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Effects of *Moringa oleifera* Leaf and Seed Powder on the Quality and Viability of Probiotic Fermented Milk

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ABSTRACT

This study aimed to evaluate the effects of *Moringa oleifera* on the chemical, physical, rheological and sensory properties of probiotic-fermented milk, as well as the viability of probiotic strains. *Moringa oleifera* leaf and seed powders at 0.5 and 1% concentrations were added to buffalo's milk, followed by a probiotic starter culture containing: *Lactobacillus acidophilus*, *Bifidobacterium bifidum* and *Streptococcus thermophilus*. Various analyses were conducted at fresh and after 7 and 15 days of storage. Results showed that, *Moringa oleifera* significantly increased total solids, fat and protein and levels in the fermented milk, with 1% seed powder (T4) yielding the highest levels. Fortified samples demonstrated improved viscosity and water-holding capacity, with T4 showing the highest values at 1883.33 centipoise and 50.37%; respectively. Microbiological tests showed that, *Moringa oleifera* kept more *Lactobacillus acidophilus* and *Streptococcus thermophilus* during storage, which means that the probiotics were more stable. Sensory evaluation indicated that, while *Moringa oleifera* improved nutritional quality, careful management of fortification levels is essential to maintaining desirable sensory properties, particularly flavor and texture. The study concluded that, fortifying probiotic fermented milk with higher levels of *Moringa oleifera* seed powder significantly enhances its nutritional and functional properties, extends shelf life and provides health benefits. However, optimizing fortification levels is crucial for maintaining consumer acceptability. Using 1% *Moringa oleifera* seed powder may improve the nutritional profile and balance the sensory properties. This is because *Moringa* can improve functional properties, extend shelf life and promote health benefits when combined with probiotics.

Keywords: Probiotic, Fermented milk, *Moringa oleifera*, Sensory properties

INTRODUCTION

The global food industry is actively pursuing innovative approaches to developing functional dairy products that address consumers' growing interest in health and wellness. This trend is exemplified by probiotic-stirred fermented milk fortified with Moringa oleifera, which combines the well-documented benefits of probiotics with Moringa oleifera's potent nutritional and therapeutic properties. This plant is known for its high antioxidant, anti-inflammatory, and nutritional content, including vitamins, minerals, and other beneficial compounds. Merging these attributes with probiotic-stirred fermented milk is significant for a variety of reasons, including foods that provide preventive and therapeutic benefits (Dou et al., 2019; Lisak Jakopović et al., 2022; Zhang et al., 2019).

First, probiotics play a critical role in improving gut health, immunity, and digestion by balancing the gut microbiome. By introducing *Moringa oleifera* into the mix, researchers aim for the vitamins, minerals and antioxidants to stimulate probiotic bacteria, and to produce a product that combines the functional properties of both moringa and probiotics and results in improved shelf life, flavor and health benefits, in line with consumer demand for functional foods that provide Preventive and therapeutic benefits.

Despite extensive research into fermented dairy products and the role of lactic acid bacteria (LAB) in enhancing nutritional profiles, flavor, and texture, *Moringa oleifera* integration remains underexplored. Previous studies have highlighted how LAB strains can produce low-cholesterol, antioxidant-rich dairy products, but the synergistic effects of *Moringa* and LABs in stirred fermented milk need further exploration. Research suggests that combining these elements may yield a product with superior health benefits and sensory attributes (Borgonovi *et al*., 2023; Almada-Corral *et al*., 2022 and Shahein *et al*., 2022).

Furthermore, the market demand for functional foods that are both delicious and offer therapeutic benefits has never been greater. Understanding how probiotics and *Moringa oleifera* can interact to improve the quality of stirred fermented milk presents an opportunity for researchers to fill existing knowledge gaps and deliver innovative, health-enhancing dairy products. By investigating how probiotic cultures interact with *Moringa oleifera*, this research could establish a strong foundation for developing new functional dairy products that meet current wellness trends and address consumer needs (Fan *et al*., 2022 and Ismael *et al*., 2022).

MATERIALS AND METHODS

Materials:

Moringa oleifera obtained from Agriculture Research center El Doki, Ministry of Agriculture, Egypt. Oxoid MRS Broth and MRS agar medium were obtained from Thermo

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Fisher Scientific Inc. Waltham, MA, USA. Oxoid M17 Broth and M17 agar medium were obtained from Thermo Fisher Scientific Inc. Waltham, MA, USA. Fresh buffalo whole milk (8.1% fat, 9.5% SNF) was obtained from animal production research, faculty of agriculture, Kafrelsheikh University, Egypt. Lyophilized probiotic starter (ABT culture) contains *Lactobacillus acidophilus*, *Bifidobacterium bifidum* and *Streptococcus thermophilus*. The starter was obtained from Chr. Hansen. Laboratories, Copenhagen, Denmark.

Methods:

Production of stirred fermented milk:

Heat five-treatment Buffalo milk (8.1% fat & 9.5% SNF) control and four treatments fortified with different levels of *Moringa oleifera* (0.5 & 1% powder leaves and 0.5 & 1% powder seeds) to 90°C for 7 min. Inoculation with ABT 10^6-10^7 CFU/ml starter culture at 42°C. Treatments were incubated at 42°C until pH drops to 4.7 and then kept at 5°C for overnight. Coagulated bio yoghurt was stirred by mechanical mixer, filled in plastic bottles and stored at 5ºC for 15 days as modification described by Eman *et al*. (2019).

Chemo-physical analysis of fermented milk:

Total solids of milk samples were estimated as described by Ling (1963), milk fat content (%) were estimated as described by AOAC (2016).. The titratable acidity was determined based on the method described by Tamjidi *et al.* (2012), the results were recorded as a percentage of lactic acid. pH values measured electrometrically using a pH meter (Crison BASIC 20 +, manufactured in Spain), the electrode was immersed directly into the milk samples. Acetaldehyde content in the yoghurt was estimated according to Lees and Jago (1969) with slight modifications. The water-holding capacity (WHC) of yoghurt was determined using a method previously described by Harte *et al*. (2003). The stirred fermented was centrifuged for 15 min at 7000 rpm at a temperature of 4°C using a Universal 32R centrifuge (HETTICH- ZENTRIFUGEN, Germany), WHC was calculated using the formula below:

$$\mathbf{WHC\ (\%) = (1- \frac{W1}{W2}) \times 100}$$

Where: W1=Weight of whey after centrifugation; W2=Yoghurt weight.

TVFA in bio yoghurt samples was measured using Kosikowski and Mistry (1997), by direct distillation method; the results were expressed as ml 0.1N-NaOH/100 g sample. The apparent viscosity and shear rate of the bio yoghurt were determined at 7±2°C according to Tamjidi *et al*. (2012).

All measurements were performed in triplicate.

Microbiological analysis:

One gram from the stirred bio yoghurt samples was collected and diluted with 9 ml physiological solution (8.5-9.0 g NaCl /1 L distilled water) and gently mixed uniformly with a vortex mixer. Using the pour plate count technique, subsequent serial dilutions were prepared, and viable numbers were counted. *Lactobacillus acidophilus* was enumerated in MRS media and *Streptococcus thermophiles* was enumerated in M17 media at according to Ashraf and Shah (2011). The results were expressed as log10 cfu /g fermented milk.

Sensory evaluation:

The sensory evaluation of yoghurt was performed according to Ismail *et al*. (2016), using the following points for different properties: Appearance (50 points), body & texture (30 points), taste (10 points) and smell & flavor (10 points).

Statical analysis: The SPSS version 10.0 program was used to do statistical analysis, using Duncan's test and analysis of variance. Any significant variations between means were evaluated at the significance threshold of p = 0.05. The information was presented as three replicates' mean ± standard error (SE) (Di Leo & Sardanelli, 2020; Aguinis et al., 2019).

RESULTS AND DISCUSSION

Table 1 shows the chemical makeup of fresh and stored stirred fermented milk that had different amounts of *Moringa oleifera* powder (leaves and seeds) added to it at different times (Fresh and after 7 & 15 days).

Table 1. Chemical composition of stirred fermented milk (%) fortified with different levels of *Moringa oleifera* powder Leaves and seeds (0.5and1%) during storage periods.

Storage (days)	Treatments	T.S. (%)	Fat (%)	Protein (%)	Ash (%)
Fresh	C*	16.40 ^{D}±1.00	5.20 ^{D}±0.28	4.0600 ^{D} ±0.00	0.73^{C}±0.10
	T1	14.67 ^{D}±1.27	5.80 ^{B}±0.14	4.1500 ^{D}±0.00	0.95^{B}±0.87
	T2	16.69 ^{C}±0.16	4.60 ^{D}±0.42	4.2600 ^{D} ±0.00	0.83^{C}±0.25
	T3	17.80 ^{B}±0.78	5.85 ^{B}±0.21	4.3400 ^{C} ±0.00	0.83^{C}±0.71
	T4	20.08 ^{A}±0.06	6.20 ^{A}±0.14	4.68 ^{B} ±0.00	0.72^{C}±0.10
7days	C	17.15 ^{C}±0.18	5.25 ^{D}±0.21	4.1133 D. ± 01	0.95^{B}±0.87
	T1	17.24 ^{C}±0.71	5.50 ^{C}±0.00	4.2367 ^{D}±0.01	0.90^{C}±0.15
	T2	18.71 ^{A}±0.23	5.23 ^{D}±0.06	4.5367 ^{B}±0.03	1.18^{B}±0.39
	T3	17.36 ^{B}±0.29	6.05 ^{B}±0.07	4.4600 ^{C}±0.01	1.17^{B}±0.23
	T4	22.11 ^{A}±0.11	6.24 ^{A}±0.06	5.2200 ^{A}±0.02	0.96^{B}±0.64
15days	C	16.19 ^{D}±0.08	4.70 ^{D}±0.14	4.3400^{C}±0.00	1.09^{B}±0.19
	T1	16.31 ^{D}±0.49	5.50 ^{C}±0.00	4.5400 ^{B} ±0.00	1.52^{A}±1.03
	T2	17.54 ^{B}±0.06	5.50 ^{C}±0.00	4.6800 ^{B} ±0.00	1.05^{B}±0.37
	T3	16.91 ^{C}±0.26	6.45 ^{A}±0.07	4.7900 ^{A} ±0.00	0.54^{D}±0.19
	T4	19.97 ^{A}±0.12	6.25 ^{A}±0.21	5.3200 ^{A} ±0.00	0.83^{C}±0.71

***C: Control; T1: 0.5% Leaves; T2: 0.5% Seeds; T3: 1% Leaves; T4: 1% Seeds**

A, B, C: Means with the same letter among treatments are not significantly different($p \geq 0.05$)

The treatments include; a control (C) and four fortification levels: 0.5% leaves (T1), 0.5% seeds (T2), 1% leaves (T3), and 1% seeds (T4). At fresh time, the total solids (T.S.) content increased significantly($P \geq 0.05$) with higher fortification levels, with T4 (1% seeds) exhibiting the highest T.S. at 20.08%. Fat content varied similarly, with T4 showing the highest fat percentage (6.20%), while the control had the lowest (5.20%). Protein content also showed an increase with fortification, particularly in T4 (4.68%). Ash content remained relatively stable across treatments but was slightly higher in T1 (0.95%). Over time, the T.S. content generally increased, particularly in T4, which reached to 22.11 and 19.97% at 7 and 15 days; respectively. T3 and T4 had consistently higher fat content across storage periods, with T3 peaking at 6.45% at 15 days. Protein content showed significant retention at7and 15 days, particularly in T4 (5.22 and 5.32%). The ash content showed some variability but was notably high in T1 at 15 days (1.52%). These results indicate that, fortification with *Moringa oleifera*, especially at higher levels, enhances the nutritional profile of fermented milk, making it richer in solids, fat, protein, and carbohydrates. This has important implications for dairy science, suggesting that *Moringa oleifera* could be a valuable additive for improving the nutritional quality and shelf-life of dairy products (Shiriki *et al*., 2015; Gopalakrishnan *et al*., 2016 and Saeed *et al*., 2021).

Table 2 shows the effect of *Morina oleifera* powder from leaves and seeds on acidity, pH, total volatile fatty acids, acetaldehyde, viscosity and the ability to retain water during different storage periods.

Significant variations in acidity, pH, TVFA, acetaldehyde, viscosity and WHC were observed. Acidity levels ranged from 0.92 to 1.29%, with treatments incorporating higher concentrations of *Moringa oleifera* powder showing elevated acidity (Hamad *et al*., 2022). pH values ranged from 4.31 to 4.62, indicating alterations in the acidity or alkalinity of the milk. TVFA, an important sign of fermentation activity, ranged from 0.70 to 1.53 ml 0.1 NaOH/ 100 g stirred yoghurt, which suggests that different microbes were using different metabolic processes (Saleh *et al*., 2023).

Acetaldehyde levels, a byproduct of fermentation, ranged from 8.86 to 9.32 µmol/100 ml, reflecting changes in flavor compounds. Protein interactions may have caused changes in texture, as indicated by the range of viscosity values from 680.0 to 1883.33 CP. Lastly, WHC ranged from 40.3600 to 50.37, implying alterations in water-binding capacity (Johnson *et al*., 2021). These findings underscore the complex interactions between *Moringa oleifera* powder supplementation and the quality attributes of probiotic-fermented milk. This paper has implications in this regard for dairy science, offering insights into novel approaches for enhancing the nutritional and functional properties of dairy products through natural supplementation, thereby catering to consumer demands for healthier and more diverse dairy options.

Table 2. The effect of added different levels of *Moringa oleifera* powder (Leaves and seeds) on Acidity, pH, TVFA, Acetaldehyde, Viscosity and WHC of stirred fermented milk during storage period.

Storage period (days)	Treatments	Acidity (%)	pH	TVFA*	Acetaldehyde (µmol/100 ml)	Viscosity (cp)	WHC (%)
Fresh	C	$0.92^{D}\pm0.03$	$4.58^{A}\pm0.01$	$1.20^{B}\pm0.28$	$9.04^{C}\pm0.12$	$1185.00^{B}\pm77.78$	$45.15^{C}\pm1.25$
	T1	$1.06^{C}\pm0.03$	$4.47^{B}\pm0.01$	$1.35^{B}\pm0.07$	$9.03^{C}\pm0.01$	$870.00^{C}\pm28.28$	$40.36^{D}\pm3.07$
	T2	$0.95^{D}\pm0.01$	$4.58^{A}\pm0.01$	$1.40^{B}\pm0.28$	$9.04^{C}\pm0.03$	$1025.00^{C}\pm21.21$	$44.43^{C}\pm0.18$
	T3	$1.09^{B}\pm0.01$	$4.62^{A}\pm0.00$	$0.75^{D}\pm0.07$	$9.32^{A}\pm0.02$	$715.00^{D}\pm21.21$	$42.37^{D}\pm4.04$
	T4	$1.10^{B}\pm0.00$	$4.53^{B}\pm0.01$	$1.40^{B}\pm0.00$	$9.17^{Q}\pm0.03$	$1345.00^{B}\pm63.64$	$49.73^{A}\pm3.01$
7days	C	$1.02^{D}\pm0.00$	$4.43^{C}\pm0.00$	$0.80^{D}\pm0.00$	$9.12^{B}\pm0.07$	$1660.00^{A}\pm0.00$	$47.69^{B}\pm10.39$
	T1	$1.09^{B}\pm0.01$	$4.41^{D}\pm0.00$	$0.70^{D}\pm0.14$	$9.08^{B}\pm0.11$	$680.00^{D}\pm0.00$	$48.22^{B}\pm0.20$
	T2	$1.07^{C}\pm0.00$	$4.43^{C}\pm0.00$	$1.47^{A}\pm0.50$	$9.03^{C}\pm0.16$	$1353.33^{B}\pm30.55$	$47.24^{B}\pm1.44$
	T3	$1.09^{B}\pm0.01$	$4.54^{B}\pm0.00$	$0.90^{C}\pm0.14$	$9.22^{A}\pm0.13$	$850.00^{C}\pm42.43$	$44.43^{C}\pm0.20$
	T4	$1.21^{A}\pm0.01$	$4.40^{D}\pm0.03$	$1.53^{A}\pm0.42$	$9.03^{B}\pm0.10$	$1883.33^{A}\pm37.86$	$50.37^{A}\pm1.00$
15days	C	$1.04^{D}\pm0.00$	$4.41^{D}\pm0.00$	$1.20^{B}\pm0.28$	$9.13^{B}\pm0.11$	$875.00^{C}\pm63.64$	$45.21^{C}\pm1.49$
	T1	$1.14^{B}\pm0.00$	$4.47^{B}\pm0.01$	$1.30^{B}\pm0.42$	$8.90^{D}\pm0.01$	$1070.00^{C}\pm0.00$	$44.18^{C}\pm0.16$
	T2	$1.11^{B}\pm0.01$	$4.31^{D}\pm0.01$	$1.10^{B}\pm0.14$	$9.01^{C}\pm0.05$	$1050.00^{C}\pm56.57$	$45.43^{B}\pm3.18$
	T3	$1.16^{A}\pm0.00$	$4.49^{B}\pm0.01$	$0.90^{C}\pm0.14$	$9.11^{B}\pm0.21$	$730.00^{D}\pm42.43$	$43.56^{D}\pm1.24$
	T4	$1.29^{A}\pm0.01$	$4.42^{C}\pm0.01$	$1.00^{C}\pm0.00$	$8.86^{D}\pm0.07$	$1875.00^{A}\pm49.5$	$47.18^{B}\pm0.20$

For details, See Table 1; TVFA: Total Volatile Fatty Acids (ml 0.1 NaOH/ 100g stirred bio yoghurt)**

The obtained results in this study align with the findings of Hamad *et al*. (2022), who observed that the incorporation of *Moringa oleifera* leaves powder into probiotic yoghurt significantly increased the acidity levels, which is consistent with our observation of elevated acidity levels in treatments with higher concentrations of *Moringa oleifera* powder. Saleh *et al*. (2023) supported these findings by demonstrating that *Moringa oleifera* serves as an effective natural additive in enhancing the quality and nutritional attributes of functional dairy products, particularly in terms of fermentation activity as indicated by TVFA levels. Additionally, Johnson *et al*. (2021) highlighted that the addition of *Moringa oleifera* leaf powder in probiotic yoghurt enhances the physicochemical properties, such as viscosity and water-holding capacity, which corroborates our observations of changes in texture and WHC. These scientific explanations reinforce the potential of *Moringa oleifera* as a valuable supplement for improving the quality of probiotic-fermented milk.

Table 3 shows the microbiological analysis of fresh and stored fermented milk fortified with different levels of *Moringa oleifera* powder (leaves and seeds).

Table 3. Microbiological analysis (cfu/g^{-1}) of fresh and stored stirred fermented milk (%) fortified with different level of *Moringa oleifera* powder (Leaves and seeds).

Storage (days)	Treatments	*Streptococcus thermophillus* (cfu/g^{-1})	*Lactobacillus acidophlilus* (cfu/g^{-1})
Fresh	C	$8.64^{C}\pm0.62$	$7.24^{D}\pm0.51$
	T1	$8.59^{C}\pm0.48$	$7.48^{D}\pm0.81$
	T2	$8.62^{C}\pm0.70$	$7.66^{D}\pm0.19$
	T3	$8.57^{C}\pm0.56$	$8.25^{B}\pm0.36$
	T4	$8.79^{C}\pm0.60$	$7.30^{D}\pm0.10$
7days	C	$8.86^{C}\pm0.44$	$8.51^{B}\pm0.59$
	T1	$8.50^{C}\pm0.71$	$8.59^{B}\pm0.45$
	T2	$8.77^{C}\pm0.68$	$8.41^{B}\pm0.34$
	T3	$8.25^{D}\pm0.50$	$8.00^{C}\pm0.26$
	T4	$8.98^{B}\pm0.54$	$8.18^{C}\pm0.69$
15days	C	$9.23^{B}\pm0.28$	$9.30^{A}\pm0.29$
	T1	$9.54^{A}\pm0.26$	$9.38^{A}\pm0.41$
	T2	$9.57^{A}\pm0.27$	$9.10^{A}\pm0.42$
	T3	$9.69^{A}\pm0.32$	$9.28^{A}\pm0.46$
	T4	$9.48^{A}\pm0.23$	$9.34^{A}\pm0.07$

For details, See Table 1

The numbers of *Streptococcus thermophilus* and *Lactobacillus acidophilus* (cfu/g^{-1}) in the milk show how stable the cultures were. At the first stage (fresh time), the numbers of *S. thermophilus* are pretty much the same in all treatments, except for T4. This suggests that, adding *Moringa oleifera* does not have a big effect on the initial microbial load. However, *L. acidophilus* shows a notable increase in T3, indicating a potential synergistic effect of *Moringa oleifera* at this level. After 7 days of storage, there is a general increase in *S. thermophilus* counts across all treatments, with T4 showing the highest count, which may indicate enhanced microbial stability due to *Moringa oleifera*. On the other hand, the counts of *L. acidophilus*, change. Treatments; C, T1 and T2 maintain high counts, while T3 and T4 show lower counts.

After 15 days of storage, all treatments show a significant increase in both *S. thermophilus* and *L. acidophilus* counts, with the highest counts seen in treatments T1, T2, T3 and T4. This shows that, *Moringa oleifera* can keep probiotics alive for a long time. These findings have significant implications for dairy science, suggesting that *Moringa oleifera* can enhance the quality and stability of probiotic-fermented milk, potentially offering a natural means to improve the health benefits and shelf life of dairy products. Recent studies corroborate the observed effects of *Moringa oleifera* on the stability and growth of probiotic cultures in dairy products. Repajić *et al*. (2022) found that, the addition of *Moringa oleifera* powder to yoghurt significantly increased the growth of yoghurt bacteria and improved the rheological properties and antioxidant capacity of the product. This backs up the initial rise in *L. acidophilus* seen in T3 and the fact that *S. thermophilus* stayed the same across treatments, while being stored (Repajić *et al*., 2022). A study by Ao *et al*. (2021) also talked about the antimicrobial properties of *Moringa oleifera*, they suggested that adding it to dairy products might help keep probiotics alive for longer, which fits with the fact that microbial counts went up in all of the treatments after 15 days.

Table 4 presents the sensory evaluation of fresh and stored stirred fermented milk fortified with various levels of *Moringa oleifera* powder (leaves and seeds) over a 15-day storage period.

The sensory properties assessed include; flavor, body & texture and appearance, with total scores calculated for each treatment (C, T1, T2, T3 & T4). The control samples (C) consistently show the highest scores in all sensory properties throughout the storage period, indicating superior flavor, texture, and appearance retention compared to samples fortified with *Moringa oleifera*. Notably, flavor scores for treatments with *moringa* powder (T1–T4) decrease over time, with T3 exhibiting the most significant decline, particularly on day 15. This trend suggests that, higher levels of *Moringa oleifera* powder might negatively affect the flavor stability of fermented milk.

Table 4. Sensory evaluation of stirred fermented milk (%) fortified with either different level of Moringa oleifera powder (Leaves and seeds) during storage period.

Components	Storage (day)	Treatments C	T1	T2	T3	T4
Flavor (60)	Fresh	58.90^{B}±1.20	40.80^{D}±12.58	57.60^{B}±1.26	42.30^{C}±10.20	58.40^{A}±1.43
	7 days	58.80^{A}±1.48	45.90^{C}±4.41	55.00^{B}±4.35	36.30^{D}±12.04	56.30^{B}±2.79
	15days	58.20^{A}±2.30	41.00^{D}±6.27	52.00^{C}±5.75	30.30^{D}±7.80	53.40^{C}±4.65
Body & Texture (30)	Fresh	28.80^{B}±1.69	25.30^{C}±3.09	28.40^{B}±1.43	24.20^{D}±4.18	27.50^{C}±1.96
	7days	29.20^{A}±1.55	24.90^{D}±3.45	27.20^{C}±3.61	19.90^{D}±5.53	28.30^{B}±1.16
	15days	29.30^{A}±0.67	24.20^{D}±3.97	26.90^{C}±3.07	19.80^{D}±3.58	27.60^{C}±1.58
Appearance (10)	Fresh	9.70^{B}±0.48	7.60^{C}±1.58	9.30^{B}±0.82	6.20^{D}±1.55	8.70^{C}±1.49
	7days	9.60^{B}±0.70	7.60^{C}±1.17	9.20^{B}±0.79	5.90^{D}±1.66	9.20^{B}±0.79
	15days	9.60^{B}±0.52	7.40^{C}±0.84	8.40^{C}±0.84	4.90^{D}±0.88	8.60^{C}±0.84
Total Scores (100)	Fresh	97.40^{A}±1.71	73.70^{D}±15.58	95.30^{B}±2.54	72.70^{D}±12.81	94.60^{B}±4.12
	7days	97.60^{A}±3.57	78.40^{C}±6.42	91.40^{B}±8.46	62.10^{D}±16.91	93.80^{B}±3.94
	15days	97.10^{A}±2.81	72.60^{D}±9.79	87.30^{C}±8.72	55.00^{D}±7.69	89.60^{C}±4.84

For details, See Table 1

The body and texture scores follow a similar pattern, with the control samples maintaining higher scores, while fortified samples, especially T3, exhibit a marked decline by day 15. The appearance scores also reflect a consistent trend where the control samples outperform the *moringa*-fortified treatments, particularly T3. The total scores, which incorporate all sensory attributes, reveal that, the control maintains the highest acceptability, while T3 shows the lowest scores across the storage period. These findings suggest that, although *Moringa oleifera* can improve the nutritional profile of fermented milk, we must carefully manage its impact on sensory qualities, especially flavor and texture, to ensure the consumer acceptability of dairy products. This research highlights the need for optimizing *Moringa oleifera* fortification levels to balance health benefits with sensory quality in dairy science.

Studies have shown that, fortifying fermented dairy products with *Moringa oleifera* can alter flavor profiles, often resulting in decreased consumer acceptability over time. Specifically, products fortified with higher levels of *Moringa oleifera* tend to have a pronounced decline in flavor scores, similar to the findings of this study. For example, Saeed *et al*. (2021) found that while *Moringa oleifera* leaf powder enhanced the nutritional profile of mango-flavored yoghurt, it resulted in lower flavor scores over a 15-day period.

Studies have documented the impact of *Moringa oleifera* on the textural properties of dairy products. Jakopović *et al*. (2022) noted that, *Moringa oleifera* leaf powder, when added to yoghurt, improved the rheological properties but could negatively affect texture stability over extended storage periods. This aligns with the current study's findings, where the body and texture scores of fortified samples declined significantly over 15 days.

Fortification of dairy products with *Moringa oleifera* also influences appearance and overall sensory acceptability. Malla *et al*. (2021) found that, while fortification improved the nutritional value of finger millet porridge, the appearance and overall acceptability scores decreased, especially at higher fortification levels. This is consistent with the observed decline in appearance scores, as well as the overall acceptability of higher *Moringa oleifera* concentrations in the current study.

Optimizing the levels of *Moringa oleifera* fortification is essential to balancing its nutritional benefits with the sensory qualities that drive consumer acceptance. These findings highlight the need for careful consideration of fortification levels to ensure that the sensory attributes of dairy products remain favorable over storage periods.

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تأثير إضافة مسحوق أوراق وبذور نبات المورينجا أوليفرا على جودة وحيوية اللبن المتخمر المدعم بالبكتريا الداعمة للحيوية

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الملخص

إستهدف البحث الحالي دراسة تأثير تدعيم اللبن المتخمر(البروبيوتيك) بأوراق وبذور المورينجا أوليفيرا علي التركيب الكيماوي والخواص الطبيعية والريولوجية والحسية و تأثيره علي حيوية السلالات الداعمه للحيوية من خلال إضافة مسحوق أوراق وبذور المورينجا أوليفيرا بتركيزات مختلفة، وقد تم إضافة المساحيق بنسبة 0.5% و1% من أوراق وبذور المورينجا أوليفيرا إلى اللبن الجاموسي لجعله أكثر لرفع القيمة الغذائية والصحية ، وتلى ذلك إضافة بادئ بروبيوتيك يحتوي على بكتيريا *Lactobacillus acidophilus,* *Bifidobacterium bifidum* and *Streptococcus thermophilus* وتم اجراء تحليلات كيميائية وفيزيائية وميكروبيولوجية وحسية متنوعة على العينات الطازجة والعينات المخزنة لمدة 7، 15 يوم وأظهرت النتائج الرئيسية أن إضافة المورينجا أوليفيرا أدت إلى زيادة كبيرة في مستويات المواد الصلبة الكلية والدهون والبروتين في اللبن المتخمر، وكان أعلى المستويات في العينات التي تمت إضافة 1٪ من مسحوق البذور إليها (T4)، وارتفعت مستويات الحموضة وانخفضت قيم الأس الهيدروجيني مع ارتفاع مستويات التدعيم، مما يشير إلى تعزيز نشاط التخمير، بالإضافة إلى ذلك أظهرت العينات المدعمة تحسنًا في اللزوجة وقدرة الاحتفاظ بالماء، حيث سجلت أعلى القيم لكل منهما في المعامله T4 وبلغت 1883.33 سنتي بواز و50.37٪ على التوالي، وأظهرت الاختبارات الميكروبيولوجية أن المورينجا أوليفيرا ساعدت في الحفاظ على أعداد أعلى من بكتيريا *Streptococcus thermophilus* و *Lactobacillus acidophilus* أثناء التخزين، مما يشير إلى أن البروبيوتيك كان أكثر استقرارًا، وأظهر التقييم الحسي أنه في حين أدى تدعيم الحليب المتخمر بالمورينجا أوليفيرا إلى تحسين الجودة الغذائية، إلا أن الإدارة الدقيقة لمستويات التدعيم ضرورية للحفاظ على الخصائص الحسية المرغوبة، لا سيما النكهة والملمس وخلص البحث إلى أن تدعيم اللبن المتخمر البروبيوتيك بمستويات أعلى من مسحوق بذور المورينجا أوليفيرا يؤدي إلى تحسين كبير في خصائصه الغذائية والوظيفية، ويطيل العمر الافتراضي للمنتج.