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A Comparative Evaluation of the Nutritional, Functional, and Sensory Properties of Paneer Enriched with Selected Green Leaves Additives

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Abstract- Paneer, is a fresh dairy product, is valued for its high protein content and versatility. It lacks essential micronutrients, necessitating strategies to incorporating nutrient-rich leafy greens to enhance its nutritional and functional properties. This study evaluates the effects of incorporating moringa (*Moringa oleifera*) leaf powder (T2), sesbania (*Sesbania grandiflora*) leaf powder (T3), and spinach (*Spinacia oleracea*) leaf puree (T4) into paneer, compared to a control (T1) sample. Proximate analysis indicated higher levels of protein, ash, and carbohydrates in the enriched samples. Spinach-enriched paneer exhibited the highest protein content (26.46%), followed by sesbania (25.88%), and moringa (25.62%). And moringa-enriched paneer had the highest ash content (1.97%). The antioxidant activity was significantly enhanced in enriched samples, with moringa-enriched paneer exhibiting the highest (71.30%), followed by sesbania (62.54%), and spinach (51.66%). Significant differences were observed in textural properties, the highest hardness was recorded in moringa-enriched paneer (8.88N), while sesbania-enriched paneer exhibited the highest chewiness (0.02J) and gumminess (6.57N). Total plate count revealed no significant differences ($p > 0.05$) among four treatments. Overall, the incorporation enhanced the nutritional and antioxidant potential of paneer without compromising its microbial safety or sensory attributes, demonstrating their potential as functional fortifying agents in dairy-based foods.

Keywords- Fortification, Moringa, Paneer, Sesbania, Spinach

Recommended APA Citation

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Introduction

Paneer is a South Asian fresh cheese prepared by acid–heat coagulation of milk. It is a rennet-free, non-fermented, non-melting, and unripened cheese that is rich in fat (22–25%) and protein (16–18%) but relatively low in lactose (2.0–2.7%) (Aneja, 2007; Kanawjia and Singh, 1996; Singh and Kanawjia, 1988;). Despite its nutritional value, paneer is typically bland, making it a suitable base for fortification with nutrient-rich ingredients (Shrivastava and Goyal, 2007).

Leafy greens such as moringa (*Moringa oleifera*), sesbania (*Sesbania grandiflora*), and spinach (*Spinacia oleracea*) are rich in proteins, minerals, vitamins, fiber, and bioactive compounds with proven health benefits (Ansari et al., 2020; Ghani, 2002; Kavitha and Ramadas, 2013; Rockwood et al., 2013; Roy and Chattopadhyay, 2011;). Their incorporation can enhance the nutritional, functional, and antioxidant properties of dairy products. This study therefore aimed to fortify paneer with moringa leaf powder, sesbania leaf powder, and spinach leaf puree, and to evaluate the effects on nutritional composition, and functional quality.

Materials and Methods

Materials

Fresh cow milk was sourced locally, while moringa leaves, sesbania leaves, and spinach leaves were collected from Akkaraipattu, Eastern Province, Sri Lanka. All experimental work was carried out at the Food Science Laboratory, Faculty of Technology, South Eastern University of Sri Lanka (SEUSL).

Preparation of Leaf Additives

Preparation of Moringa Leaf Powder

Fresh moringa leaves were collected and inspected to remove any damaged or discolored parts. The selected leaves were thoroughly washed with potable water to remove dirt and impurities. The cleaned leaves were blanched in hot water 95±1°C for 60 seconds, immediately cooled in ice water, and then dried in a forced-air oven (Biobase BJPS series) at 45±2°C for 5 hours. The dried moringa leaves were ground into a fine powder (Wickramasinghe et al., 2020).

Preparation of Sesbania Leaf Powder

Fresh sesbania leaves were collected, sorted to remove damaged or discolored parts, and thoroughly washed with potable water. The cleaned leaves were subjected to blanching in hot water 95 ± 2 °C for 60 seconds and then cooled quickly in ice water. After cooling, the leaves were dried in a forced-air oven (Biobase BJPS series) at 45 ± 1° C for 5 hours, ground into a fine powder using a grinder (Bhokre et al., 2022).

Preparation of Spinach Leaf Puree

Fresh spinach leaves were collected and inspected to discard any damaged or discolored parts before being washed thoroughly with potable water. The washed leaves were blanched in hot water (95 ± 2 °C) for 60 seconds and immediately cooled in ice water to preserve color and nutritional quality. The cooled spinach leaves were then drained to remove excess water and blended into a smooth puree (Nisha et al., 2004).

Paneer Making Process

Three paneer formulations were prepared by adding moringa, sesbania, and spinach, which served as the three treatments. Fresh cow milk was heated to 80 ± 2 °C for 5 minutes with continuous stirring. After heating, moringa powder, sesbania powder, or spinach puree was added to the respective treatment batches and thoroughly mixed. The milk was then cooled to 70 °C, followed by the addition of 0.1% calcium chloride and 2% citric acid to induce coagulation. After 5–10 minutes, the curd was separated using a muslin cloth, and whey was drained off. The curd was pressed for 30 minutes and then chilled in water at 4 ± 2 °C for 2 hours. The paneer was cut into cubes, packed in polyethylene pouches, and stored at 4 °C for subsequent analysis. Table 1 presents the different formulated paneer samples.

Table 1

Experimental design

Treatments	
T1	Control
T2	Moringa leaf powder (1%) incorporated
T3	Sesbania leaf powder (1%) incorporated
T4	Spinach leaf puree (1%) incorporated

Optimization of Leaf Additive Concentrations

In formulating paneer with leaf additives, the appropriate quantity of each leaf powder or puree was determined by preparing samples with different concentrations (0.5%, 1%, 2%, and 5%). These formulations were then subjected to sensory evaluation using 9-point hedonic scale with 30 semi-trained panelists. Based on the sensory scores, the optimal concentration for each leaf additive was identified and used for developing the final paneer formulation. Table 2 presents the paneer samples prepared with different concentrations of leaf additives.

Table 2

Different concentration of leaf additives treatments

Treatments	**0.5%**	**1.0%**	**2.0%**	**5.0%**
Moringa	M1	M2	M3	M4
Sesbania	A1	A2	A3	A4
Spinach	S1	S2	S3	S4

Analytical Procedures

Physicochemical Analysis

The yield of paneer was determined by weighing the final product obtained from one liter of milk. The pH was measured at room temperature using a calibrated digital pH meter (Hanna H198191), with samples prepared by blending 10 g of paneer with 10 mL of distilled water. For acidity, 25 mL of paneer extract titrated against 0.1 N NaOH using phenolphthalein as an indicator. Texture analysis was conducted using a Brookfield Texture Analyzer with a TA10 cylindrical probe on paneer cubes (2 × 2 × 1 cm), measuring hardness, cohesiveness, springiness, and chewiness through a double-compression test. Color was analyzed using a smart-phone colorimeter app under consistent lighting on a neutral white background, recording L*, a*, and b* values.

Proximate Analysis

The proximate composition of paneer samples was analyzed using standard methods (AOAC, 2005). Moisture content was determined by the oven-drying method at 105 °C until a constant weight was obtained (AOAC, 2005). Ash content was estimated using the dry ashing method in a muffle furnace at 550 °C (AOAC, 2005). Protein content was measured using the

Kjeldahl method (AOAC, 2004). Fat content was determined by the Van Gulik method involving sulfuric acid digestion, centrifugation, and butyrometer reading (ISO 3433 / IDF 222:2008). Carbohydrate content was calculated by difference, subtracting the combined percentages of moisture, ash, fat, and protein from 100% (AOAC, 2005).

Antioxidant Activity - DPPH (2,2-Diphenyl-1-picrylhydrazyl) Assay

Antioxidant activity of paneer samples was assessed using the DPPH assay. 2 g sample was homogenized in 20 mL methanol and centrifuged; the supernatant was used for analysis. A 0.1 M DPPH solution was prepared in methanol. For the assay, 1 mL of extract was mixed with 2 mL DPPH solution, incubated in the dark for 30 minutes, and absorbance was measured at 517 nm. Methanol served as the blank. Scavenging activity (%) was calculated using the standard formula. (Singh et al., 2023).

Microbial Analysis - Total Plate Count

Total Plate Count (TPC) was determined using the pour plate method under aseptic conditions. A 1 g sample of paneer was homogenized and serially diluted up to 10^{-4}. From each dilution, 1 mL was transferred into sterile petri dishes, followed by pouring molten nutrient agar (44 ± 2 °C). Plates were incubated at 37 °C for 48 hours, and colonies were counted to calculate microbial load in CFU/g.

$$\text{TPC (CFU/g)} = \frac{\text{Average Number of Colonies}}{\text{Dilution Factor}} \quad (1)$$

Data Analysis

The data were analyzed using Minitab version 17 based on a Completely Randomized Design (CRD). The results were expressed as mean ± SE One-way Analysis of Variance (ANOVA) was used to evaluate the effects of treatment and paired-wise tukey comparisons revealed significant differences at 0.05 level.

Results

Selection of Optimal Leaf Additive Concentration

1% concentration (M2, A2, S2) consistently showed the highest overall acceptability scores across all three leafy additives, as shown in Figure 1. Based on panel scores for attributes of appearance, texture, odor, taste, and overall acceptability 1% was selected as the optimal level for further analysis of enriched paneer samples.

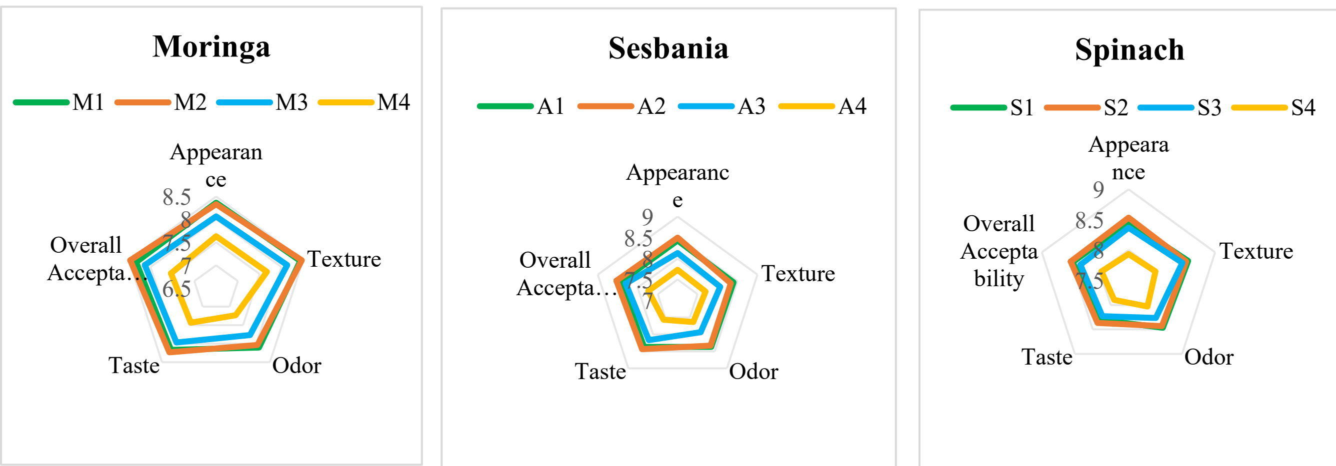

Figure 1. *Radar diagram for sensory evaluation of leaf additive concentration*

Physico-Chemical Properties of Paneer

Yield of Paneer

The yield of paneer differed significantly among treatments ($p < 0.001$). Enriched paneer samples showed higher yields than the control. The highest yield was observed in T2 (moringa, 133.39 ± 1.74 g/L), followed by T3 (sesbania) and T4 (spinach). The lowest yield was recorded in T1 (control, 113.15 ± 1.82 g/L) (Table 3).

Table 3

Physicochemical properties of paneer

Treatment	Yield (g/L)	pH	Acidity (%)
T1	113.15 ± 1.82^{b}	5.43 ± 0.03^{a}	0.43 ± 0.01^{d}
T2	133.39 ± 1.74^{a}	5.27 ± 0.03^{b}	0.61 ± 0.00^{b}
T3	128.48 ± 1.18^{a}	5.27 ± 0.03^{b}	0.50 ± 0.01^{c}
T4	127.35 ± 0.99^{a}	5.13 ± 0.03^{b}	0.75 ± 0.02^{a}
p-value	0.001	0.002	0.001

pH of Paneer

Significant differences in pH were observed among the paneer samples ($p = 0.002$). The highest pH value was noted in the control sample (5.43 ± 0.03), while the lowest was recorded in T4 (spinach, 5.13 ± 0.03). The enriched treatments exhibited lower pH values compared to the control (Table 3).

Acidity of Paneer

Acidity varied significantly among treatments ($p < 0.001$). The highest acidity was observed in T4 (spinach, 0.75 ± 0.02%), whereas the lowest acidity was recorded in the control sample (0.43 ± 0.01%). Enriched paneer samples showed higher acidity values than the control (Table 3).

Texture Properties of Paneer

The incorporation of moringa, sesbania, and spinach significantly affected the texture properties of paneer ($p < 0.001$), except for springiness, which did not differ significantly among treatments ($p = 0.057$). T2 (moringa-enriched) showed the highest hardness (905.60 ± 1.20^{a} g), followed by T3, while T1 had the lowest. Cohesiveness was highest in T3 (sesbania, 0.75 ± 0.03^{a}), and T4 had the lowest. Although springiness differences were not statistically significant, T2 (3.38 ± 0.08^{a} mm) and T3 (3.38 mm) showed higher values. Chewiness was also highest in T3 (sesbania, 20.10 mJ), followed by T2, with T4 recording the lowest (Table 4).

Table 4

Texture analysis of paneer

Treatment	Hardness (g)	Cohesiveness	Springiness (mm)	Chewiness (mJ)
T1	633.30 ± 0.80^{d}	0.67 ± 0.01^{ab}	2.94 ± 0.04^{a}	12.67 ± 0.46^{b}
T2	905.60 ± 1.20^{a}	0.65 ± 0.02^{b}	3.38 ± 0.08^{a}	19.12 ± 0.16^{a}
T3	849.60 ± 0.80^{b}	0.75 ± 0.03^{a}	3.37 ± 0.28^{a}	20.10 ± 1.11^{a}
T4	730.60 ± 1.40^{c}	0.45 ± 0.02^{c}	2.75 ± 0.13^{a}	09.61± 0.32^{c}
p-value	0.001	0.001	0.057	0.001

Color Analysis

Color attributes of paneer were significantly influenced by enrichment with leafy additives. Significant differences were observed for L* and a* values ($p < 0.001$) and for b* values ($p = 0.001$). The highest lightness (L*) value was recorded in the control sample (73.00), while the lowest was observed in T3 (sesbania-enriched paneer) (37.00). The a* values indicated increased greenness in enriched samples, with the most negative value recorded in T2 (moringa-enriched paneer) (-13.00). The highest b* value was observed in the control sample (51.67), while the lowest was recorded in T2 (39.33) (Table 5).

Table 5

Color parameters of paneer

Treatment	L* Value	a* Value	b* Value
T1	73.00 ± 2.31[a]	-05.00 ± 1.00[a]	51.67 ± 2.33[a]
T2	38.00 ± 2.31[b]	-13.00 ± 0.58[c]	39.33 ± 0.88[b]
T3	37.00 ± 2.65[b]	-09.67 ± 0.33[b]	42.67 ± 0.88[b]
T4	48.67 ± 3.18[b]	-11.67 ± 0.33[bc]	50.67 ± 0.88[a]
p-value	0.001	0.001	0.001

Proximate Analysis of Paneer

Moisture Content of Paneer

The moisture content of paneer differed significantly among treatments ($p = 0.043$). The highest moisture content was recorded in the control sample (T1) (53.69 ± 0.58%), while the lowest was observed in T3 (sesbania, 50.83 ± 0.50%). T2 (moringa) and T4 (spinach) showed slightly reduced moisture values (Table 6).

Table 6

Proximate analysis of paneer

Treatment	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)
T1	53.69 ± 0.58[a]	1.26 ± 0.01[d]	24.05 ± 0.33[b]	17.81± 0.29[a]	3.67 ± 0.92[a]
T2	51.96 ± 0.72[ab]	1.97 ± 0.01[a]	25.62 ± 0.33[ab]	16.85 ± 0.14[ab]	3.78 ± 1.06[a]
T3	50.83 ± 0.50[b]	1.88 ± 0.01[b]	25.88 ± 0.43[a]	16.53 ± 0.30[b]	5.42 ± 0.93[a]
T4	51.12 ± 0.63[ab]	1.73 ± 0.02[c]	26.46 ± 0.33[a]	16.28 ± 0.26[b]	4.69 ± 0.98[a]
p-value	0.043	0.001	0.008	0.015	0.575

Ash Content of Paneer

Ash content increased significantly with the incorporation of plant additives ($p < 0.001$). The highest ash content was found in T2 (moringa, 1.97 ± 0.01%), followed by T3 (sesbania) and T4 (spinach). The lowest ash content was recorded in the control sample (1.26 ± 0.01%) (Table 6).

Protein Content of Paneer

The protein content was significantly affected by the incorporation of leafy additives ($p = 0.008$). T4 (spinach) had the highest protein content (26.46 ± 0.33%), followed by T3 (sesbania) and T2 (moringa), while the lowest was recorded in T1 (control, 24.05 ± 0.33%) (Table 6).

Fat Content of Paneer

Fat content differed significantly among treatments (p = 0.015). The highest fat content was recorded in the control sample (T1, 17.81 ± 0.29%), followed by T2 (moringa) and T3 (sesbania), while the lowest was observed in T4 (spinach, 16.28 ± 0.26%) (Table 6).

Carbohydrate Content of Paneer

No significant difference was observed in carbohydrate content among the treatments (p = 0.575). The highest carbohydrate content was recorded in T3 (sesbania, 5.42 ± 0.93%), while the lowest was observed in the control sample (3.67 ± 0.92%) (Table 6).

Antioxidant Activity - DPPH Assay

The antioxidant activity of paneer, measured using the DPPH assay, differed significantly among treatments ($p < 0.001$). The highest DPPH radical scavenging activity was observed in T2 (moringa, 71.30 ± 0.52%), followed by T3 (sesbania, 62.54 ± 0.83%) and T4 (spinach, 51.66 ± 0.72%). The lowest antioxidant activity was recorded in the control sample (T1, 45.46 ± 0.82%) (Table 7).

Table 7

DPPH Assay of paneer

Treatment	DPPH %
T1	45.46 ± 0.82^{d}
T2	71.30 ± 0.52^{a}
T3	62.54 ± 0.83^{b}
T4	51.66 ± 0.72^{c}
p-value	0.001

Microbial Analysis - TPC

No significant difference was observed in the TPC among the paneer samples (p = 0.151). The highest microbial count was recorded in T4 (spinach, $(3.1 \pm 0.2) \times 10^5$ CFU/g), followed by T2 (moringa, $(2.7 \pm 0.7) \times 10^5$ CFU/g) and T3 (sesbania, $(1.8 \pm 0.3) \times 10^5$ CFU/g). The lowest microbial count was observed in the control sample (T1, $(1.3 \pm 0.5) \times 10^5$ CFU/g) (Table 8).

Table 8

TPC of paneer

Treatment	TPC (CFU/g)
T1	$1.3 \pm 0.5 \times 10^{5a}$
T2	$2.7 \pm 0.7 \times 10^{5a}$
T3	$1.8 \pm 0.3 \times 10^{5a}$
T4	$3.1 \pm 0.2 \times 10^{5a}$
p-value	0.151

Discussion

The incorporation of moringa, sesbania, and spinach leaves significantly influenced the physicochemical properties of paneer. The increased yield observed in enriched paneer samples can be attributed to the enhanced water-holding capacity and fiber content of the leafy additives, with moringa showing the greatest effect. Similar increases in yield have been reported by Kaur et al. (2003) and Bajwa et al. (2005) in coriander- and mint-fortified paneer. The reduction in pH and the corresponding increase in acidity in enriched samples are likely due to the presence of natural organic acids and phenolic compounds in the leafy additives. Comparable trends have been reported by Tanwar (2022) and Pallavi et al. (2021), who also observed reduced pH and increased acidity in herb-fortified paneer, which may contribute to improved product stability and firmer texture.

Textural and color characteristics of paneer were markedly affected by the incorporation of leafy additives. Moringa- and sesbania-enriched paneer exhibited increased hardness, cohesiveness, and chewiness, indicating clear modifications in the protein matrix, whereas spinach-enriched paneer showed a comparatively softer and less cohesive texture. Although springiness did not differ significantly, slightly higher values in moringa- and sesbania-enriched samples suggest improved elasticity. Significant changes in color parameters, including reduced lightness and increased greenness, were observed in enriched paneer due to the presence of natural pigments such as chlorophylls, carotenoids, and flavonoids. These findings are consistent with structural and compositional changes reported in dairy products fortified with plant-based ingredients and highlight the influence of leafy additives on both the functional and visual attributes of paneer.

The proximate composition of paneer was influenced by the incorporation of moringa, sesbania, and spinach additives. The reduction in moisture content observed in enriched paneer samples may be attributed to the higher solid content and water-binding interactions of bioactive compounds present in the leafy additives. Similar reductions in moisture content have been reported by Tanwar (2022) in moringa-fortified paneer and by El-Sayed (2020) in spinach-enriched soft cheese. The significant increase in ash content reflects the mineral-rich nature of the plant additives, which is consistent with the findings of Singh et al. (2023) in moringa-fortified chhana and El-Sayed (2020).

An increase in protein content in enriched paneer samples may be associated with the high protein and essential amino acid content of the leafy additives, a trend also reported by Singh et al. (2023) and Pallavi et al. (2020) in spinach-fortified paneer. Conversely, the decrease in fat content observed in enriched samples may be due to the dilution effect caused by the incorporation of fiber-rich plant materials, as previously reported by Abdulrashid (2024) in mint-based paneer and Pallavi et al. (2020). Although carbohydrate content did not change significantly, slight increases observed in some treatments may be attributed to the presence of dietary fiber and polysaccharides from the leafy additives, in agreement with earlier findings by El-Sayed (2020) and Singh et al. (2023).

The significant increase in antioxidant capacity of enriched paneer is attributed to the presence of bioactive compounds such as phenolics and flavonoids in the leafy additives, particularly moringa. Similar enhancements in antioxidant activity have been reported by Singh et al. (2023) in moringa-fortified chhana and by El-Sayed (2020) in spinach-enriched cheese, confirming that leafy additives can effectively increase the free radical scavenging potential of dairy products.

Microbial analysis revealed no significant differences in TPC among the paneer samples, indicating that fortification did not compromise microbial safety. The slight variations observed in TPC may be linked to the antimicrobial properties of plant bioactive compounds, including flavonoids, tannins, and phenolics (Cowan, 1999; Cushnie and Lamb, 2011; Gupta et al., 2020); however, these effects were not strong enough to produce statistically significant changes. All microbial counts remained within the acceptable range for paneer (Food Safety and Standards Authority of India [FSSAI], 2016), suggesting that enrichment with leafy additives is safe when hygienic processing and proper storage are maintained.

Conclusion

The study concluded that fortifying paneer with moringa leaf powder, sesbania leaf powder, and spinach leaf puree improved its nutritional, functional, and antioxidant properties compared to the control. Paneer enriched with spinach had the highest protein content, while moringa contributed the most ash content, reflecting enhanced mineral composition. The fat content slightly decreased in all enriched variants, and carbohydrate content showed no significant changes. Among the treatments, moringa-enriched paneer exhibited the highest antioxidant activity, followed by sesbania and spinach, indicating improved functional quality. The incorporation of leafy additives significantly influenced the physicochemical properties of paneer. The yield increased in all fortified samples, while enrichment also led to a reduction in pH and a corresponding increase in acidity across the treatments. These changes are attributed to the organic acids and phenolic compounds present in the leaves, contributing to better microbial stability. Texture analysis revealed that moringa and sesbania improved hardness, cohesiveness, and chewiness, while spinach resulted in a softer and less cohesive texture. Color was also significantly affected, with fortified samples appearing darker and greener due to natural pigments like chlorophyll. Microbial analysis showed no significant differences in total plate count among treatments, indicating that fortification did not compromise microbial safety. Overall, the findings suggest that leafy green additives can be effectively used to enhance the nutritional and functional qualities of paneer, but further strategies are needed to improve its shelf stability.

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