J. of Food and Dairy Sci., Mansoura Univ., Vol. 15 (3): 55 - 59, 2024

Journal of Food and Dairy Sciences

Journal homepage & Available online at: www.jfds.journals.ekb.eg

Quality of Nonfat Yoghurt Made from Skim Milk Powder Reconstituted in Aqueous Extract of Moringa Leaves

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ABSTRACT

Moringa leaves have well-known health and nutritional benefits. This work aimed to study the properties of nonfat yoghurt prepared from skim milk powder reconstituted in an aqueous extract of Moringa leaves (MLE). Three nonfat yoghurt treatments were manufactured from three concentrations of MLE 0.5, 1 and 1.5%, which were used to reconstitute skim milk powder (10%). The results showed that, compared with the control, MLE had no effect on the pH value, acidity% or protein content, but increased the TS, ash and mineral contents (Ca, K, Mg and Fe) in nonfat yoghurt treatments. Nonfat yoghurt made with MLE showed higher antioxidant activity (%) than the control. The curd tension and viscosity of the control were higher than those of the applied treatments, but the nonfat yoghurt with MLE exhibited the lowest syneresis compared with the control. Nonfat yoghurt made with MLE at concentrations of 0.5 and 1% was organoleptically acceptable, but treatment with 1.5% MLE had the lowest sensory properties.

***Keywords*: Extract of Moringa leaves, Nonfat yoghurt, Composition, Quality**

INTRODUCTION

Recently, consumers have been looking for healthy foods and have specialized demands for those foods to enhance their healthiness, in addition to providing basic nutrition (Ortiz *et al.*, 2017). Functional food is any food or food component that can improve health and prevent or cure disease by accomplishing physiological functions beyond nutritional value (Roberfroid, 2000). Several functional foods have been prepared. During processing or through genetic engineering, the functional components are added, removed or modified, resulting in a new product (Khalaf *et al*., 2021). Minerals, vitamins, flavonoids, omega-3 fatty acids, fiber, and probiotic cultures are components that can provide additional functionality to food (Khalaf *et al*., 2021). Functional dairy foods are those enriched with functional food components derived from dairy or nondairy sources (Özer and Kirmaci, 2010).

Moringa oleifera (moringa) has gained significant attention for its nutritional and therapeutic advantages. Moringa leaves have been shown many health benefits, such as antitumour, anticancer, antihepatotoxic, antiatherosclerotic, anticonvulsant, anti-inflammatory, antiulcer, antibacterial, antifungal, antioxidant, antitoxic, anti-diarrheal, and antidiabetic effects, as well as neuroprotective, hepatoprotective, kidney- protective, injury healing and hypotensive effects (Amin *et al*., 2024).

Concerning nutritional benefits, Moringa leaves were found to contain high concentration of several essential nutrients, such as minerals (Ca, K and Fe), vitamins (C and A), and high-quality protein (Abdelazim *et al.*, 2024). Moringa has been introduced as an alternative food by WHO to overcome malnutrition (Aznury *et al*., 2020). Due to the previously mentioned benefits, Moringa leaves have attracted much interest as food additives for improving the functionality of fermented dairy products (Trigo *et al*., 2023).

Yoghurt is a popular dairy product in most countries worldwide. This popularity has possibly been acquired from their high nutritional, health and flavour qualities (Farag *et al*., 2021). Low-fat and nonfat yoghurt represent healthy choices for consumers who seek low-calorie dairy products to limit the risk of coronary diseases.

The objective of this study was to investigate the impact of using aqueous extract of Moringa leaves on some properties of nonfat set yoghurt.

MATERIALS AND METHODS

Preparation of Moringa leaf extract (MLE)

Fresh Moringa leaves (ML) were washed carefully with distilled water, oven dried at 55 °C for 48 h, crushed into a fine powder with a grinder, and stored in airtight plastic containers in the dark at room temperature until use. The leaf powders were soaked in boiled distilled water at ratios of 0.5, 1 and 1.5% (w/v) under continuous stirring and held at room temperature for 30 min. The mixtures were then filtered twice through double layer muslin and then through Whatman No.1 filter paper.

Manufacture of nonfat yoghurt

Skim milk powder (SMP, 96% TS, a product of Elsdorfer Molkerei und Feinkost GmbH, Germany) was reconstituted in Moringa leaf extracts (45 °C) at a ratio of 10% under continuous stirring. The treatments were coded as T1, T2 and T3 for nonfat yoghurt made from aqueous extract of Moringa leaf powder of 0.5, 1 and 1.5% in boiled distilled water, respectively. Control treatment of nonfat yoghurt base was prepared by reconstituting SMP in distilled water (45 °C) at the same ratio. Nonfat yoghurt bases were kept overnight in a refrigerator (6 ± 1°C) to allow full hydration of the

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DOI: 10.21608/jfds.2024.268384.1152

dispersed powder. Nonfat yoghurt was manufactured according to Tamime and Robinson (2007). The resultant nonfat yoghurt samples were kept in a refrigerator at 5±1ºC.

Analysis of nonfat yoghurt samples

Determination of pH, titratable acidity % and acetaldehyde content

Fresh and stored (for 7 days in a refrigerator) nonfat yoghurt samples were analyzed for pH using a digital pH meter (Crison, Spain), titratable acidity% (Ling, 1963), and acetaldehyde content (Lees and Jago, 1969).

Gross chemical composition

Total solids (Michael *et al*., 2010), protein (Ling, 1963) and ash (AOAC, 2007) were determined in fresh samples.

Mineral content and antioxidant activity%

Calcium (Ca), magnesium (Mg), potassium (K) and iron (Fe) were determined using an atomic absorption spectrophotometer (BB model Avanta Σ mar GBC, Australia) according to AOAC (2000). Determination of antioxidant activity % (1,1-diphenyl-2 picrylhydrazyl free radical scavenging activity) was carried out according to the procedure described by Lim and Quah (2007).

Curd tension, apparent viscosity and syneresis

Curd tension (g/50 ml) was measured according to the method described by Kaushik *et al.* (2015). The apparent viscosity (P) was determined using a digital Brookfield viscometer (LVDV–E, Brookfield Eng. Lab., Middleboro, MA, USA) using spindle No. 63 (Ghanimah, 2018). Curd syneresis (g/50 ml) was carried out (only for fresh samples) according to Amatayakul *et al*. (2006).

Sensory properties

Fresh and stored nonfat yoghurt samples were organoleptically evaluated mainly according to El-Shibiny *et al.* (1979). Sensory evaluation was performed by professional panelists from the Faculty of Agriculture, Kafrelsheikh University, using a score scheme for appearance (10 points), body and texture (30 points) and flavour (60 points).

Statistical Analysis

Statistical analysis was performed using the SPSS version 16 computer program (SPSS Inc. Chicago IL. USA). The results were subjected to ANOVA and Duncan's test to determine significant differences among means at the significance ≤ 0.05.

RESULTS AND DISCUSSION

pH value, titratable acidity %and acetaldehyde content of nonfat yoghurt samples

Table (1) illustrates the pH values, titratable acidity and acetaldehyde content in fresh and stored yoghurt samples for 7 days in a refrigerator. The data showed that the pH and titratable acidity did not significantly differ between the control and treatments either in fresh or stored samples. Similar results were given by Zhang *et al.* (2019), who demonstrated that the addition of Moringa extract had no effect on the pH of yoghurt. In addition, El-Gammal *et al.* (2017) and Al-Ahwal *et al.* (2017) found slight differences in the pH and titratable acidity between yoghurt samples supplemented with an aqueous extract of Moringa oleifera and the control. Cold storage significantly decreased the pH values and increased the acidity of yoghurt samples. This is due to the slow fermentation of lactose by lactic acid bacteria during the cold storage of yoghurt (Hassan and Frank, 2001).

Among the nonfat yoghurt samples, the highest (P≤0.05) acetaldehyde content was found in T3 treatment either fresh or stored samples. No significant differences were observed among the control and treatments T1 and T2. These results may be due to the enhancement of yoghurt culture activity by Moringa extract (Shokery *et al*., 2017). Hassan *et al.* (2016) found that yoghurt samples made with 0.5% moringa powder had the highest acetaldehyde content compared with that of the control. The acetaldehyde content significantly decreased at the end of the storage period. This result is presumably due to the ability of numerous lactic acid organisms to reduce or hydrolyze acetaldehyde to ethanol via dehydrogenase activity (Hofi *et al*., 1994; Guler-Akin, 2005). During cold storage of fermented milk, the acetaldehyde content was decreased, while the contents of ethanol and diacetyl were increased (Vahčič and Hruškar, 2000).

Table 1. pH value, titratable acidity (%) and acetaldehyde content (µmol/100g) of nonfat yoghurt samples

Treatments*	pH values		Titratable acidity%		Acetaldehyde(µmol/100g)	
	Fresh	Stored**	Fresh	Stored**	Fresh	Stored**
C	4.52^{aA}±0.01	4.39^{aB} ±0.05	0.87^{aB} ±0.02	0.99^{aA} ±0.03	27.5^{bA} ±0.25	20.4^{bB} ±0.40
T1	4.50^{aA}±0.04	4.36^{aB} ±0.04	0.86^{aB} ±0.01	0.99^{aA} ±0.02	25.3^{bA} ±0.30	20.1^{bB} ±0.35
T2	4.48^{aA}±0.02	4.33^{aB} ±0.03	0.89^{aB} ±0.01	1.03^{aA} ±0.02	28.4^{bA} ±0.20	23.5^{bB} ±0.31
T3	4.48^{aA}±0.03	4.32^{aB}±0.04	0.90^{aB}±0.02	1.05^{aA} ±0.03	34.2^{aA} ±0.28	29.8^{aB}±0.28

***C Nonfat yoghurt manufactured from reconstituted skim milk powder in distilled water. T1, T2 and T3 Nonfat yoghurt manufactured from reconstituted skim milk powder in MLE 0.5, 1 and 1.5%, respectively.**

****The samples were stored for 7 days at 5±1ºC -Data are the mean ± SE for 3 replicates.**

-Means with different small letters are significantly different among treatments (P ≤ 0.05).

- Means with different capital letters are significantly different between storage periods (P ≤ 0.05)

Gross chemical composition of nonfat yoghurt samples

The gross chemical composition of nonfat yoghurt samples is listed in Table (2). The TS values showed a gradual and significant increase with increasing MLE concentration. Treatments T2 and T3 had the highest TS, while the differences between the control and T1 treatment were not significant. This increase is related to the solid content in the MLE. There were no significant differences in the protein content between the control and treatments with MLE. A considerable increase in the ash content was found in the applied treatments compared with the control. The highest (P≤ 0.05) ash content was observed in T3, whereas the control had the lowest. These results are in accordance with those of Ahmadiyan *et al.* (2023). Furthermore, Saeed *et al.* (2021) demonstrated that Moringa leaf powder contained a high amount of total minerals (10.72%).

Table 2. Gross chemical composition of fresh nonfat yoghurt samples

Treatments*	TS%	Protein%	Ash%
C	10.19^{b} ±0.2	3.57^{a} ±0.5	0.78^{b}±0.06
T1	10.25^{b} ±0.2	3.57^{a} ±0.35	0.93^{ab}±0.01
T2	10.33^{a} ±0.1	3.45^{a} ±0.39	0.99^{ab}±0.05
T3	10.44^{a} ±0.1	3.40^{a} ±0.42	1.14^{a}±0.02

***See Legend to Table (1) for details -Data are the mean ± SE for 3 replicates.**

-Means with different small letters are significantly different among treatments (P ≤ 0.05).

Mineral content and antioxidant activity of nonfat yoghurt samples

The mineral contents of nonfat yoghurt samples are shown in Table (3). Mineral contents increased proportionally with increasing MLE concentration. T3 treatment had higher Ca, Mg, K and Fe contents than the other treatments, while the control sample had lower values. The richness of Moringa leaves with different minerals (Abdelazim *et al.,* 2024) was responsible for such increase in the treated samples. Ahmadiyan *et al.* (2023) found that the addition of Moringa oleifera significantly increased the Ca, K and Fe contents in dairy drink desserts. Dairy products are usually contain a negligible concentration of iron and consequently supplementing it with this mineral would be highly important. Moringa leaves contain twenty-five times more iron than Spanish, fifteen times more potassium than banana and seventeen times more calcium than milk (Saeed *et al*., 2021). Salama *et al.* (2014) stated that adding Moringa leaf powder to permeate increased the mineral content of beverages. El-Gammal *et al.* (2017) found that Moringa leaf powder contained 845 and 421 mg/kg Ca and K, respectively.

The data presented in Table (3) show the antioxidant activity% of the nonfat yoghurt samples. The antioxidant activity of yoghurt results from the presence of protein and its derivatives (peptides, amino acids, uric acid), vitamins, and enzymatic systems (glutathione peroxidase, SOD and catalase), as well as the antioxidant activity of lactic acid bacteria (Fardet and Rock, 2018). It has been found that the intracellular cell-free extract of the yoghurt starter exhibited antioxidant activity (Lin and Yen, 1999). Clearly, nonfat yoghurt samples manufactured with MLE exhibited stronger radical scavenging effect compared with that of the control. This could be attributed to the high antioxidant activity of ML resulting from the presence of considerable amounts of natural antioxidants, including flavonoids, plant phenolic compounds and carotenoids (Amin *et al*., 2024). Moringa leaves contain a high concentration of vitamin C (Abdelazim *et al*., 2024). Additionally, Moringa leaves contain bioactive compounds such as kaempferol and quercetin, which exhibit strong antioxidant activities (Wang *et al*., 2017). It has been found that the antioxidant activity of MLE is higher than that of the synthetic antioxidant TBHQ (El-Gammal *et al*., 2017). This result agrees with Zhang *et al*. (2019), who reported that yoghurt supplemented with MLE showed higher antioxidant activity than the control. In addition, Shamsia (2016) found that labneh supplemented with MLE showed higher antioxidant activity than the control. Furthermore, El-Ziney *et al.* (2017) reported that MLE protects against oxidative stress caused by lead acetate in rats.

Table 3. Mineral content (µg/100 gm) and antioxidant activity (%) of nonfat yoghurt samples*

Treatments*	Ca	Mg	K	Fe	Antioxidant activity%
C	107.2	22.7	121.2	0.195	26.8
T1	110.2	32.6	136.1	0.250	92.4
T2	114.5	36.4	150.6	0.305	ND
T3	120.3	39.9	156.6	0.400	95.8

*** See Legend to Table (1) for details ND Not determined**

Curd tension, apparent viscosity and syneresis of nonfat yoghurt samples

Table (4) shows the curd tension and apparent viscosity of nonfat yoghurt samples. It is clear from the results that using MLE in the manufacture of nonfat yoghurt significantly decreased (P≤0.05) the curd tension. Both the fresh and stored control sample showed the highest (P≤ 0.05) curd tension values, while treatment T3 exhibited the lowest. No significant differences were observed between T1 and T2 treatments. A similar trend was observed by Al-Ahwal *et al.* (2017), who found that yoghurt made with MLE had very low curd tension compared with that of the control. Table (4) shows that the cold storage of all treatments had a positive impact on the curd tension of the yoghurt gel. The curd tension values significantly increased in the stored samples.

Table 4. Curd tension and apparent viscosity of nonfat yoghurt samples

Treatments*	Curd Tension (gm/50 ml)		Apparent Viscosity (P)	
	Fresh	Stored	Fresh	Stored
C	26.8^{aB}±1.5	42.1^{aA} ±1.5	11.26^{aB}±1.5	14.81^{aA}±1.2
T1	22.1^{bB} ±1.1	35.2^{bA} ±1.8	10.00^{aB}±1.4	11.93^{bA}±1.4
T2	20.2^{bB}±1.2	33.5^{bA} ±1.7	10.4^{aB} ±1.5	11.40^{bA}±1.3
T3	17.5^{cB} ±1.6	31.0^{cA} ±1.5	9.82^{bB} ±1.1	10.50^{bA}±1.1

*** See Legend to Table (1) for details.**
-Means with different small letters are significantly different among treatments (P ≤ 0.05).
- Means with different capital letters are significantly different between storage periods (P ≤ 0.05).

The apparent viscosity results (Table 4) showed a trend similar to that recorded for the curd tension. The use of MLE decreased the apparent viscosity of nonfat yoghurt. However, no significant differences were detected among fresh control, T1 and T2 treatments, while T3 had the lowest (P≤0.05) apparent viscosity value. The apparent viscosity values of stored samples significantly increased, but no significant differences were found among nonfat yoghurt treatments with MLE. Hassan *et al.* (2016) found that fresh and stored yoghurt made with 0.5% Moringa leaf powder had lower viscosity values than the control.

In contrast, the control treatment had the highest (P≤0.05) susceptibility to syneresis, and treatment T3 had the lowest syneresis value (Fig. 1). This means that MLE had a positive effect on the water holding capacity of nonfat yoghurt. The ANOVA results showed that the differences among treatments were significant. These results agree with those of Zhang *et al.* (2019).

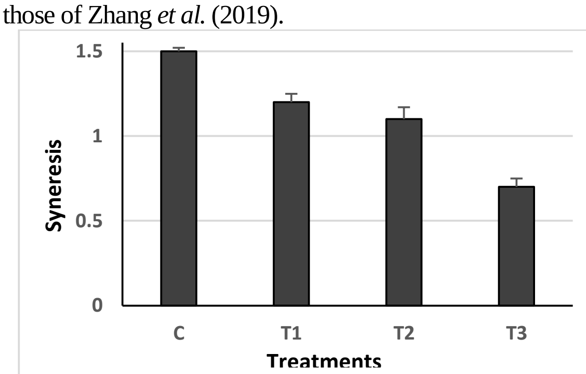

Fig. 1. Syneresis of nonfat yoghurt samples

Supplementation of nonfat yoghurt with MLE may cause interactions between milk protein and some Moringa leaf extract components. These interactions may increase the yoghurt gel matrix and consequently improve the water holding capacity and decrease the syneresis of yoghurt (Zhang *et al.*,2019). These interactions, however, might be responsible for the decrease in curd tension and viscosity of the nonfat yoghurt made with MLE. The impact of cold storage on curd tension and viscosity may be due to a decrease in the pH and increase in the titratable acidity, elevation of the hydrophilic properties of casein particles and soluble calcium ions or complete setting of the curd during cold storage (Denin-Djurdjević, *et al.*; 2002; El-Garawany, 2004; Walstra et al., 2006).

Sensory properties of nonfat yoghurt samples

Table (5) shows that the appearance scores significantly decreased with increasing MLE concentration, and T3 treatment ranked the lowest score. This could be related to the green colour resulting from the chlorophyll compounds in MLE. The appearance scores decreased slightly (P>0.05) in stored samples. Hassan *et al.* (2016) reported that yoghurt manufactured without Moringa leaf powder had higher whiteness than yoghurt made with 0.5% Moringa leaf powder. Additionally, they found that whiteness gradually decreased during storage. Shokery *et al*. (2017) found that yoghurt manufactured with MLE had a darker colour than the control yoghurt.

Clearly, the body and texture of fresh and stored T3 treatment gained the lowest scores, while the differences among control, T1 and T2 were not significant. These results are in accordance with the curd tension and viscosity data. Table (5) shows that the use of MLE affected the flavour of fresh and stored yoghurt at different concentrations compared with that of control. Treatment T3 ranked the lowest (P≤0.05) scores because the flavour of the moringa leaves was the dominant flavour of the yoghurt. Generally, all the tested samples were acceptable to the panelists except treatment T3.

Table 5. Sensory evaluation of nonfat yoghurt samples

Property	Storage period	Treatments*			
		Control	T1	T2	T3
Appearance (10)	Fresh	$9.6^{Aa} \pm 0.2$	$8.9^{Aa} \pm 0.2$	$8.5^{Ab} \pm 0.3$	$7.9^{Ac} \pm 0.3$
	Stored	$9.5^{Aa} \pm 0.2$	$8.7^{Aa} \pm 0.3$	$8.4^{Ab} \pm 0.3$	$7.5^{Ac} \pm 0.2$
Body &Texture (30)	Fresh	$27.8^{Aa} \pm 05$	$26.4^{Aa} \pm 0.9$	$25.0^{Aab} \pm 0.4$	$22.5^{Abc} \pm 0.9$
	Stored	$28.4^{Aa} \pm 0.5$	$27.25^{Aa} \pm 0.7$	$26.25^{ABb} \pm 0.3$	$23.8^{Abc} \pm 0.3$
flavour (60)	Fresh	$55.4^{Aa} \pm 1.9$	$53.8^{Aab} \pm 0.9$	$51.6^{Ab} \pm 1.9$	$48.0^{Ac} \pm 1.5$
	Stored	$54.2^{Ba} \pm 0.7$	$52.0^{Ab} \pm 0.3$	$49.0^{Abc} \pm 0.9$	$45.9^{Ac} \pm 0.8$
Total (100)	Fresh	$92.8^{Aa} \pm 1.6$	$89.1^{Aab} \pm 1.2$	$85.1^{Abc} \pm 2.3$	$78.4^{Ac} \pm 2.9$
	Stored	$92.1^{Ba} \pm 0.8$	$87.95^{Ab} \pm 0.8$	$83.65^{Bb} \pm 1.3$	$77.2^{Abc} \pm 0.4$

*** See Legend to Table (1) for details.**

-Means with different small letters are significantly different among treatments (P ≤ 0.05).

- Means with different capital letters are significantly different between the storage periods (P ≤ 0.05).

CONCLUSION

In conclusion, the data indicated that the aqueous extract of Moringa leaves is a good source for improving the nutritional and functional properties of nonfat yoghurt. The use of Moringa extract increased the mineral contents and elevated the antioxidant activity of the nonfat yoghurt. Nonfat yoghurts made using Moringa extract had lower curd tension, viscosity and syneresis than the control. Nonfat yoghurt samples made with 0.5 and 1% concentrations had acceptable sensory properties.

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جوده الزبادي الخالي من الدسم المصنع من لبن فرز مجفف والمسترجع في المستخلص المائي لأوراق المورينجا

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الملخص

تتمتع أوراق المورينجا بفوائد صحية وغذائية معروفة. الهدف من هذا العمل هو دراسة خصائص الزبادي الخالي من الدهن المحضر من مسحوق اللبن الفرز المجفف المعاد استرجاعه في المستخلص المائي لأوراق المورينجا. في هذه الدراسة تم تصنيع ثلاث معاملات للزبادي الخالي من الدسم من ثلاث تركيزات من المستخلص المائي لأوراق المورينجا وهى 0.5 و 1 و 1.5%، والتي تم استخدامها لإعادة استرجاع مسحوق اللبن الفرز المجفف (10٪) بينما تم تصنيع زبادي المقارنة من لبن فرز مسترجع فى ماء مقطر. أظهرت النتائج أنه لم يكن لاستخدام المستخلص المائي لأوراق المورينجا أي تأثير على pH أو الحموضة أو محتوى البروتين مقارنه بعينه المقارنة ، ولكن أدى استخدام المستخلص الى زياده الجوامد الكلية والرماد والمعادن (Ca و K و Mg و Fe)في معاملات الزبادي الخالي من الدهن. أظهرت النتائج أن الزبادي الخالي من الدهن المصنوع من المستخلص المائي لأوراق المورينجا نشاطا مضادا للأكسدة أعلى بكثير من عينه المقارنة. تميزت عينه المقارنة بقيم قوة شد الخثرة ولزوجة ظاهرية أعلى من المعاملات الاخرى، ولكن تميزت معاملات الزبادي الخالي من الدهن المصنعة من المستخلص المائي لأوراق المورينجا بمعدل تشريش اقل مقارنه بعينه المقارنة. أظهرت نتائج التحكيم الحسي ان معاملة الزبادي الخالي من الدهن المصنع من المستخلص المائي لأوراق المورينجا بتركيزات 0.5 و1%ة كانت مقبولة حسيا بينما اكتسبت عينه الزبادي المصنع من تركيز 1.5% مستخلص مورينجا أدني درجات تحكيم حسي.

الكلمات الدالة: المستخلص المائي لأوراق المورينجا، الزبادي الخالي من الدسم، التركيب، الجودة