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Physicochemical properties of kashk supplemented with encapsulated lemongrass extract

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Abstract:
Kashk is a perishable fermented dairy product. Since chemical preservatives are harmful for human health, we aimed to study lemongrass (*Cymbopogon citratus* L.) as a natural preservative.
First, we assessed the phytochemical properties of lemongrass extract. Then, we added lemongrass extract and microencapsulated lemongrass extract to kashk samples. Finally, we analyzed their physicochemical and sensorial properties during 60 days of storage.
Catechin (419.04 ± 0.07 mg/L), gallic acid (319.67 ± 0.03 mg/L), and chloregenic acid (4.190 ± 0.002 mg/L) were found to be the predominant phenolic constituents in lemongrass. Total phenolics, total flavonoids, and antioxidant activity (IC_{50}) values of the lemongrass extract were 26.73 mg GA/g, 8.06 mg Quercetin/g, and 2751.331 mg/L, respectively. The beads were spherical in shape with a 35.03-nm average particle diameter and 47.81% microencapsulation efficiency. The pH of the supplemented kashks decreased during the storage time. They showed lower acid degree values than the control at the end of storage. The peroxide, *p*-anisidine, and thiobarbituric acid values of the sample fortified with microencapsulated lemongrass extract were 6.15, 4.76, and 44.12%, respectively, being the lowest among the samples. This kashk sample had the highest hardness (570.62 ± 21.87 g), adhesiveness (18.10 ± 4.36 mJ), and cohesiveness (0.56 ± 0.25) but the lowest chewiness (72.66 ± 3.08 mJ) among the samples. It also had a better sensory profile than the control samples.
Our results indicated that microencapsulated lemongrass extract could be incorporated into kashk to ensure suitable sensorial and textural properties. Furthermore, it may delay fat oxidation and lipolysis during storage.

Keywords: Polyphenols, lemongrass extract, encapsulation, fat oxidation, kashk

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INTRODUCTION

Kashk, in a dried or liquid form, is a fermented dairy product that is very popular in Iran. It is used as a major protein source by nomadic populations in the Middle East. Salty by-products, such as buttermilk, are traditionally used to produce kashk [1]. It chemical composition includes 84.25% of dry matter, 8.57% fat, 95.9% salt, 53.60% total protein, 11.08% ash, and 1.06% lactose. Kashk also contains amino acids and minerals such as calcium, magnesium, iron, sodium, and potassium. Due to its high moisture and protein content, kashk has a high microbial contamination potential [2].

Two major mechanisms are involved in the spoilage of milk products, lipolysis and oxidation. The release of various lengths of fatty acids during the cleavage of milk fat by lipase and phospholipase can contribute to an intense flavor in milk. In particular, short-chain fatty acids released between C_4 and C_8 account for a rancid flavor and odor, while free medium-chain fatty acids released between C_{10} and C_{12} produce a soapy flavor. Finally, the oxidation of lipids cause off-flavor and odors [3].

Lipid oxidation occurs when free radical chain reactions propagate in food. Antioxidants can significantly prevent or inhibit the oxidation of lipids in foods,

even at low concentrations. Additionally, some studies have shown that mixtures of synthetic antioxidants can cause carcinogenic effects. Thus, the use of these synthetic food additives is tightly controlled.

The demand for new, naturally-derived, and more effective antioxidants as alternatives to synthetic products is driven by their unsafety and toxic effects on health, as well as by negative consumer perceptions of chemical additives [4]. Furthermore, the use of plant extracts in dairy products, such as milk, cheese, yogurt, labneh, ayran, and doogh, have been successfully reported. Nevertheless, the efficacy of microencapsulated plant extracts in controlling the quality of industrial liquid kashk has not been studied yet [5].

Lemongrass typically grows to 1.8 m in height and 1.2 m in the spread. It has a small rhizome and its leaves emerge straight out of the ground without stems. They are 1.3–2.5 cm wide and about 1 m long. The *Cymbopogon* genus includes more than 55 species across the world, with different physical and chemical properties [6].

Lemongrass is used in food preparation, especially in Malaysia, Thailand, Vietnam, Sri Lanka, and in the Caribbean islands. It is a highly nutritional functional ingredient with antioxidant and anticancerous properties [7].

Recent years have seen an increased consumer interest in functional foods, especially dairy products. Lemongrass extract has been reported to improve the color and odor attributes of supplemented cheese and reduce cheese environmental pollution. In addition, lemongrass extract or essential oil is a potential antimicrobial agent against a wide variety of pathogenic Gram-positive and Gram-negative bacterial species [8].

In a study by Hematian *et al.*, extracts from the caper plant (*Capparis spinose* L.) were added to kashk [2]. Caper extract had no adverse effects on kashk's pH. Increasing the extract's concentration and storage time decreased *L** and increased *b**, but did not affect the *a** color parameter. Caper extract not only improved the textural properties of kashk but also reduced its odor at the end of the storage period. However, no differences in taste and mouthfeel were observed between the samples. In general, the kashk samples containing 0.350 mg/mL of caper extract had enhanced antibacterial, antioxidant, and antifungal properties and therefore can be considered a novel functional product [2]. Peppermint essential oil (*Mentha pulegium*) can also be used to enrich kashk in concentrations of 1500 and 2500 ppm [5].

Microencapsulation of essential oil facilitates its application as a food ingredient and is therefore recommended to improve the stability of the product. Encapsulation protects the oil from oxidation, limits unwanted environmental impacts, and promotes long-term release, ensuring extra time for its activity [9]. Emulsion is one of the techniques used in microencapsulation. Emulsions are colloidal dispersions of at least two immiscible liquids, one dispersed in the other. They are stabilized with surfactants that have a proper hydrophilic-lipophilic balance. Emulsions have a potential advantage of encapsulation and protection of water-soluble bioactive nutrients, such as vitamins, minerals, probiotics, amino acids, and caffeine [10].

The preparation of emulsion is one of the crucial steps for successful encapsulation. It depends on the selection of wall materials obtained from a variety of natural and synthetic polymers [11].

Microencapsulated lemongrass essential oil was used in several foods such as Coalho cheese and stirred yogurt [9, 12].

Yet, there has been no research into the microencapsulation of lemongrass extract and its application in kashk. Therefore, we aimed to evaluate the impact of microencapsulated lemongrass extract (MLGE) and lemongrass extract (LGE) on kashk and determine its sensory and physicochemical properties.

STUDY OBJECTS AND METHODS

Plant collection and identification. Fresh lemongrass was collected from Firoozabad, Fars province (south of Iran), in April 2020. It was identified by a senior plant taxonomist at the Department of Botany, Fars Agricultural and Natural Resources Research and Education Center, Shiraz, Iran.

Chemicals and materials. All the solvents were of the HPLC grade. A Millipore Direct-Q UV system was used to prepare deionized water. A Biotek microplate reader El×818 was applied to investigate the antioxidant activity. 2,2-diphenyl-1-picrylhydrazyl (DPPH) was obtained from the Sigma-Aldrich company. Reference standards of 17 polyphenols (p-comaric acid, trans-ferulic acid, catechin, carvacrol, eugenol, chlorogenic acid, rosmarinic acid, quercetin, gallic acid, caffeic acid, ellagic acid, rutin, hesperetin, vanillin, hesperidin, coumarin, and sinapic acid) were also obtained from the Sigma-Aldrich company for HPLC analysis.

Preparation of methanolic extract. A Moulinex AR1100 grinder (Coulsdon, Surrey, UK) was applied to grind dried seeds to a fine powder. The powder was used for methanolic extraction by the maceration technique. For this, a certain amount of powdered seed was soaked in methanol (1:10) for about 24 h, filtrated, and injected to determine polyphenols by HPLC. The residue was concentrated by a rotary evaporator at 40°C for antioxidant activity analysis [13].

Determination of antioxidant activity (DPPH). The DPPH free radical scavenger method was employed to evaluate the standard antioxidant activity of lemongrass extract [13]. Gallic acid was the standard compound for this test.

HPLC analysis of polyphenol. Gradient elution was selected for maximum sensitivity. Various ratios of solvent A (1% formic acid in deionized water) to solvent B (methanol, v/v) were used, namely 10:90, 25:75, 60:40, and 70:30 at 0, 10, 20, and 30 min, respectively, which were then maintained isocratic till 40 min. HPLC

was executed on an Agilent 1200 series, with a Zorbax Eclipse XDB-C18 column (4.6×5 μm i. d.; ×150 mm film thickness, RP) and a photodiode array detector. Elution was monitored at 280 and 230 nm. The column temperature was 30°C. The injection volume was 20 μL. The standard solutions had a linear calibration curve with a good correlation.

Spectrophotometric determination of total phenolics. Folin Ciocalteu's reagent was used to spectrophotometrically measure total phenols. The results were shown as gallic acid equivalents. A gallic acid calibration curve was based on the equation: $c = 1.885 \times A + 2.81$, $R^2 = 0.9953$. Finally, four calibration points were plotted within the range of 6.25–50 mg/mL of gallic acid in the reaction mixture.

Spectrophotometric determination of total flavonoids. The aluminum chloride colorimetric method was used to determine total flavonoids**.** Quercetin was used to make a calibration curve. Ten milligrams of quercetin were dissolved in 80% ethanol and then diluted to 6.25, 12.5, 25, 50, 80, and 100 mg/L. The standard solutions (0.5 mL) were diluted and separately mixed with 0.1 mL of 10% aluminum chloride, 0.1 mL of 1 M potassium acetate, 1.5 mL of 95% ethanol, and 2.8 mL of distilled water. After incubating at 27°C for 30 min, a Shimadzu UV-160A spectrophotometer (Kyoto, Japan) was used to assess the optical density of the reaction mixture at 415 nm. The blank sample consisted of an equal amount of 10% aluminum chloride that was replaced with an equal amount of distilled water. Similarly, the fifteen flavonoid standard solutions (100 ppm) or 0.5 mL of ethanol extracts were reacted with aluminum chloride to assess the flavonoid content as stated above.

Microencapsulation of extract. All the glassware and solutions used in this protocol were sterilized at 121°C for 15 min. The lemongrass extract was added to the sodium alginate mixture containing 2% (w/v) of maize starch (Starch Australia Ltd.). The mixture was dropped into the oil containing Tween 80 (0.02%). On completion of the dropping, the mixture was stirred vigorously until it was fully emulsified to a creamy form. A solution of 0.1 M calcium chloride was then added fast along the side of the beaker, and the phase separation of oil/water emulsion took place. To separate and settle the emulsion at the bottom of the calcium chloride layer, the mixture was allowed to stand for 30 min. The oil layer was drained and the beads were collected by slow centrifugation (3503 g, 15 min), washed once with 0.9% saline containing 5% glycerol, and stored at 4°C.

Particle size, morphology of beads, and microencapsulation efficiency. The aspect ratio of 20 beads was analyzed using a digital microscope and MicroMeasure software version 1.07 (Eq. (1)).

$$\text{Aspect ratio} = \frac{\text{Large diameter}\,(\text{mm})}{\text{Small diameter}\,(\text{mm})} \quad (1)$$

A dynamic light scattering device (90 Plus, Brookhaven Instruments Corp., Vienna, Austria) was used to measure the particle size distribution. Analyses were performed at a scattering angle of 90 at 25°C.

The efficiency of encapsulation was verified by the determination of phenolic compounds. For this, 800 mg of microencapsulated powder was accurately weighed, added to 4 mL of methanol (as solvent), and gently shaken using a vortex for 2 min at room temperature. The tube was then centrifuged (IEC Centra3M Centrifuge, UK) at 3000 rpm for 5 min. The Folin-Ciocalteu colorimetric method was used to measure phenolic compounds in the slurry, which were eventually called microencapsulated polyphenols (P_{encap}, mg GA/g DE). The total polyphenol content of dried lemongrass extract was assessed based on the Folin-Ciocalteu colorimetric method (P_{total}, mg GA/g DE). The following equation was then applied to calculate the efficiency of microencapsulation (E_{encap}, %).

$$E_{encap} = \frac{P_{encap}}{P_{total}} \quad (2)$$

Kashk samples preparation. To prepare kashk samples, milk fat was initially standardized at 1.3% w/v followed by homogenization at 100–200 kg/cm^2, pasteurization at 90°C for 15 min, and cooling down to 43°C. The lyophilized starter culture, CH1 (50U) DVS, was added to the milk and incubated at 43°C until optimal acidity was achieved (150°D). The produced yogurt was then kept at 4–5°C for 24 h. After that, it was transferred to a cooking tank (heated at 80°C for 4 h) and constantly stirred, to prevent burning, until a light brown color appeared in the product. The kashk's total solids were measured on an MA100 infrared moisture analyzer (Sartorius, Gottingen, Germany) and then adjusted to 20% m/m (SNF 14.28 m/m). Sterile salt (1%) was added and the sample was homogenized at 75°C at 100–150 kg/cm^2. Based on the results of sensory evaluation, lemongrass extract (5%, w/w) was added to the milk. The ranking test was performed by 50 non-trained panelists of both sexes, aged 20 to 45, who were pre-selected according to their interest in the study. Various concentrations of lemongrass extract (1, 3, 5, and 7%) were used to assess the flavor preference. Approximately 20 g of each kashk sample was served to every panelist randomly encoded with a 3-digit number. The panelists were asked to select the most and the least preferred samples based on their overall impression. Finally, the total priorities were calculated. An equal quantity of lemongrass extract at a concentration of approximately 10% (w/w) was added to each sample. The samples free of lemongrass extract or microencapsulated lemongrass extract were considered as a control. All the samples were packed hot (80°C) in plastic containers and stored at 4°C. Their sensory and structural properties were eventually analyzed during storage.

pH and acidity of kashk. The pH values of the kashk samples were recorded using a pH meter (Greisinger Electronic, Germany). The Dornic degree (National Standard of Iran, 2852) was then used to show their titrable acidity [14].

Acid degree value. The acid degree value of the samples was determined as described by Borhanpoor *et al.* using the following equation [15]:

$$\text{Acid degree value} = \frac{5.61 \times \text{Titration}(\text{mL})}{\text{Sample}(\text{g})} \quad (3)$$

Color. The kashk's color was measured using a CR-400 Chroma Meter (Konica-Minolta, Osaka, Japan). The *L** value is an indicator of lightness (black to white). The *a** values indicate green and red, while *b** indicates blue and yellow.

Texture. The texture profile analysis was employed to measure the texture of the samples using a CT3 texture analyzer (Brookfield Engineering Laboratories, Inc., Middleboro, MA, USA). The test was performed on the first and the 60th day of the storage period. A sample (diameter 20.0 ± 0.5 mm, height 10.0 ± 0.5 mm) was taken from the center of the kashk. Next, the cylindrical kashk was covered with a stretch film and brought to room temperature of 20 ± 1°C. The analysis conditions were as follows: a TA11/1000 aluminum cylinder probe (25.4 mm in diameter), compression to 20% of the initial height, a test speed of 1 mm/s, a penetration rate of 2 mm/s, a pre-test speed of 2 mm/s, and a retention time of 5 s. The textural parameters included hardness (g), chewiness (mJ), adhesiveness (mJ), gumminess (g), and cohesiveness.

Sensory analysis. The control kashk sample, the kashk with lemongrass extract, and the kashk with microencapsulated lemongrass extract (MLGE) were evaluated by 45 educated panelists. They were divided into two age groups, 18–24 years and 24–51 years (42% of males and 58% of females). A 5-point hedonic scale was applied to assess the flavor, odor, color, texture, and overall acceptability, where 5 indicated "like extremely" and 1 indicated "dislike extremely" in comparison with the control kashk. The samples were evaluated by the panelists every 15 days during the storage period.

Peroxide value. The peroxide value was calculated using a method described by Siddique and Park based on Eq. (4) [16]:

$$\text{POV} = \frac{\left[T_{\text{sample}} - T_{\text{blank}}\right] \times 0.01\text{N} \times 1000}{\text{Sample weight}} \quad (4)$$

where POV is the peroxide value, milliequiv. of Peroxide per 1000 g sample; T_{sample} is the titration of sample, mL; T_{blank} is the titration of blank, mL; sample weight, g.

The *p*-anisidine value. The *p*-anisidine value (AnV) indicates the degree of lipid oxidation and is used to measure stable secondary oxidation products. Measurements were performed on a DR5000 UV-V spectrophotometer (Hach Lange, Germany), with iso-octane used as a blank. AnV was determined according to Eq. (5):

$$p\text{-anisidine value} = \frac{25 \times (1.2As - Ab)}{m} \quad (5)$$

where *As* is the absorbance of the sample; *Ab* is the absorbance of the blank; *m* is the mass of the sample, g [17].

Thiobarbituric acid reactive substances. To determine thiobarbituric acid reactive substances (TBARS), one gram of a kashk sample was mixed with 9 mL of 0.25 N HCl solution containing 0.375% TBA (Sigma-Aldrich, USA) and 15% TCA (Merck, Germany). The mixture was heated in boiling water for 10 min, followed by cooling with running water. The mixture was then centrifuged at 3500 rpm for 15 min. The supernatant was collected, and the absorbance was read at 532 nm using a spectrophotometer. TBARS were calculated from the standard curve of malonaldehyde (0–2 mg/kg) (Merck, Germany) and expressed as mg malonaldehyde per kg of the sample.

Statistical analysis. Experimental data were analyzed using SPSS Statistics Version 21.0 (IBM Corp., Armonk, NY, USA). ANOVA ($p \leq 0.05$) and Duncan's multi-range test were employed to perform a mean comparison. All the experiments were carried out in triplicate, unless otherwise stated in the text. All the graphs were created in Microsoft Excel Version 16 (Microsoft, Redmond, WA, USA).

RESULTS AND DISCUSSION

Polyphenol, total phenolic content, flavonoid, and antioxidant activity. Of 17 polyphenols identified (Table 1), the main phenol components in the lemongrass extract were gallic acid (138.95 mg/L), trans-ferulic acid (20.58 mg/L), and thymol (47.9 mg/L). Sinapic acid, catechin, caffeic acid, quercetin, coumarin, vanillin, hesperidin, ellagic acid, and eugenol were not detected in the lemongrass extract. Total phenolics and flavonoids in the lemongrass extract were 26.73 mg GA/g and 8.06 mg Quercetin/g, respectively.

A similar study by Gazwi reported slightly different results, with total phenols and flavonoids amounting to 65.20 mg GA/g and 46.57 mg Quercetin/g, respectively [18]. Alterations in the values might result from the fact that the raw plant material was taken from different plant parts [15]. Furthermore, the differences can be related to the plant populations that originate from various altitudes, geographic origins, and climates [19].

In our study, the antioxidant activity of the LGE was 512.95 μg/mL, which was different from IC_{50} (1998.10 ± 0.02 μg/mL) reported by Lahlou *et al.* [20]. The structure and contents of polyphenols are associated with different factors including plant varieties, culture

Table1 Phytochemical and antioxidant contents of lemongrass extract

Polyphenolic compound	Amount	Retention time, min
Sinapic acid, mg/L	n.d.	16.5
Gallic acid, mg/L	138.9532	3.3
Catechin, mg/L	n.d.	8.3
Caffeic acid, mg/L	n.d.	11.6
Chloregenic acid, mg/L	14.7	10.5
Quercetin, mg/L	n.d	21.6
p-coumaric acid, mg/L	3.040196	15.6
Coumarin, mg/L	n.d.	17.4
Carvacrol, mg/L	10.8	28.4
Vanillin, mg/L	n.d.	13.5
Trans-ferulic acid, mg/L	20.58616	16.3
Hesperidin, mg/L	n.d.	18.5
Ellagic acid, mg/L	n.d	19.02
Eugenol, mg/L	n.d.	23.7
Hesperetin, mg/L	13.11011	22.4
Rosmarinic acid, mg/L	16.53507	19.2
Thymol, mg/L	47.90072	28.9
Flavonoids, mg Quercetin/g	8.06	–
Total phenolic compounds, mg GA/g	26.73	–
IC_{50}, mg GA/L	2751.331	–

n.d. – not detected

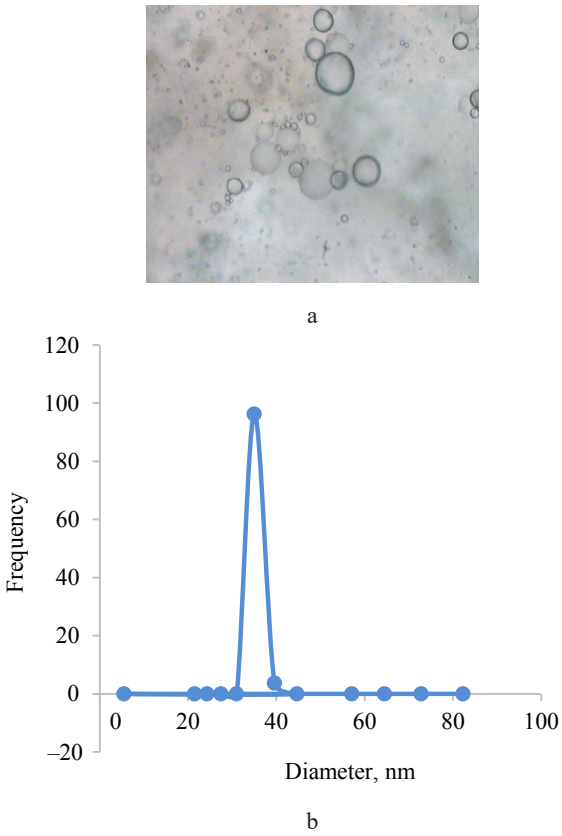

Figure 1 Microencapsulated lemongrass extract: (a) light microscopy image; (b) droplet size distribution

conditions, maturation, and processing, which affect total polyphenols mainly present in the combined form [21].

Particle size, the morphology of beads, and microencapsulation efficienc The beads containing starch had a spherical shape (Fig. 1). They were observed by light microscopy (×100). The type of wall material is an important factor for the bead shape. For example, alginate beads showed a smaller size and a more regular shape compared to pectin [22].

In our study, the average particle diameter was 35.03 nm. Size is an important indicator of the beads' stability and efficiency [23]. We found the efficiency of microencapsulation to be 47.81%. In contrast, Mehran *et al.* reported values of 93.1 and 97.4% for encapsulation efficacy. The main reason for this variation was the composition of the wall material used for encapsulation [24].

pH and acidity of kashk. Changes in the pH and acidity of the kashk samples supplemented with lemongrass extract and microencapsulated lemongrass extract during 60 days of storage at 4°C are presented in Fig. 2a and b. The pH values significantly ($p<0.05$) decreased in both experimental groups on the first day of storage and continued to decrease throughout the whole storage period. The pH ranged from 3.89 to 3.95 and was considered acceptable for the commercial kashk varieties. The presence of lactic acid bacteria in yogurt inevitably leads to post-acidification, which may cause increased post-acidification in kashk [25]. The acidity of different sorts of kashk could effectively increase due to post-acidification during storage. These results reflect those of Kim *et al.*, who reported that the pH values of Gouda cheese supplemented with pepper extract were not significantly different from those of the control cheese at each time point. However, the pH of each sample did not change significantly throughout the aging period [26].

Acid degree value. The levels of free fatty acids in the samples were expressed as acid degree values (Fig. 3). We found that the kashk samples supplemented with lemongrass extract and microencapsulated lemongrass extract had lower acid degree values than the control at the end of the storage time. The ADVs in all kashks increased during the storage time. However, molds and lactic acid bacteria were the main agents responsible for lipolysis in this product [27]. Spontaneous lipolysis happens during cold storage. This view is supported by Khan *et al.*, who enriched cheese with mango kernel oil (*Mangifera indica* L.). They concluded that the amount of free fatty acids increased in all treatments and the control samples over the entire 90-day period. Bacterial lipase and moisture contents are the main causes of free fatty acids [28].

Color analysis. Lightness (L^*), red-green axis (a^*), and yellow-blue axis (b^*) are the factors that evaluate the color of kashk (Table 2). Our results showed the highest values of L^* in the control samples. We hypothesized that the kashk samples containing

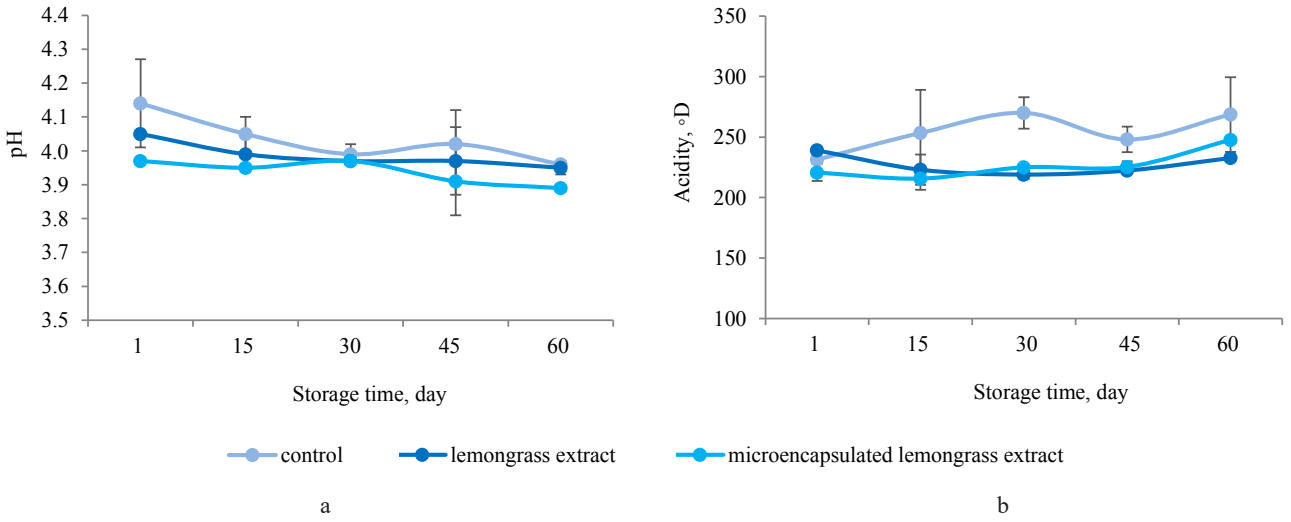

Figure 2 Chemical parameters of kashk samples supplemented with lemongrass extract and microencapsulated lemongrass extract during storage: (a) pH; (b) acidity

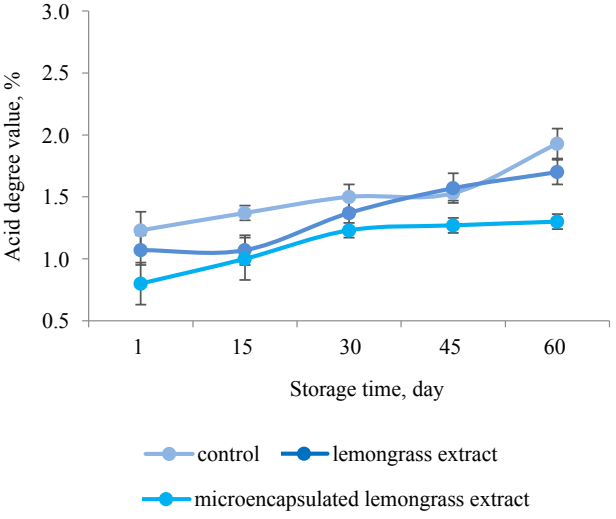

Figure 3 Acid degree values of kashk samples supplemented with lemongrass extracts during storage

lemongrass extract and beads showed lower light scattering and brightness due to water absorption, so the final product looked darker. The white appearance of this product was due to the presence of colloidal particles, such as milk fat globules and casein micelles, that could scatter visible spectrum light. In a similar study of yogurt, the encapsulated polyphenolic compounds extract powder showed lower lightness than the plain yogurt due to the presence of pigments such as anthocyanin [29]. Further, the *a** (redness) decreased but *b** (yellowness) values increased for the kashk samples fortified with microencapsulated lemongrass extract. The more yellowish color was due to an increase in the encapsulated extract in the kashk. Higher greenness of the microencapsulated samples could be related to the green color of LGE.

Texture. In our study, the texture profile analysis of the kashk samples correlated well with their sensory parameters (Table 3). In particular, hardness decreased during storage in the control and lemongrass extract and increased in the microencapsulated lemongrass extract. A similar result was reported by Pérez-Soto *et al.* for the control cheese on the first day of storage in comparison with the other microencapsulated enriched cheese [30]. Furthermore, hardness is related to the pH of the kashk samples. The lower the pH, the higher the stiffness of the kashk structure. At decreasing pH values, the covalent bind of ionic species to the casein strand becomes protonated during curd formation. This phenomenon subsequently increases hydrophobic interactions between protein molecules to finally make the curd harder [31]. Therefore, the sample with microencapsulated extract with the lowest pH (Fig. 2a) revealed the greatest hardness at the end of the storage time.

The results also showed that in the kashk samples, cohesiveness values were equal during the storage time and among the kashk samples on the same storage day. According to results obtained in a previous study for yogurt enriched with iron-entrapped niosomes, adhesiveness had no significant differences between the control and microencapsulated yogurt [32]. Increased water in the gel system could be one of the reasons for downgrading adhesiveness [33]. Further, we found that gumminess increased in the fortified samples during storage. This finding was consistent with a study by Sah *et al.*, where higher gumminess was attributed to the reduction in pH followed by structural shrinking and rearrangement of the kashk structure [34]. Ahmed *et al.* reported a stabilized casein network and improved gumminess due to the interaction between phenolic compounds in the extract and proteins, which could lead to the rearrangement of proteins during storage [33]. In our research, the sample with

Table 2 Color parameters of kashk samples supplemented with lemongrass during storage

Parameters	Days	Control kashk	Lemongrass extract	Microencapsulated lemongrass extract
*L**	1	66.22 ± 5.31^{aA}	61.22 ± 3.53^{aA}	58.33 ± 3.92^{aAB}
	15	65.44 ± 2.92^{aA}	62.89 ± 3.62^{aA}	51.89 ± 3.45^{bB}
	30	64.22 ± 5.09^{aA}	60.56 ± 4.26^{aA}	63.44 ± 2.68^{aA}
	45	65.33 ± 2.91^{aA}	60.33 ± 2.77^{aA}	65.22 ± 3.40^{aA}
	60	66.56 ± 3.83^{aA}	58.89 ± 3.36^{aA}	67.00 ± 2.56^{aA}
*a**	1	-3.33 ± 0.57^{bB}	-2.11 ± 0.48^{abC}	-0.67 ± 0.55^{aB}
	15	-3.22 ± 0.62^{bB}	-3.44 ± 0.29^{bC}	-1.56 ± 0.53^{aB}
	30	0.78 ± 0.83^{aA}	0.44 ± 0.70^{aB}	1.67 ± 0.57^{aA}
	45	-1.00 ± 0.57^{bA}	2.22 ± 0.57^{aAB}	2.33 ± 0.66^{aA}
	60	-1.00 ± 0.62^{bA}	0.78 ± 0.40^{aB}	-0.78 ± 0.52^{bB}
*b**	1	11.33 ± 0.79^{bC}	16.22 ± 0.54^{aB}	11.67 ± 0.62^{bC}
	15	12.33 ± 1.24^{aC}	12.33 ± 0.83^{aC}	13.11 ± 0.97^{aC}
	30	16.44 ± 0.41^{aAB}	14.44 ± 0.93^{bB}	17.67 ± 0.44^{aB}
	45	18.00 ± 0.62^{bA}	19.78 ± 0.59^{abA}	21.22 ± 0.77^{aA}
	60	15.56 ± 0.64^{aB}	16.11 ± 0.26^{aB}	16.44 ± 0.33^{aB}

*L** is the luminance or lightness component, *a** (from green to red) and *b** (from blue to yellow)

[A-B] Means in the same column with different uppercase letters differ significantly ($p \leq 0.05$)

[a-b] Means in the same row with different lowercase letters differ significantly ($p \leq 0.05$)

*Mean ± SD (n = 4)

Table 3 Texture analysis of kashk samples fortified with lemongrass extract and microencapsulated lemongrass extract during storage

Parameters	Samples	Day 1	Day 60
Hardness, g	Control kashk	802.25 ± 83.75^{aA}	309.75 ± 36.00^{bB}
	Lemongrass extract	700.38 ± 66.62^{aAB}	199.54 ± 3.03^{bC}
	Microencapsulated lemongrass extract	494.54 ± 8.50^{aB}	570.62 ± 21.87^{aA}
Adhesiveness, mJ	Control kashk	33.97 ± 10.41^{aA}	12.49 ± 2.17^{aA}
	Lemongrass extract	27.21 ± 21.20^{aA}	11.63 ± 1.09^{bA}
	Microencapsulated lemongrass extract	13.62 ± 2.48^{aA}	18.10 ± 4.63^{aA}
Cohesiveness	Control kashk	0.70 ± 0.01^{aA}	0.45 ± 0.04^{aA}
	Lemongrass extract	0.760 ± 0.015^{aA}	0.36 ± 0.15^{aA}
	Microencapsulated lemongrass extract	0.72 ± 0.04^{aA}	0.56 ± 0.25^{aA}
Gumminess, g	Control kashk	773.05 ± 120.85^{aA}	460.82 ± 26.68^{aB}
	Lemongrass extract	566.20 ± 44.10^{bAB}	838.75 ± 2.25^{aA}
	Microencapsulated lemongrass extract	372.05 ± 9.45^{bB}	472.35 ± 11.25^{aB}
Chewiness, mJ	Control kashk	117.54 ± 29.72^{aB}	135.56 ± 8.67^{aA}
	Lemongrass extract	90.60 ± 3.77^{aB}	273.69 ± 81.29^{aA}
	Microencapsulated lemongrass extract	430.32 ± 10.13^{aA}	72.66 ± 3.80^{bB}

[A-C] Means in the same column with different uppercase letters differ significantly ($p \leq 0.05$)

[a-b] Means in the same row with different lowercase letters differ significantly ($p \leq 0.05$)

* Mean ± SD (n = 4)

microencapsulated lemongrass extract had the greatest gumminess among the samples at the end of the storage time. However, chewiness was the highest in the kashk with lemongrass extract and lowest in the sample with microencapsulated extract on the 60th day of storage. This finding was similar to the results reported by Ojagh *et al.* [35].

Sensory analysis. The results of sensory analysis for color, odor, flavor, texture, and overall acceptability of the kashks stored at 4°C for 60 days are provided in Fig. 4. Significant differences ($p < 0.05$) were observed for flavor and odor between the control and the samples fortified with lemongrass extract and microencapsulated lemongrass extract at the end of the storage time. In a study by Sawale *et al.*, accelerated amounts of herb (0.1 to 0.5%, *Pueraria tuberosa*) added into milk caused lower color, appearance, and mouthfeel scores [36]. In our study, the samples with microencapsulated extract revealed a better sensory profile than the control samples, which verified their high acceptability. These results were in agreement with a study by Balabanova *et al.* [37]. The texture of the kashk supplemented with microencapsulated lemongrass extract increased at the end of storage because sodium alginate,

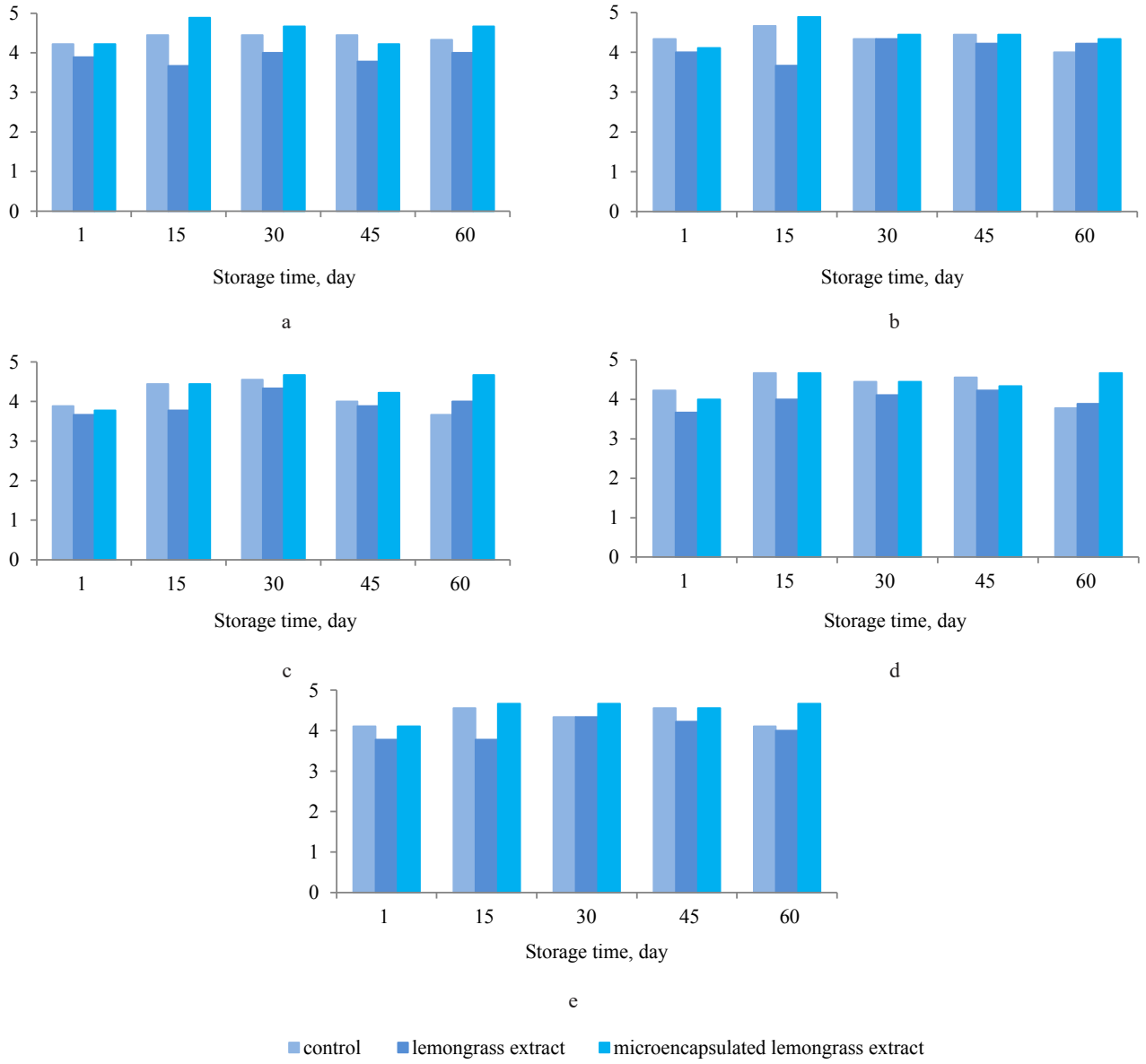

Figure 4 Sensory characteristics of lemongrass extracts during storage for 60 days at 4°C: (a) flavor; (b) color; (c) odor; (d) texture; (e) overall acceptability

an anionic polysaccharide, formed complex coacervates with two milk proteins, *β*-lactoglobulin and bovine serum albumin, through electrostatic interactions under specific conditions, which seemed to strengthen the gel in yogurt [38].

The peroxide value, *p*-anisidine value, and thiobarbituric acid values. Table 4 shows an increasing trend in the peroxide value, *p*-anisidine value, and thiobarbituric acid values during the storage period for all the samples. However, this increase was slower in the samples fortified with lemongrass extract and microencapsulated lemongrass extract, compared to the control. This means that fat oxidation was reduced in the fortified kashks. It might be related to gallic acid, a major antioxidant compound in lemongrass extract [39]. The antioxidant activity of phenolic compounds in lemongrass extract during storage was enhanced by its encapsulation. Therefore, the peroxide value was decreased in the kashk containing emulsion nanoparticles (dispersed droplets in W/O emulsions), compared to simple extract throughout storage.

In contrast, encapsulation can raise the inhibitory ratio of natural antioxidants due to the controlled release of phenolic compounds and continuing availability of the antioxidant [40]. The decomposition of the primary oxidation products of the emulsion lipid increased the *p*-anisidine value of the kashk samples during storage. This value was considerably influenced by the addition of lemongrass extract during 60 days. It was significantly ($p < 0.05$) lower in the experimental samples compared to the control. The antioxidant function of the microencapsulated polyphenols may reduce both the primary and secondary oxidation of lipids [41].

Table 4 Peroxide, *p*-ansidine, and thiobarbituric acid values in kashk samples during storage

Parameters	Days	Control kashk	Lemongrass extract	Microencapsulated lemongrass extract
Peroxide value (milliequiv of peroxide/ 1000 g sample)	1	0.77 ± 0.18^{aA}	0.67 ± 0.25^{aA}	0.65 ± 0.11^{aA}
	60	2.86 ± 1.11^{aA}	2.02 ± 0.98^{aA}	0.69 ± 0.21^{aA}
p-anisidine	1	18.32 ± 1.08^{bB}	26.44 ± 0.97^{aB}	21.24 ± 1.06^{bA}
	60	29.25 ± 0.90^{bA}	40.92 ± 1.04^{aA}	22.25 ± 0.79^{cA}
Thiobarbituric acid content (mg malonaldehyde/kg)	1	0.034 ± 0.002^{aA}	0.031 ± 0.004^{aA}	0.034 ± 0.005^{aA}
	60	0.051 ± 0.009^{aA}	0.048 ± 0.011^{aA}	0.049 ± 0.012^{aA}

[a-b] Data within the same row marked with different lowercase letters are significantly different ($p \leq 0.05$)

[A-B] Data within the same column marked with different uppercase letters are significantly different ($p \leq 0.05$)

* Mean ± SD (n = 3)

Throughout storage, all the samples showed a significant increase in thiobarbituric acid values. The control kashk obtained a higher value (0.034 on the initial day to 0.051 on day 60) followed by the sample with lemongrass extract (0.031 on the initial day to 0.048 on day 60) and the sample with microencapsulated extract (0.034 on the initial day to 0.048 on day 60). The thiobarbituric acid value increases in the lemongrass-fortified samples were lower than in the control. These results were consistent with those of El-Sayed *et al.*, who indicated that the butter fortified with sage and rosemary essential oils had smaller concentrations of secondary oxidative products like malonaldehyde and ketones [42].

CONCLUSSION

Lemongrass extract was successfully encapsulated using the emulsion method. The phytochemical screening of the extract revealed the presence of Gallic acid, Thymol, Rosmarinic acid, Hesperetin, and Trans-ferulic acid as major compounds. The microcapsules were spherical in shape. The acidity and pH of the samples fortified with lemongrass extract were acceptable for commercial kashk varieties. These samples had lower acid degree values than the control at the end of the storage time. The application of microencapsulated lemongrass extract in the kashk matrix did not have a negative effect on the color parameters. The kashk with microencapsulated extract had the highest hardness on the 60th day of storage but the lowest chewiness. The fortified samples were able to reduce fat oxidation compared to the control. High overall acceptability showed that encapsulation could be applied for kashk fortification.

CONTRIBUTION

The authors were equally involved in writing the manuscript and are equally responsible for plagiarism.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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