

Physicochemical, Rheological, Antioxidant, and Sensory Properties of Low-Fat Yogurt Fortified with Moringa Leaf Extract

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Abstract

This study investigates the impact of varying concentrations of defatted dried Moringa leaves extract in low-fat yogurt on its physicochemical, rheological, antioxidant as well as sensory properties. This extract was added to different amounts of milk at concentrations of 0.1%, 0.2%, and 0.3% by weight bases. Measurement of physicochemical analyses comprised moisture, protein, fat, carbohydrates, ash content, titratable acidity, and pH. Some of the rheological properties represented by spontaneous whey separation, water holding capacity, viscosity, and textural attributes, such as adhesiveness, firmness and elasticity, will also be assessed in addition. Additionally, antioxidant activity and sensory evaluations were performed on all yogurt samples. The yogurt samples fortified with Moringa leaf extract showed a decrease in moisture content over the storage period, along with an increase in protein, carbohydrate, and ash contents compared to the control sample (without extract). Four treatments were different in terms of rheological results but in general, keeping 0.3% extract gave the most beneficial characters. This was indicated by the lowest spontaneous whey separation along with the highest water holding capacity, viscosity, firmness, adhesiveness and elasticity. In comparing the above samples from Moringa-fortification with pure DPPH scavenging radical assays, these showed very high antioxidant activities. The sensorially more acceptable treated yogurt as fortified by Moringa extract was better preferred by consumers due to great improvements in taste, flavor, texture, mouthfeel, appearance, and acidity perception.

Keywords: DPPH, Antioxidants, yogurt, Moringa leaf extract, functional foods .

Introduction

The Moringa tree, admittedly called drumstick tree or horseradish tree, is a perennial species in the Moringaceae family. The leaves and other parts are of great nutritional and medicinal value. [1] Due to drought resistance, fast growth, and an incredible nutritional profile, it is also called the "miracle tree", "tree of life", or "plant diamond"[2.]

Phenolic compounds are chief tropical secondary plant metabolites which exhibit synergetic enhancement of functional attributes and health-promoting properties in edible products including fortified dairy products. Such composition of phenolic

compounds manifests with strong antioxidant, anti-inflammatory, and antimicrobial efficacy that makes its application value very high as natural additives in dairy processing .[5] Recently, some researchers exhibited that incorporation of phenolic compounds to dairy products plays a significant role in oxidative stability making unsaturated fatty acids more resistant against oxidative changes. This has the effect of elongating the shelf-life of dairy products and boosting the nutritional quality [6]. Furthermore, [7] elucidated that phenolic compounds obtained from plant sources also work well in improving the flavor and sensory

properties of foods while enhancing health benefits such as lowering LDL cholesterol levels and improving cardiovascular health.

The production of functional food modalities with Moringa leaf extract is a major leap towards introducing renewable natural resources into functional nutrition. These extracts improve the functional quality of food, support sustainability, and contribute to minimizing food wastes. When compared to the control yoghurt [3] discovered that yogurts containing Moringa extracts had more cohesive casein net, greater protein contents, higher consistency index values, and lower syneresis values.

According [4] adding Moringa extracts to milk prior to fermentation led to a shorter fermentation period, a lower pH of the yoghurt, more starter bacterial growth, improved rheological qualities, and an increase in the yoghurt's total phenol content and antioxidant capacity. Additionally, when compared to the control, yoghurts containing Moringa extracts had a higher mineral content and higher sensory evaluation score.

Accordingly, this study aims to:

- .1 Prepare a defatted dried extract from Moringa leaves.
- .2 Fortify non-fat yogurt with the prepared extract and evaluate its effects on the physicochemical, rheological, antioxidant, and sensory properties during storage.

Materials and Methods

Materials

Skimmed cow's milk powder was obtained by the Iranian company Ramck. The starter culture used included *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, provided by the Italian company SACO. These were added directly to the prepared milk according to the manufacturer's instructions for yogurt production.

Preparation of Moringa Leaf Powder

Fresh Moringa leaves were collected from fresh plants, washed with distilled water, and air-dried in a well-ventilated and temperature-controlled room (37–40°C) for 48 hours to

preserve bioactive compounds such as phenolics and antioxidants [8].

The dried leaves were ground using a German Silverline electric mill into a fine powder, sieved, and a total of 3 kg of fine powder was collected. The fat was removed, and an aqueous extract was prepared and subsequently dried for use in yogurt fortification.

Yogurt Preparation

Yogurt was prepared following the method described by [9]. Skim milk powder was reconstituted in water at a concentration of 12%, and the solution was divided into four treatments in 1-liter sterile glass containers:

Control (C): yogurt without extract

Treatments H1, H2, and H3 were yogurt fortified with Moringa extract, 0.1%, 0.2%, and 0.3%, respectively. The extract was put into the milk under heating. The milk was then heated at 90°C for 10 minutes, cooled at 43°C, and inoculated with 0.02% starter culture following SACO recommendations (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*).

Fifty milliliter plastic containers were filled with samples, and incubation occurred at $42 \pm 1^\circ\text{C}$ till coagulation happened. The yogurt was cooled to 4°C before conducting analyses after 1, 7, 14, and 21 days of storage.

Chemical Analysis of Yogurt and Moringa Extract

Moisture, ash, fat, carbohydrates, and total nitrogen contents of the dried Moringa extract and yogurt samples were determined according to [10]. Titratable acidity of the yogurt was also measured. The pH was determined by directly inserting the pH electrode into the yogurt sample [11].

Rheological Properties

.1 Spontaneous Whey Separation

Assessed following the method of [12]. A cold yogurt sample ($4 \pm 1^\circ\text{C}$) was used. The separated whey on the surface was extracted using a syringe, and the cup was reweighed. The process was completed in under 10 seconds to avoid further whey drainage.

.2 Water-Holding Capacity (WHC)

Measured according to [13]. Ten grams of yogurt were centrifuged at 3000 rpm for 10 minutes at $4 \pm 1^\circ\text{C}$. The supernatant was carefully removed and the sediment was weighed. WHC was calculated as:

$\text{WHC (\%)} = (\text{Weight of sediment} / \text{Original sample weight}) \times 100$

.3 Viscosity

Viscosity was measured after 1, 7, 14, and 21 days of refrigerated storage using a Brookfield DVII+ viscometer, as per (9). The gel structure was broken by stirring the yogurt with a glass rod (10 times clockwise and 10 times counterclockwise).

Measurements were taken using spindle No. 4 at 50 rpm for one minute at room temperature.

.4 Texture Profile Analysis (TPA)

Hardness, adhesiveness, and elasticity were analyzed using a CT3 Texture Analyzer (Brookfield Engineering Lab, Model 4500). A 15 mm diameter cylindrical probe was inserted into each sample to a depth of 15 mm, using a trigger force of 5.0 g and a speed of 1 mm/sec [14]

DPPH Radical Scavenging Activity

The free radical scavenging activity was quantified by the method of [15].

To this solution, 30 μL of whey (prepared by heating samples at 45°C for 15 min and centrifuging at 4000 rpm), and 200 μL of DPPH solution were added. The solution was incubated in the dark at room temperature for 30 min, and after a diluted concentration of the sample being passed through a spectrophotometer, the absorbance at 517 nm was measured.

The scavenging activity was calculated as follows:

$\text{DPPH scavenging (\%)} = [(\text{Abs control} - \text{Abs sample}) / \text{Abs control}] \times 100$

Sensory Evaluation

Sensory analysis was conducted in the Department of Dairy Science and Technology, College of Food Sciences, Al-Qasim Green University. One hour before the sensory evaluation, the yogurts were taken out of the refrigerator (4°C) and stored at room temperature ($22 \pm 2^\circ\text{C}$). Every sample was given a three-digit blinding code, and they were all provided at the same time with a glass of water so that they may rinse their mouths.

A panel of seven expert of faculty members evaluated the yogurt samples for taste and flavor (45 degree) texture (30 degree), acidity (10 degree), appearance (10 degree) and Packaging (10 degree) using a sensory evaluation form adapted from Trout & Nelson (1964).

Statistical Analysis

The results of all experiments were the mean of 3 replications. Data were analyzed using SAS statistical software

Results and Discussion

.1 Chemical Composition of the Defatted Dried Aqueous Moringa Leaf Extract

The chemical composition of the defatted dried aqueous extract of Moringa leaves used in this study is presented in Table 1. The percentages of carbohydrates, protein, moisture, fat, ash, and fiber were 45%, 36%, 5%, 0.5%, 7%, and 6.5%, respectively. These values closely align with the findings of [16].

Table 1. Chemical Composition of Defatted Dried Moringa Leaf Extract

No.	Component	Percentage(%)
1	Carbohydrates	45
2	Protein	36
3	Moisture	5
4	Fat	0.5
5	Ash	7
6	Fiber	6.5

Effect of Defatted Dried Moringa Leaf Extract on the Physicochemical Properties of Yogurt

.1 Moisture Content

As shown in Table 2, the moisture content of the control sample (without extract) on the first day of storage was 88.5%, which is consistent with the findings of [17], who reported 88.10% in non-fat yogurt. A slight reduction in moisture was observed in the fortified samples, likely due to the higher total solids content in the extract.

.2Protein Content

The protein content of the control sample, on the first day, was seen to be 4.71% (Table 2). This value agrees with the results reported by [18], who found 4.76% for plain yogurt. For the treated samples (H1, H2, H3), protein contents were 4.74, 4.76, and 4.78%, respectively. Incremental increases relate to the protein concentration in the extract of 36%, which was noted in Table 1 .

.3Fat Content

Fat content across all yogurt samples was kept constant at 0.1% throughout the storage period, as indicated in Table 2. This was due to the use of skimmed milk and fat-free extract for the preparation of yogurt. This finding agrees with that of [19] who found similar levels of fat on yogurt made from skimmed milk powder .

.4Carbohydrate Content

After a day of storage, the carbohydrate content in the control sample was measured at 5.99% and was comparable with the results of [20] who reported 5.68% for yogurt made from skimmed milk powder. Carbohydrates in the fortified samples were: H1: 6.04%, H2: 6.19%, H3: 6.34%

Increased concentrations of the extract cause a relative decrease in the carbohydrate

percentage. This effect could be attributed to the replacement by other dry matter constituents, such as protein and ash .

.5Ash Content

The ash content of the control sample after one day of storage as shown in Table 2 was 0.70%, which is fairly close to that reported by [21] as 0.65% for non-fat yogurt. The ash contents of H1, H2, and H3 were those of 0.72%, 0.75%, and 0.78%, respectively. The increase in ash content corresponds to the ash level present in the extract (7%) as shown in Table 1 and becomes more pronounced for higher inclusion levels.

.6Titratable Acidity

The titratable acidity of the control sample after one day was 0.80%, which agrees with the findings of [24] who reported the same value for non-fat yogurt. In the contrary, the treated samples showed lesser acidity numbers: H1: 0.77%, H2: 0.75%, H3: 0.73%

The decline in acidity with elevated levels of extract might be due to strong antioxidant properties of Moringa, which have an impact on acid development in dairy products [23]; [22]

pH Value

The results in Table 2 indicated that the pH of the control yogurt after one day was 4.55 close to the value of 4.94 reported by [25]. The pH values of the fortified samples were: H1: 4.60, H2: 4.67, H3: 4.74

These results indicate that with higher concentrations of extract, pH increased. This may be related to the antioxidant activity of the extract, which is known to modulate pH in food systems [23]; [22.]

Table 2. Effect of Adding different concentrations of Moringa leaf extract on the Physicochemical Properties of Yogurt

Type of Addition	Treatment	Storage Time (days)	Moisture (%)	Total Protein (%)	Fat (%)	Carbohydrates (%)	Ash (%)	Acidity (% Lactic acid)	pH
Control (No addition)	C	1	88.5	4.71	0.1	5.99	0.70	0.80	4.55
		7	88.3	4.71	0.1	6.19	0.70	0.86	4.43
		14	88.1	4.67	0.1	6.43	0.70	0.90	4.35
		21	88.0	4.62	0.1	6.58	0.70	0.95	4.28
Addition of defatted dried Moringa leaf extract	H1	1	88.4	4.74	0.1	6.04	0.72	0.77	4.60
		7	88.2	4.74	0.1	6.24	0.72	0.81	4.54
		14	88.0	4.70	0.1	6.48	0.72	0.86	4.48
		21	87.8	4.65	0.1	6.73	0.72	0.90	4.42
	H2	1	88.2	4.76	0.1	6.19	0.75	0.75	4.67
		7	88.0	4.75	0.1	6.40	0.75	0.80	4.55
		14	87.9	4.72	0.1	6.53	0.75	0.84	4.50
		21	87.7	4.66	0.1	6.79	0.75	0.88	4.45
	H2	1	88.0	4.78	0.1	6.34	0.78	0.73	4.74
		7	87.8	4.78	0.1	6.54	0.78	0.78	4.65
		14	87.6	4.74	0.1	6.78	0.78	0.82	4.57
		21	87.4	4.69	0.1	7.03	0.78	0.86	4.50
L.S.D. value			3.219 NS	0.527 *	0.00 NS	0.902 NS	0.189 NS	0.166 *	0.417 *

* ($P \leq 0.05$).**Rheological****Properties****of****Fat-Free****Yogurt**

1. Spontaneous Whey Separation (SWS)
Table 3 shows that the spontaneous whey separation in the control sample (C) was 1.89 mL/50 mL after one day of storage, consistent with [26], who reported a value of 2.00 mL/50 mL after 1 day of manufacturing. For the

Moringa-treated samples (H1, H2, H3), the values were 1.17, 1.14, and 1.11 mL/50 mL, respectively. Whey separation increased over time in all samples but remained lowest in treatment H3.

Table 3. Effect of Adding different concentrations of Moringa leaf extract on Spontaneous Whey Separation (mL/50 mL) of yogurt

Storage Time (days)	C (Control treatment 0%)	H1 (0.1% M.E.)	H2 (0.2% M.E.)	H3 (0.3% M.E.)
1 day	1.89	1.17	1.14	1.11
7 day	2.18	1.52	1.5	1.45
14 day	2.66	1.88	1.85	1.85
21 day	3.19	2.8	2.7	2.64

2. Water Holding Capacity (WHC)

As shown in Table 4, the WHC of the control sample after 1 day was 75%. Samples H1, H2, and H3 showed higher values: 79.5%, 79.7%,

and 80.1%, respectively. This enhancement is attributed to the functional compounds in Moringa leaves, such as amino acids, proteins,

and antioxidants, which improve yogurt gel strength [31].

Table 4. Effect of Adding different concentrations of Moringa leaf extract on Water Holding Capacity (%) of yogurt.

Storage Time (days)	C (Control treatment 0%)	H1 (0.1% M.E.)	H2 (0.2% M.E.)	H3 (0.3% M.E.)
1 day	75	79.5	79.7	80.1
7 day	70.5	76.2	76.5	76.8
14 day	64.2	70.4	70.6	70.9
21 day	59.8	65.1	65.4	65.4

3. Viscosity

As presented in Table 5, the viscosity of the control yogurt was 1380 cp on day 1. Treated samples H1, H2, and H3 recorded values of 1444, 1447, and 1449 cp, respectively. The increase in viscosity was positively correlated

of Yogurt with Moringa extract concentration. This agrees with [30], who noted that proteins and carbohydrates in Moringa can enhance yogurt viscosity, in addition to the effect of antioxidant compounds.

Table 5. Effect of Adding different concentrations of Moringa leaf extract on Viscosity (centipoise) of yogurt.

Storage Time (days)	C (Control treatment 0%)	H4 (0.1% M.E.)	H5 (0.2% M.E.)	H6 (0.3% M.E.)
1 day	1380	1444	1447	1449
7 day	1373	1437	1443	1445
14 day	1370	1435	1438	1441
21 day	1366	1433	1435	1437

4. Texture

4.1 Hardness

Table 6 shows that hardness in the control sample was 77.7 g on day 1. Treatments H1, H2, and H3 recorded values of 88.2, 94.1, and 97.0 g, respectively. A progressive increase in

Profile Analysis firmness was observed with increasing Moringa concentration. This is consistent with [29], who reported improved texture with higher concentrations of bioactive compounds.

Table 6. Effect of Adding different concentrations of Moringa leaf extract on Hardness (g) of yogurt.

Storage Time (days)	C (Control treatment 0%)	H4 (0.1% M.E.)	H5 (0.2% M.E.)	H6 (0.3% M.E.)
1 day	77.7	88.2	94.1	97
7 day	77.9	88.7	94.8	97.6
14 day	78.2	89.2	95.5	98.1
21 day	78.7	90.7	96.1	98.5

.4.2Adhesiveness

As shown in Table 7, adhesiveness in the control sample was 0.57 on day 1. Values for H1, H2, and H3 were 0.76, 0.78, and 0.81,

respectively. Higher adhesiveness reflects enhanced gel structure stability, possibly due to antioxidant-polymer interactions [28.]

Table 7. Effect of Adding different concentrations of Moringa leaf extract on Adhesiveness of yogurt.

Storage Time (days)	C (Control treatment 0%)	H1 (0.1% M.E.)	H2 (0.2% M.E.)	H3 (0.3% M.E.)
1 day	0.57	0.76	0.78	0.81
7 day	0.54	0.72	0.75	0.79
14 day	0.5	0.69	0.72	0.74
21 day	0.46	0.65	0.68	0.71

.4.3Springiness (Elasticity)

As detailed in Table 8, the springiness value for the control sample was 4.2 mm on day 1, whereas treatments H1, H2, and H3 showed

values of 4.6, 4.8, and 4.8 mm, respectively. This improvement is attributed to bioactive compounds in the extract that enhance gel elasticity [27.]

Table 8. Effect of Adding different concentrations of Moringa leaf extract on Springiness (mm) of yogurt.

Storage Time (days)	C (Control treatment 0%)	H1 (0.1% M.E.)	H2 (0.2% M.E.)	H3 (0.3% M.E.)
1 day	4.2	4.6	4.8	4.8
7 day	4.3	4.7	4.8	4.9
14 day	4.5	4.8	4.7	4.7
21 day	3.9	4.4	4.2	4.1

.4.4DPPH Radical Scavenging Activity

Table 9 shows the antioxidant activity after 15 minutes of reaction. The control sample exhibited 85.686% scavenging on day 1, while

H1, H2, and H3 recorded 86.875%, 87.400%, and 88.009%, respectively. Activity increased with extract concentration, consistent with [32], who linked phenolic content to enhanced radical scavenging.

Table 9. Effect of Adding different concentrations of Moringa leaf extract on DPPH Radical Scavenging Activity (%) of yogurt.

Storage Time (days)	C	H1	H2	H3
1 day	85.686	86.875	87.4	88.009
7 day	84.733	86.255	86.922	87.551
14 day	84.242	85.803	86.388	87.2
21 day	83.785	85.291	85.913	87.009

.4.5Sensory

Evaluation

According to Table 10, yogurt samples supplemented with Moringa extract showed superior sensory scores in taste, aroma,

texture, appearance, and acidity compared to the control throughout storage. These results suggest a positive impact of Moringa supplementation on consumer acceptability.

Table 10. Effect of Adding different concentrations of Moringa leaf extract on Sensory Evaluation Scores of yogurt samples.

Type of Addition	Treatment	Storage Time (days)	Flavor and Taste (45 Points)	Texture (30 Points)	Appearance (10 Points)	Acidity (10 Points)	Packaging (5 Points)	Total Score (100 Points)
Control (No addition)	c	1	41	26	10	7	5	89
		7	39	25	9	7	5	85
		14	38	25	8	7	5	83
		21	37	24	8	6	5	80
Addition of defatted dried Moringa leaf extract	H1	1	42	28	10	9	5	94
		7	41	27	10	8	5	91
		14	40	27	9	8	5	89
		21	39	26	8	7	5	85
	H2	1	42	28	10	9	5	94
		7	41	28	10	9	5	93
		14	41	27	9	8	5	90
		21	40	26	8	7	5	86
H2	1	41	28	10	9	5	93	
	7	40	28	10	9	5	92	
	14	39	27	9	8	5	88	
L.S.D.value		21	38	27	8	7	5	85
			2.445 *	2.837 *	1.453 *	1.258 *	0.00 NS	4.611 *

Conclusions:

The study demonstrated that Moringa leaf extract contains high concentrations of vitamins, minerals, dietary fiber, and antioxidants.

Incorporating the extract into skim milk yogurt enhanced its nutritional value, physicochemical properties, rheological behavior, and antioxidant activity—particularly in the sample fortified with 0.3% extract.

Moreover, sensory attributes significantly improved in this sample, indicating better

Acknowledgment:

consumer acceptability. On the basis of this study, we suggest that yogurt fortified with moringa could be marketed as a functional food that is rich in antioxidants, vitamins, and minerals. Because it would appeal to athletes, vegetarians, health-conscious consumers, and those seeking plant-based fortification, manufacturers would be able to demand more for the product than they would for regular yogurt.

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