, Model 210-VGP, USA) in accordance with (11) standards.

Sensory evaluation was conducted by a panel of seven trained judges at the Institute of Food Sciences and Technology (IFST), Sindh Agriculture University, Tandojam. The panel used a 9-point hedonic scale to assess attributes including texture, aroma, color, appearance, taste, flavor, and overall acceptability of the fortified bread samples.

STATISTICAL ANALYSIS

The data recorded for each parameter were subjected to statistical analysis using Statistix 8.1 computer program software (4).

RESULTS

The physico-chemical characteristics of *Moringa oleifera*-fortified bread were evaluated both before and after baking. The parameters assessed included diameter, volume, ash content, moisture, protein, carbohydrates, fat content, and mineral composition, along with sensory attributes.

There were no significant differences ($P > 0.05$) observed in the bread diameter across treatments. Diameter values ranged from 8.1 cm in the control (T0) to 8.2 cm in T3, with other treatments (T1, T2, T4) showing intermediate measurements (Fig. 1a). Similarly, bread volume exhibited non-significant variation ($P > 0.05$), with the lowest volume recorded in T0 (14 cm³) and the highest in T2 (14.2 cm³) (Fig. 1b).

Ash content varied significantly ($P < 0.05$) among samples, increasing with higher levels of *Moringa* incorporation. The maximum ash content was found in T4 (2.5%), followed by T3 (1.96%) and T2 (1.47%),

while T0 (0.99%) had the lowest value (Fig. 1c). Moisture content also demonstrated significant variation ($P < 0.05$), with T1 exhibiting the highest moisture (25.29%), followed closely by T0 (25.25%) and T2 (24.22%). The lowest moisture level was recorded in T4 (24.18%) (Fig. 1d).

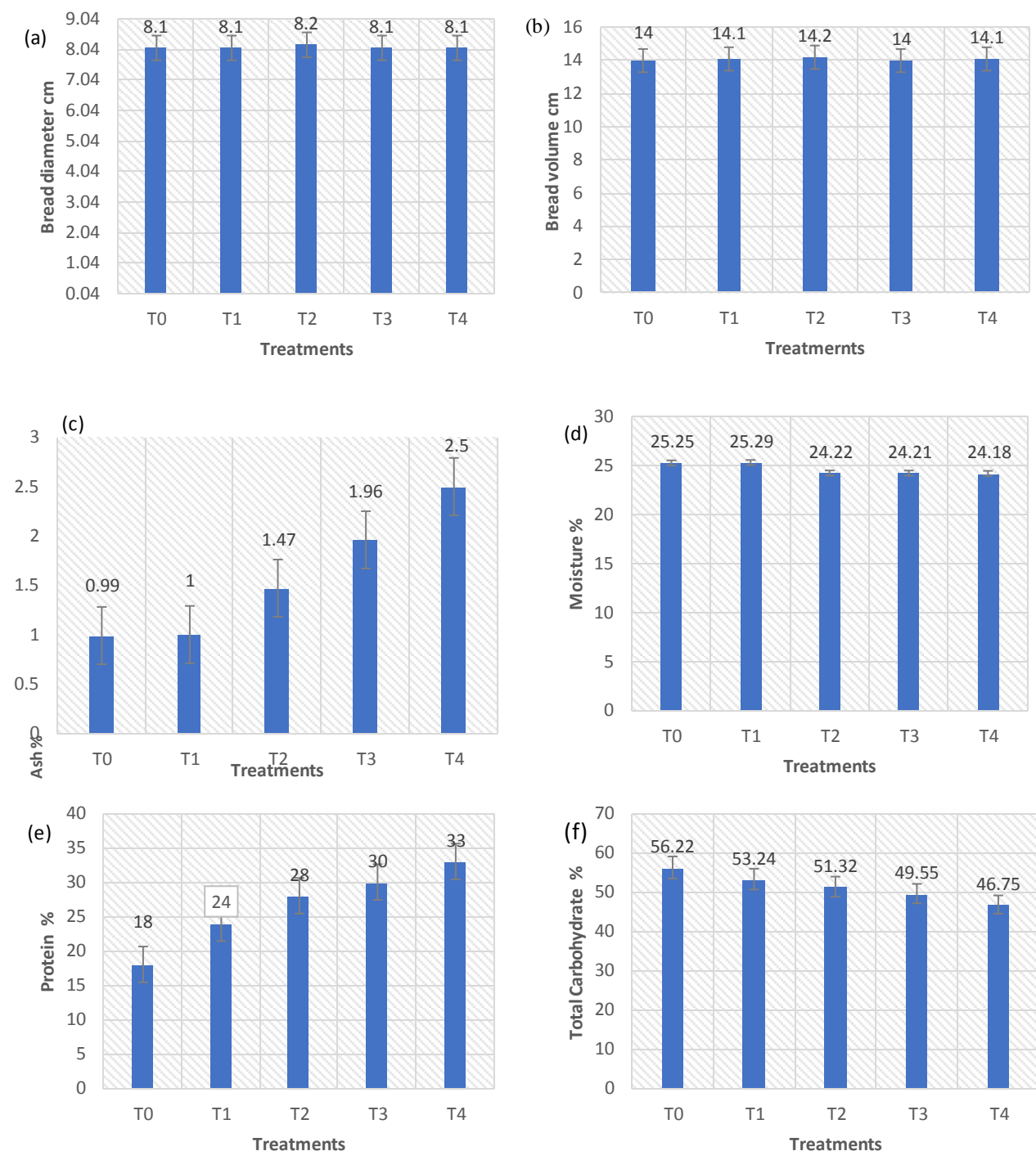


Fig. 1 (a-f). Bread diameter (cm), volume (cm), ash %, moisture %, protein % and total carbohydrates % of moringa bread prepared with various levels of Moringa leaves powder

Protein content increased significantly ($P < 0.05$) with Moringa addition, reaching the highest in T4 (33%), followed by T3 (30%), T2 (28%), and T1 (24%), while T0 had the lowest protein content (18%) (Fig. 1e). Conversely, carbohydrate content showed a declining trend with increasing Moringa levels. T0 recorded the highest carbohydrate percentage (56.22%), followed by T1 (53.24%), T2 (51.32%), and T3 (49.55%), with the lowest in T4 (46.75%) (Fig. 1f).

Fat content differed significantly ($P < 0.05$) among treatments (Fig. 2a). T2 had the highest fat percentage (5.3%), followed by T4 (3.7%), T3 (3.6%), and T1 (3.3%), whereas the control (T0) had the lowest fat content (3.2%).

Mineral analysis revealed that Moringa-fortified bread was richer in essential minerals compared to the control. Sodium content was significantly higher in T4 (4.8 mg/100g) compared to T0 (2.74 mg/100g) (Fig.

2b). Phosphorus levels also showed significant variation ($P < 0.05$), with T4 having the highest content (0.54 mg/100g), followed by T3 (0.38 mg/100g), T2 (0.25 mg/100g), and T1 (0.18 mg/100g), while T0 recorded the lowest (0.12 mg/100g) (Fig. 2c). Potassium content was highest in T4 (0.95 mg/100g) and lowest in T0 (0.15 mg/100g), with significant differences observed (Fig. 2d).

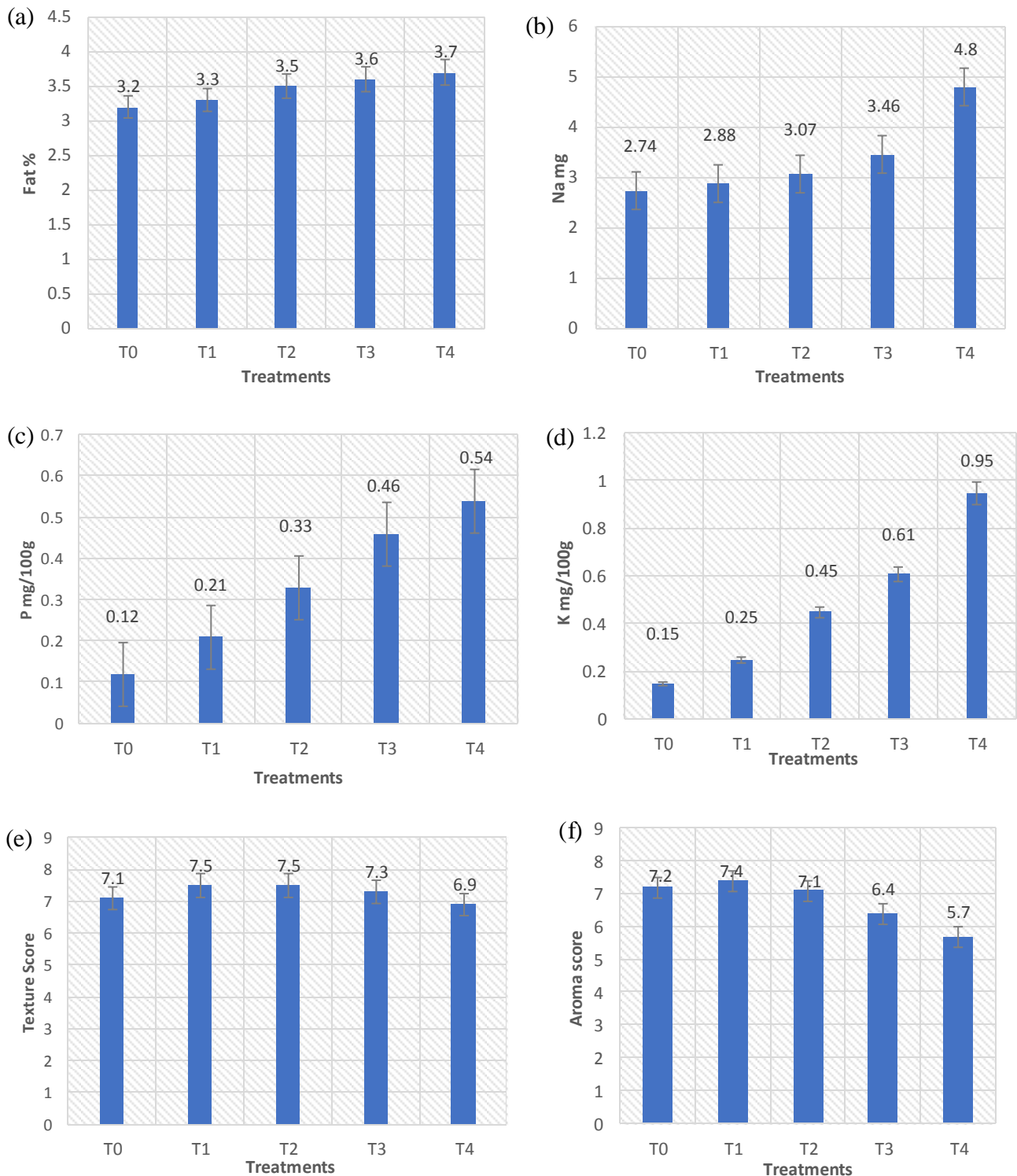


Fig. 2 (a-f). Fat %, Sodium (Na mg/g), Phosphorus (P mg/g), Potassium (K mg/g), Texture score and Aroma score of moringa bread prepared with various levels of Moringa leaves powder. *(T₀: (Control), T₁: Bread+ 5 g moringa powder, T₂: Bread+ 10 g moringa powder, T₃: Bread+ 15 g moringa powder T₄: bread+ 20 g moringa powder).

Sensory evaluation results indicated varying responses from panelists across different attributes. The highest texture scores were observed in T1 and T2 (7.5), while T4 had the lowest (6.9) (Fig. 2e). Aroma scores peaked in T1 (7.4), followed by T2 (7.1), and declined in T4 (5.7) (Fig. 2f). Color ratings were significantly different ($P < 0.05$), with T2 (8.5) and T1 (8.3) rated highest, whereas T0 and T4 scored the

lowest (7.2) (Fig. 3a). Appearance was most favored in T1 (7.5) and T2 (7.4), with T3 and T4 receiving lower scores (6.7 and 6.3, respectively) (Fig. 3b).

Taste evaluations showed that T1 (7.4) and T0 (7.1) were preferred, while T4 (6.0) scored the lowest (Fig. 3c). T1 also achieved the highest flavor score (7.8), with T2 (7.5) following closely and T4 (7.1) being the least favored (Fig. 3d). Overall acceptability scores did not differ significantly ($P > 0.05$), though T0 (8.1) and T2 (8.6) had the highest ratings, followed by T3 (7.9) and T4 (7.6) (Fig. 3e).

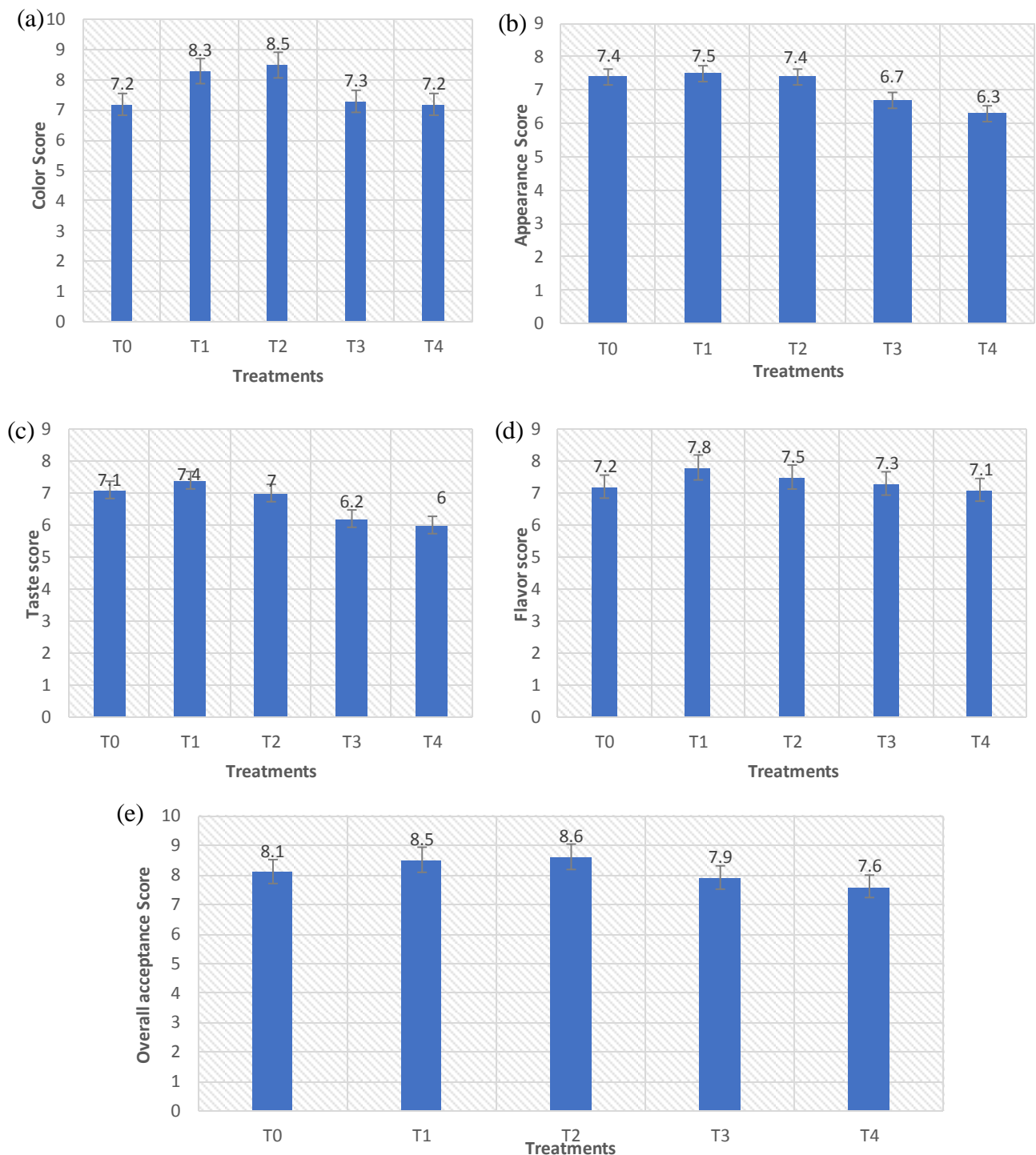


Fig. 3 (a-e). Color score, Appearance score, Taste score, Flavor score and Overall acceptability score of moringa bread prepared with various levels of Moringa leaves powder. *(T₀: (Control), T₁: Bread+ 5 g moringa powder, T₂: Bread+ 10 g moringa powder, T₃: Bread+ 15 g moringa powder T₄: bread+ 20 g moringa powder).

DISCUSSION

Moringa (*Moringa oleifera*) is recognized as a highly nutritious plant, widely cultivated in Sindh and consumed as a dietary supplement to combat nutritional deficiencies and treat various ailments (5). The leaves are particularly rich in essential minerals, antioxidants, and bioactive compounds such as tannins, steroids, triterpenoids, and flavonoids (12). Incorporating moringa powder into bread presents a viable

strategy to enhance its nutritional value, as demonstrated by the physicochemical and sensory analyses in this study.

Table I. Analysis of variance by LSD and comparing the average of variables by \pm SEM

Variables	\pm SEM	LSD (0.05)
Ash (%)	0.0219	0.0476
Moisture (%)	0.0199	0.0434
Protein (%)	0.0463	0.0133
Total carbohydrates (%)	0.0363	0.0133
Fat (%)	0.0171	0.0373
Sodium (Na) mg/g	0.0163	0.0356
Phosphorus (P) mg/g	0.0410	0.0377
Potassium (K) mg/g	0.0410	0.0377
Texture score	0.0561	0.0803
Aroma score	0.0147	0.0319
Color score	0.0187	0.0407
Appearance score	0.0202	0.0440
Taste score	0.0203	0.0197
Flavor score	0.0791	0.752
Overall acceptability score	0.0791	0.0903

*SEM= standard error of the mean; Least Significant Difference (LSD) test was applied for the analysis of variance

Bread diameter and volume showed minimal variation (8.1–8.2 cm and 14–14.2 cm, respectively), aligning with findings by Gallagher *et al.*, 2004 and Mahmood *et al.*, 2010 (13, 14). This indicates that moringa supplementation does not significantly compromise bread structure.

The results regarding physico-chemical characteristics of moringa bread prepared with the addition of various levels of moringa powder were observed statistically different ($P < 0.05$) for ash percentage. The ash results revealed that the ash percentage of bread increased as the amount of moringa powder increased by 2.5 % was observed. The results of ash % was found more or less similar with study conducted by Al-Kahtani & Abou-Arab, 2010 (15).

The results regarding physico chemical characteristics of moringa bread prepared with the addition of various levels of moringa powder were observed statistically different ($P < 0.05$) for moisture percentage. The moisture % result revealed that as the amount of moringa powder was increased the moisture decreased 24.18 % whereas the control sample without the addition of moringa powder resulted 25.25%. The results of moringa bread are comparable with the study conducted by Oyeyink & Oyeyinka (2014) and found more or less similar to the study conducted by Habeych *et al.*, 2016 (16). Another similar study also had similar results of with moringa bread moisture % reported by Sultana, 2020 (17).

The results regarding the protein percentage of moringa bread at various levels remained statistically different ($P < 0.05$). The results revealed that protein percentage remained significantly higher ($P < 0.05$) in T₄ (33 %) and lower ($P < 0.05$) in T₀ (18 %) sample. Similar results regarding white bread fortified with moringa leaf powder were found by Martínez-Monzó *et al.*, 2013 (18), our results are supported and are comparatively similar (19).

The results regarding total carbohydrate percentage of moringa bread at various levels remained statistically different ($P < 0.05$). The results revealed that total carbohydrate percentage remained significantly higher ($P < 0.05$) in T₀ (56.22 %) followed by T₄ (46.75 %). The results of our findings are supported by Mishra, *et al.*, (2021) who found that carbohydrate was decreased as protein increased (20).

The results regarding fat percentage of moringa bread at various levels remained statistically different ($P < 0.05$). The results showed bread fat percentage remained significantly higher ($P < 0.05$) in T₄ (3.7 %). The results of this research are compared with the findings reported by Bancesi *et al.*, 2020 (1).

The moringa bread samples were analyzed for sodium, phosphorus, and potassium. The bread samples were found rich in certain minerals sodium (Na), phosphorus (P) potassium (K). The highest Na amount was found in T₄ (4.8 mg/g). The bread samples were found rich in certain minerals phosphorus (P). The highest P amount was found in T₄ (0.54 mg/g) the lowest was found in T₀ (0.12 mg/g). These results are supported by study conducted. The moringa bread samples were found rich in potassium (K). The highest K

amount was found in T₄ (0.95 mg/g) whereas the lowest was found in T₀ (0.15 mg/g). There was a significant difference ($p < 0.05$) among the treatments in terms of mineral elements (21).

The results regarding the color score of moringa bread resulted statistically different ($P < 0.05$) and the results showed the color score remained significantly higher ($P < 0.05$) in T₂ (8.5) followed by (7.2) respectively. The results of this study are supported by the work done by Sultana, 2020 (17).

The results regarding the appearance score of moringa bread resulted statistically different ($P < 0.05$) and showed the appearance score remained significantly higher ($P < 0.05$) in T₁ (7.5) followed by T₁ and T₂ (7.4). Results are supported by the work done Mishra *et al.*, (2021). The results regarding the taste score of moringa bread resulted statistically different ($P < 0.05$) and the results showed the taste score remained significantly higher ($P < 0.05$) in T₁ (7.4) followed by (7) respectively. The results of this study are supported by the work done by Al-Kahtani & Abou-Arab, 2010 (15). The results regarding the aroma score of moringa bread resulted statistically different ($P < 0.05$) and the results showed the aroma score remained significantly higher ($P < 0.05$) in T₂ (7.2) followed by (7) respectively. The results of this study are supported by the work done by Govender & Siwela (2020a). The results of this study are supported by the research work of Bourekoua *et al.*, 2018 (8). The results regarding the flavour score of moringa bread resulted statistically different ($P < 0.05$) and results showed the flavor score remained significantly higher ($P < 0.05$) in T₁ (7.8) followed by (7) respectively. The results of this study are supported by the work done by Olaitan *et al.*, 2014 (6). The results of this study are supported by the work of Falade *et al.*, 2014 and Martínez-Monzó *et al.*, 2013 (12, 18). The results regarding the texture score of moringa bread resulted statistically different ($P < 0.05$) and the results showed the texture score remained significantly higher ($P < 0.05$) in T₁ (7.5) followed by (7) respectively. The results of this study are supported by the work done by Firdausy *et al.*, 2020 and Nour *et al.*, 2018 (5, 22). The results of this study are supported by the work of Monzó *et al.*, 2013 (18). The results regarding the overall acceptability score of moringa bread resulted statistically different ($P < 0.05$) and the results showed the overall acceptability score remained significantly higher ($P < 0.05$) in T₃ (8.6) followed by (7.5) respectively. The results of this study are supported by the work done by Oyeyinka *et al.*, 2018 and *et al.*, 2020 (23, 24).

CONCLUSION

It is concluded from the study that bread prepared by use of moringa (*Moringa oleifera*) powder improved bread's nutritional, sensory, and mineral properties. The bread samples of bread prepared with 5% (T₁) and 15% T₄ moringa powder showed higher acceptability due to better flavor, taste, and aroma. The physico chemical and sensory analysis of moringa bread revealed the rich source of essential micro minerals that enhanced dietary nutrition and recommended for peoples diet in term of their health and nutrition. The moringa powder widely available in Sindh, Pakistan, this research supports its use in food industries to develop nutritious bakery products for betterment of consumer health and to reduce malnutrition from Pakistan and around the globe

Acknowledgements:

The authors gratefully acknowledge the financial support provided by Hamdard University, Karachi, Pakistan, which was instrumental in facilitating this research.

Conflict of interest:

There is no conflict of interest among authors regarding this article.

Authors` contribution:

All authors contributed equally to the design and execution of the experiment, data analysis, interpretation of results, and preparation of the manuscript. Each author reviewed and approved the final version of the manuscript.

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