Effect of *Moringa oleifera* Leaf Powder Level on the Proximate Composition and Sensory Acceptance of Roasted Chickpea Bars

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Received: 19 Jun 2026 **Accepted:** 17 July 2026 **Published:** 29 July 2026

Abstract

This screening study evaluated roasted chickpea bars in which *Moringa oleifera* leaf powder (MLP) replaced 0%, 2%, 4%, or 6% of a 250-g chickpea-MLP base while jaggery and cocoa spread remained fixed. These levels corresponded to 0%, 1.35%, 2.70%, and 4.05% MLP in the complete 370-g formulation. Four treatments (T_o-T_3) were assessed for crude fat, crude protein, moisture, ash, and six sensory attributes on a nine-point scale. In the supplied results, protein increased from 25.6% in T_o to 25.9% in T_3, ash increased from 3.24% to 3.44%, and moisture decreased from 8.26% to 7.51%. Fat varied non-monotonically from 27.9% to 28.3%. Treatment differences were reported for each proximate variable ($p < 0.05$). Among the sensory attributes, only the moringa-flavour item was reported to differ significantly; overall acceptability did not differ significantly. T_1 had the highest overall acceptability score (7.66 ± 0.57), whereas T_3 had the highest protein and ash values. Thus, T_1 may be advanced as a candidate for confirmatory testing, but the data do not establish a statistically superior or optimized formulation. Independent batch replication, validated analytical methods, panel characteristics, ethics documentation, and the statistical model must be confirmed before inferential conclusions are accepted.

Keywords: Chickpea-based bar; *Moringa oleifera;* Leaf powder; Proximate composition; Sensory acceptance; Formulation screening

DOI: https://doi.org/10.65749/pjfs.2026.30.2.0008

1. Introduction

Chickpea *(Cicer arietinum L.)* is a pulse valued for protein, dietary fibre, starch, vitamins, and minerals. Its nutritional composition and wide availability make it a useful base for plant-forward convenience foods (Jukanti et al., 2012). Roasting also changes chickpea colour, flavour, and functional properties and can therefore influence its performance in ready-to-eat products (Jogihalli et al., 2017).

Moringa oleifera leaves contain protein and mineral matter as well as multiple phytochemicals, but their composition depends on cultivar, maturity, processing, and storage. MLP has consequently been investigated as a natural food fortificant. Fortification can improve selected compositional attributes while also changing colour, flavour, and texture; formulation therefore requires an explicit balance between composition and acceptability (Stohs & Hartman, 2015; Vishwakarma et al., 2022).

Snack bars provide a convenient matrix for combining cereal, pulse, fruit, and binding ingredients. Previous work has shown that formulation strongly affects the physicochemical and sensory properties of cereal and protein bars, including bars containing roasted chickpea flour (Jabeen et al., 2022; Samakradhamrongthai et al., 2021). However, evidence remains limited for roasted chickpea bars in which low levels of MLP directly replace part of the chickpea component while jaggery and cocoa spread remain fixed.

The objective was therefore to formulate roasted chickpea bars containing 0-6% MLP in the chickpea-MLP base and compare their reported proximate composition and sensory scores. The primary outcomes were overall acceptability and crude protein; moisture, ash, crude fat, and the remaining sensory attributes were secondary outcomes. It was hypothesized that increasing MLP would increase protein and ash and would alter sensory perception. Because only four inclusion levels were examined, the study was treated as exploratory formulation screening rather than definitive optimization.

2. Materials and Methods

2.1 Raw materials and moringa-leaf preparation

Roasted chickpeas, jaggery, and cocoa spread were purchased from retail markets in Chiniot, Pakistan, and transported to the Food Processing Laboratory, Riphah International University, Faisalabad Campus. Mature *M. oleifera* leaves were collected from a healthy plant, washed, shade-dried, milled, and used as MLP.

2.2 Formulation and experimental design

A single-factor formulation design was used, with MLP inclusion as the factor and four levels (0%, 2%, 4%, and 6%). The supplied treatment plan indicates that MLP replaced chickpea within a 250-

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g chickpea-MLP base, whereas jaggery and cocoa spread were held constant at 60 g each. The reconstructed mass formulation is shown in Table 1.

Table 1. Reconstructed formulation of the chickpea-moringa bars

Treatment	MLP in 250-g base (%)	Roasted chickpea (g)	MLP (g)	Jaggery (g)	Cocoa spread (g)	MLP in complete formulation (%)
T_o	0	250	0	60	60	0.00
T_1	2	245	5	60	60	1.35
T_2	4	240	10	60	60	2.70
T_3	6	235	15	60	60	4.05

MLP, *Moringa oleifera* leaf powder. Percentages are expressed on the 250-g chickpea-MLP base unless otherwise specified. The reconstructed starting mass was 370 g for every treatment.

2.3 Bar preparation

Roasted chickpeas and MLP were weighed according to the treatment plan. Chickpeas were coarsely ground. Jaggery was heated to 80-90 °C and blended with cocoa spread to form a binder. The chickpea and MLP mixture was added gradually and stirred while the mass was heated over low heat for 3-5 min until semi-solid. The mixture was spread in a greased, parchment-lined tray, cooled at room temperature for 30-40 min, cut into bars, wrapped in aluminium foil, and retained for analysis. This general preparation sequence is consistent with published cereal-bar processing approaches (Samakradhamrongthai et al., 2021).

2.4 Proximate analyses

Finely ground bar samples were analysed for moisture, ash, crude protein, and crude fat. Results were expressed as percentages by mass on the as-is basis. The original draft did not identify validated method numbers; these must be supplied so that the work can be reproduced and checked against the current AOAC compendium (AOAC International, 2023).

2.4.1 Moisture

A 2-3 g test portion was dried in a hot-air oven at 105 °C to constant mass. Moisture (%) was calculated as 100 × (initial test-portion mass − dried mass)/initial test-portion mass.

2.4.2 Ash

A test portion was incinerated in a muffle furnace at 550 °C for 4-6 h, or until complete ashing, cooled in a desiccator, and weighed. Ash (%) was calculated as 100 × ash residue mass/test-portion mass.

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2.4.3 Crude protein

Total nitrogen was determined by Kjeldahl digestion, distillation, and titration. Crude protein was calculated as nitrogen (%) multiplied by the conversion factor used for the analysis.

2.4.4 Crude fat

Crude fat was described in the original records as a gravimetric extraction. Fat (%) was calculated as 100 × mass of recovered extract/test-portion mass. The earlier label 'Gerber method' has been removed because it conflicted with the stated gravimetric procedure and is not, without further adaptation, a sufficient description for this solid food matrix.

2.5 Sensory evaluation

Appearance, flavour, texture, chewiness, moringa-flavour liking, and overall acceptability were evaluated on a nine-point hedonic scale anchored from 1 (dislike extremely) to 9 (like extremely). A controlled hedonic test should document participant recruitment, serving conditions, coding, order randomization, palate cleansing, and consent in accordance with accepted sensory practice (ISO 11136:2014/Amd 1:2020).

2.6 Statistical analysis

Each response was summarized as mean ± standard deviation. The treatment effect was assessed by one-way analysis of variance, with pairwise mean separation at $p < 0.05$. For valid inference, independently prepared batches not repeated readings from the same batch must be the experimental units for composition. Sensory observations must likewise be analysed with participant dependence accounted for when each participant rates all formulations.

3. Results and Discussion

3.1 Proximate composition

The reported proximate results are presented in Table 2. All four variables were reported to differ among formulations at $p < 0.05$; however, the inferential results remain provisional until batch replication and the post-hoc procedure are confirmed.

Table 2. Reported proximate composition of chickpea bars containing 0-6% MLP

Treatment	Crude fat (%)	Crude protein (%)	Moisture (%)	Ash (%)
T_o (0%)	27.9 ± 0.01^d	25.6 ± 0.01^d	8.26 ± 0.01^d	3.24 ± 0.05^d
T_1 (2%)	28.3 ± 0.05^a	25.7 ± 0.01^c	7.91 ± 0.02^c	3.31 ± 0.00^c
T_2 (4%)	28.1 ± 0.05^c	25.8 ± 0.01^b	7.77 ± 0.01^b	3.37 ± 0.01^b
T_3 (6%)	28.2 ± 0.05^b	25.9 ± 0.02^a	7.51 ± 0.02^a	3.44 ± 0.05^a

Values are the means ± SD supplied in the original manuscript. Insert n. Within a column, unlike superscripts were reported to indicate $p < 0.05$; confirm the post-hoc test and experimental unit.

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Protein increased monotonically by 0.3 percentage point from T_o to T_3, and ash increased by 0.20 percentage point. These directions are compatible with replacing part of the chickpea base with a leaf powder containing protein and mineral matter, but the effect sizes are small and do not identify individual amino acids or minerals. Accordingly, ash should not be described as a direct measure of nutritional mineral quality. Studies of natural food fortification and chickpea-containing bars similarly show that compositional effects depend on both the fortificant and the full product matrix (Jabeen et al., 2022; Vishwakarma et al., 2022).

Moisture declined by 0.75 percentage point between T_o and T_3. This result may reflect changes in formulation, water binding, heating, or sample handling, but no water activity, microbial counts, packaging comparison, or storage study was performed. The observed moisture difference therefore cannot support a shelf-life claim.

Crude fat showed no dose-response pattern: T_1 had the highest mean, T_2 was lower, and T_3 was intermediate. The small separation among means, together with the unresolved extraction method and replication, makes a causal explanation based on MLP lipid content premature.

3.2 Sensory scores

Table 3 shows that all formulations had mean overall-acceptability scores above 6 on the nine-point scale. Only the moringa-flavour item was reported to differ significantly. No statistically significant difference was reported for appearance, flavour, texture, chewiness, or overall acceptability.

Table 3. Reported sensory scores of chickpea bars containing 0-6% MLP

Treatment	Appearance	Flavour	Texture	Chewiness	Moringa-flavour liking	Overall acceptability
T_o (0%)	7.00 ± 1.00	7.00 ± 1.73	6.66 ± 0.57	8.00 ± 1.00	5.00 ± 0.00^{b}	7.33 ± 1.15
T_1 (2%)	7.30 ± 1.15	6.66 ± 0.57	7.00 ± 1.73	8.00 ± 1.00	8.33 ± 0.60^{a}	7.66 ± 0.57
T_2 (4%)	8.00 ± 1.00	8.00 ± 1.00	8.33 ± 0.57	6.30 ± 1.15	7.00 ± 1.00^{a}	6.66 ± 0.57
T_3 (6%)	7.30 ± 1.15	8.33 ± 0.57	8.33 ± 1.15	7.30 ± 1.02	6.67 ± 0.60^{ab}	7.33 ± 1.15

Values are the means ± SD supplied in the original manuscript. Insert n. Unlike superscripts in the moringa-flavour column were reported to indicate $p < 0.05$; the other attributes were reported as non-significant. The label 'moringa-flavour liking' assumes that this item used the same hedonic anchors; confirm before submission.

T_2 had the highest numerical appearance score, T_3 the highest flavour score, T_2 and T_3 the highest texture scores, and T_o and T_1 the highest chewiness scores. T_1 had the highest numerical overall-

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acceptability score, but its mean was not statistically distinguishable from the other treatments. The data therefore support acceptable average ratings across the tested range, not superiority of one formulation.

The moringa-flavour item was highest for T_1 and lower for T_3. If this was a hedonic item, the pattern suggests that moderate MLP inclusion was liked more than the control or the highest inclusion level. If it was an intensity item, however, the analysis and interpretation must be rewritten because intensity is not equivalent to liking. A larger, well-characterized consumer test with randomized serving order is needed to estimate preference and to test whether 2% MLP is robustly preferred (ISO 11136:2014/Amd 1:2020).

3.3 Candidate formulation and study limitations

On a descriptive basis, T_1 combines the highest mean overall acceptability with slightly higher protein and ash than T_o. It may therefore be advanced as a candidate for confirmatory testing. It should not be described as a statistically optimized formulation because overall acceptability did not differ significantly and the experiment did not use an optimization model or a sufficiently resolved concentration range.

Interpretation is limited by the missing documentation of independent batches, the unresolved analytical methods, and the absent panel description and ethics statement. The study also did not measure dietary fibre, individual minerals, vitamins, phenolics, antioxidant activity, instrumental colour or texture, water activity, microbial quality, nutrient bioavailability, storage stability, or serving-level nutrition. Consequently, the data establish only the reported proximate and sensory outcomes under the tested conditions; they do not establish therapeutic, disease-prevention, or shelf-life benefits.

4. Conclusion

Replacing 0-6% of the chickpea-MLP base with MLP was associated with small increases in the reported protein and ash values and a decrease in moisture, while crude fat changed non-monotonically. Mean sensory scores remained above 6 across treatments, and only the moringa-flavour item was reported to differ significantly. T_1 (2% of the 250-g base; 1.35% of the complete formulation) had the highest numerical overall-acceptability score and is a reasonable candidate for further development, but the present data do not demonstrate a statistically superior optimum. Before publication, the authors should verify the formulation basis and raw data, report independent replication and validate analytical methods, and supply complete sensory and statistical procedures. Confirmatory work should include an adequately powered consumer test, instrumental quality measures, nutrient-specific analyses, and a designed storage study.

DOI: https://doi.org/10.65749/pjfs.2026.30.2.0008

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DOI: https://doi.org/10.65749/pjfs.2026.30.2.0008