



Effects of encapsulated black caraway extract and sesame oil on kolompeh quality

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Abstract: In this study, the physicochemical and sensory properties of kolompeh containing black caraway and sesame oil were investigated. Black caraway extract (BCE), encapsulated black caraway extract (EBCE), and black caraway powder (BCP) were added to kolompeh and compared to the sample without black caraway (FBC). All products contained sesame oil and were compared to control (without sesame oil). Among the samples, kolompeh with encapsulated extract demonstrated a higher oxidative stability (24.37 h), with a high IC_{50} of black caraway extract ($124.1 \mu\text{g}\cdot\text{mL}^{-1}$). In addition, the emulsion exhibited size distribution between 3.20 and 8.51 μm , and Fourier transform infrared spectroscopy confirmed the well encapsulated extract. Gas chromatography identified oleic and linoleic acids as the main fatty acids in kolompeh with the black caraway encapsulated extract. Although, there were no significant differences in the colour parameters (L^* , a^* and b^*) of the samples, kolompeh with EBCE had the highest score given by panelists. The control had a higher (2466 g) hardness compared to kolompeh containing EBCE (1688 g) at the end of storage. Therefore, the encapsulated extract of black caraway not only had no an adverse effect on the properties of kolompeh but also improved its quality.

Keywords: Kolompeh, black caraway extract, encapsulation, sesame oil, antioxidant activity, sensory properties

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INTRODUCTION

Kolompeh is an Iranian date-based cookie baked traditionally by local citizens, especially in Kerman, and industrially produced in Kerman and other parts of the country. This cookie has a high nutritional and energy value and includes date paste, walnut, wheat flour, butter, and eggs as the main ingredients. Pistachios or sesame powder are often used for decorating kolompeh [1].

Fats and oils, being important components of kolompeh, help soften the texture, maintain the moisture, improve the flavour, and preserve the quality of the product [2]. Their oxidation and microbial degradation leads to the reduced sensory characteristics and shelf life of the product [3]. Compounds resulted from oxidation cause rancidity. To prevent the oxidative deterioration, antioxidants have been widely used [4]. Thus, natural antioxidants, such as aromatic plants and spices, have gained their popularity in the bakery industry; they preserve bakery products from oxidation

and microorganism spoilage, extend their shelf life, and have therapeutic benefits [5]. Antioxidant activity of black caraway has been proved by Kamkar [6].

In recent years, there has been a tendency to use encapsulation for improving the delivery of bioactive agents. Therefore, the application of microencapsulation in food and agricultural industries can contribute to such characteristics of food as sensory properties, especially texture, and their stability during shelf-life. In addition, encapsulation can also amend the water solubility, thermal stability, and oral bioavailability of bioactive compounds [7].

This fact stimulates the development and production of new products. Among the various methods of encapsulation, considerable research efforts have been applied to emulsion based encapsulation of different sensitive materials [8]. This method aims to improve the chemical stability during processing and storage, to protect from degradation, and to keep the release of bioactive molecules under control [9].

To our knowledge, the use of sesame oil and encapsulated extract of black caraway in kolompeh have not been studied. Thus, the purpose of this study was to evaluate an effect of black caraway and sesame oil on the physical and sensory properties of kolompeh. The kolompeh contained sesame oil and different forms of black caraway, including powder, extract, and encapsulated extract.

STUDY OBJECTS AND METHODS

Materials. Wheat flour, dates, black caraway (*Bunium persicum* L.), and flavouring ingredients were purchased from local market in Shiraz, Fars, Iran. *Saccharomyces cerevisiae* lyophilised powder (PTCC 5269) was supplied by Arya Toos Co., Mashhad, Khorasan, Iran. DPPH and other chemical reagents were obtained from Merck Co., Darmstadt, Germany.

This research was conducted at the Fars Agricultural and Natural Resources Research and Education Center.

Extraction. The extraction was carried out by the method of Upadhyay *et al.*, with some modifications [10]. Ten grams of grounded black caraway was added to 100 mL of distilled water and kept in a water bath for 45 min. Then the slurry was cooled at room temperature and filtered to obtain a clear extract for analyses.

Encapsulation of BCE. Microencapsulation of black caraway extract was performed using W/O emulsion based on the method given by Tran, with some modifications [11]. The oil phase of the W/O emulsion was prepared by adding glycerol monostearate (GMS) with HLB 3.8 (1.5 wt%) to canola oil and shaking at 4000 rpm and 70°C. The aqueous solution containing black caraway extract was heated to 40°C. The W/O emulsion (10:90) was prepared by blending the aqueous phase and the oil phase at 27000 rpm and 70°C for 2 min. Then the suspension was cooled while stirring with a magnet at 1000 rpm for 2 h and kept for 30 min to precipitate microcapsules. Finally, the suspension was centrifuged at 350 g for 10 min (4°C). The precipitate was washed with saline twice and filtered. The

microcapsules obtained were stored in a refrigerator until usage.

Kolompeh preparation. Five formulations of kolompeh were developed (Table 1).

The following kolompeh samples were prepared: with 2.5% of encapsulated black caraway extract, with 0.25% of black caraway extract, with 0.4% of black caraway powder, and without (free) black caraway. All of them included sesame oil. To investigate an influence of sesame oil on the kolompeh properties, control sample was prepared with canola oil instead of sesame oil. Kolompeh was made by mixing wheat flour, yeast and oil and keeping for 30 min for proofing. Then kolompeh was formed, minced date with flavouring ingredients were put in the centre of the dough, and the samples were baked in an oven at 150°C for 30 min.

Antioxidant activity. Radical scavenging activity of black caraway extract against stable DPPH (2,2-diphenyl-2-picrylhydrazyl hydrate) was measured with a spectrophotometer. DPPH methanol solution (0.1 mmol·L⁻¹) had been prepared just before measurements. Two millilitre of the extract with different concentrations was mixed with 2 mL of 0.004% methanol solution. The samples were kept in dark room for 15 min, and then the absorbance of the solution resulted was measured at a wavelength of 517 nm. Blank sample contained 2 mL of methanol and 2 mL of DPPH solution. The experiment was conducted in triplicate. The antioxidant activity was calculated as a percentage of the radical scavenging activity [12]. Finally, the concentration of sample needed to inhibit 50% of radical scavenging activity (in mg·mL⁻¹) was appointed and demonstrated as IC₅₀ value [13].

Oxidative stability. The oxidative stability measurement was performed using a Rancimat instrument (Metrohm, Herisau, Switzerland) by heating 3 g of sample at a temperature of 110°C and the air flow rate of 20 L·h⁻¹.

Particle size distribution. The mean particle size of the microcapsules was determined by dynamic light scattering technique at ambient temperature (Nano

Table 1 Kolompeh formulations

Ingredients	Samples				
	with EBCE	with BCE	with BCP	FBC	Control
Wheat flour, g	1000	1000	1000	1000	1000
Vegetable oil (combination of hydrogenated soybean and palm oil), g	–	–	–	–	500
Sesame oil, g	500	500	500	500	–
Date, g	1000	1000	1000	1000	1000
<i>Saccharomyces cerevisiae</i> , %	3	3	3	3	3
Flavouring ingredients, g	30	30	30	30	40
EBCE, %	2.5	–	–	–	–
BCE, %	–	0.25	–	–	–
BCP, %	–	–	0.4	–	–

EBCE is encapsulated black caraway extract

BCE is black caraway extract

BCP is black caraway powder

FBC is without (free) black caraway

Particle Analyzer Malvern 2000, Worcestershire, UK). In order to measure the particle size of the produced powder, a small quantity of powder was dissolved in 2-propanol, and then a few drops were added to the water containing reservoir of the apparatus [14].

Morphology. The morphological characteristics of encapsulated black caraway extract were determined by optical microscopy (Olympus BX51, Japan).

Fatty acid compositions. Fatty acid analysis of kolompeh samples was performed using the Alavi and Golmakani method [15]. First, fatty acids were converted to fatty acid methyl esters by shaking 60 mg oil with a mixture of 3 mL of hexane and 0.3 mL of 2 mol·L⁻¹ methanolic potassium hydroxide. Then, fatty acids were analysed by gas chromatography (GC) using a SP-3420 gas chromatograph (Beijing, China) coupled to a flame ionisation detector (FID) and a BPX-70 fused silica capillary column (30 m × 0.25 mm; 0.25 μm film thickness). N₂ with the split ratio of 1:10 was used as carrier gas. The temperature of the injector and the detector was 250 and 300°C, respectively. The oven temperature was increased from 140 to 200°C as follows: the temperature of 140°C was maintained for 5 min, then it was increased to 180°C by 20°C/min and remained constant for 9 min, and, finally, the temperature was increased to 200°C by 20°C/min and maintained for 3 min. Fatty acids were identified by comparing their retention times with standard values. The results were expressed as percentage of relative peak area.

Fourier transform infrared spectrometry (FTIR). FTIR spectroscopy was performed to analyse functional groups and to provide an insight into the structural characteristics of the samples. The spectrum was recorded on a Perkin-Elmer Spectrum RXI spectrophotometer (USA). All spectra were recorded at a wavelength of 4000–400 cm⁻¹.

Texture profile analysis. A CT3 4500 texture analyser (Brookfield, USA) was used to determine hardness of samples. An aluminum TA25/1000 probe

was used. The samples were compressed twice (TPA test). The probe speed was considered in a compression condition of 0.5 mm·s⁻¹ and a cavity depth of 5 mm. The experiments were carried out in triplicate at 25°C [16].

Colour analysis. The colour analysis was performed using a Hunter Lab model Colorflex colorimeter (USA). Lightness (L*), redness (a*), and yellowness (b*) colour parameters of kolompeh samples were obtained using Photoshop software (CS3) [17].

Sensory assessment. Sensory evaluation of kolompeh was conducted by thirty trained panelists with the help of a 5-point hedonic scale (5 = like extremely, 1 = dislike extremely), following the method described by Carpenter [18]. Such quality attributes as colour, aroma, flavour, tenderness, and overall acceptability were evaluated. The panelists were then served with pieces of kolompeh in individual booths under white fluorescent light, together with cold water to clean the palate between samples. The descriptors rated from 1, the lowest score, and 5, the highest one.

Statistical analysis. The data were analysed using analysis of variance (ANOVA) at $P < 0.05$. Duncan's Multiple Range test was conducted by SAS software (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Antioxidant activity. According to the data, IC₅₀, or the inhibition concentration of 50% of the DPPH free radical activity of black caraway extract, was 124.10 μg·mL⁻¹, which was much higher than that of TBHQ.

Various studies had been investigated the antioxidant activity of black caraway extract. Nickavar *et al.* investigated the antioxidant properties of alcoholic extracts of seven medicinal plants belonging to *Umbelliferae* family, including black caraway [19]. The results showed that this species had the IC₅₀ value of 149.9 μg·mL⁻¹, which was more than that in the present study. Another research group, Sourì *et al.*, observed the IC₅₀ values for black caraway extract to be 82.25 μg·mL⁻¹ [20]. Also, 120.43 μg·mL⁻¹ was reported by Kamkar *et al.* [6].

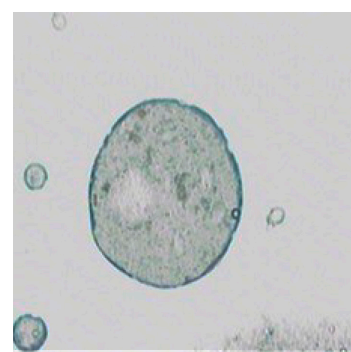
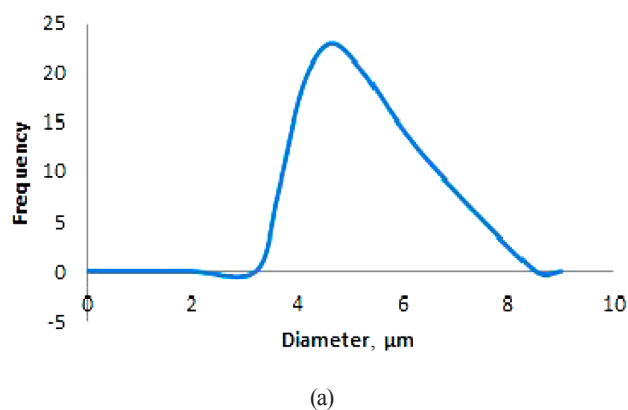


Figure 1 Initial droplet size distribution of emulsion (a), and optical microscopy image (400×) and surface morphology of EBCE microcapsules (b)

The differences observed in the antioxidant activity of black caraway in different studies could be due to the differences in the composition of these plants. Additionally, important factors are genetics, weather, harvest season, the type of solvent used for extraction, etc. Further, there is a direct relationship between the phenol content and the antioxidant activity of medicinal plants [13].

Oxidative stability. According to the results, the induction time of black caraway encapsulated extract, black caraway extract, and black caraway powder were 24.37, 23.15, and 21.88, respectively. The kolompeh containing encapsulated extract showed better oxidative stability compared to other treatments. The high oxidative stability of samples was attributed to the antioxidant activity of black caraway extract. The higher oxidation stability of encapsulated extract showed the protective influence on the encapsulation process [21]. Though, it should be taken into consideration that canola oil is exposed to oxidation because of a high amount of unsaturated fatty acids in their composition [22].

Particle size distribution. Figure 1 demonstrates the particle size distribution of microencapsulated black caraway extract at different frequencies.

According to Fig. 1, the maximum and minimal particle sizes were 3.20 and 8.51 μm , respectively. A few investigations had been carried out in the field of canola oil as wall material of microencapsulated particles. Abraham *et al.* observed a lower particle size of emulsion based on canola oil, compared with this study ($> 1\mu\text{m}$) [23]. Mohammadi *et al.* and Davidov-Pardo *et al.* used soybean oil, phosphatidylcholine/cholesterol, soy lecithin, and grape seed oil with orange oil to encapsulate olive leaf extract, *Myrtus communis* extract, polyphenolic extract of grape seed, and resveratrol, respectively [24, 25]. According to their results, particle size was also lower than that in our research ($> 0.5\mu\text{m}$). This difference might be due to the type and duration of encapsulation, as well as due to the rate of homogenisation, which determines particles size.

Optical microscopy. The structural characteristics of the microcapsules were depicted by optical microscope. The morphology of a microcapsule of encapsulated black caraway extract is illustrated in Fig. 1. The microcapsule had global and monotonous appearance with no aggregation. This observation was in agreement with Abraham *et al.* [23]. However, a low surfactant-to-emulsion ratio plays an important role in smoothly surface of particles, as was observed in resveratrol encapsulated with grape seed oil and orange oil [25]. Bylaitė *et al.* investigated the encapsulation properties of caraway essential oil by spray drying [26]. They used whey protein and maltodextrin as a wall material and observed some holes on surface of the sample encapsulated with whey protein concentrate. They suggested that whey protein concentrate had an inverse effect on surface dents; on the other hand, skimmed milk powder smoothes out wrinkles.

FTIR. Figure 2 plots FTIR spectra of black caraway extract and encapsulated black caraway extract at 400–4000 cm^{-1} .

According to the FTIR spectra analysis (Figs. 2a and 2b), both BCE and EBCE demonstrated bands at 3400 and 3427 cm^{-1} , which are assigned to vibration of O-H in the sugar units. The bands ranged from 3200 to 2800 cm^{-1} (3009, 2926, 2925, 2855 cm^{-1}) indicated the stretching hydrogen bands in C-H, and a broad band at 1746 cm^{-1} exhibited the C=O stretching of the ester carbonyl functional group [27]. This region is related to the triglycerides absorption bands [28]. A new band at 1608 cm^{-1} was found in the encapsulated extract, suggesting intermolecular interactions between C=C and the hydrocarbon chain of unsaturated fatty acid segments such as C18:1, C18:2 and C18:3 in canola oil [29].

We also recorded the other characteristic bands, such as 1461 and 1408 cm^{-1} (bending vibration of CH_2 and CH_3 aliphatic groups), as well as 1261, 1239, 1162, 1119, 1097, and 1053 cm^{-1} (stretching vibration of the C-O ester groups). They are in agreement with the results of Waterhouse *et al.* [30]. The last finger print region of FTIR spectra between 888 and 723 cm^{-1} wavelength frequencies was ascribed to the CH_2 rocking vibration and the out-of-plane vibration of *cis*-disubstituted olefins [28].

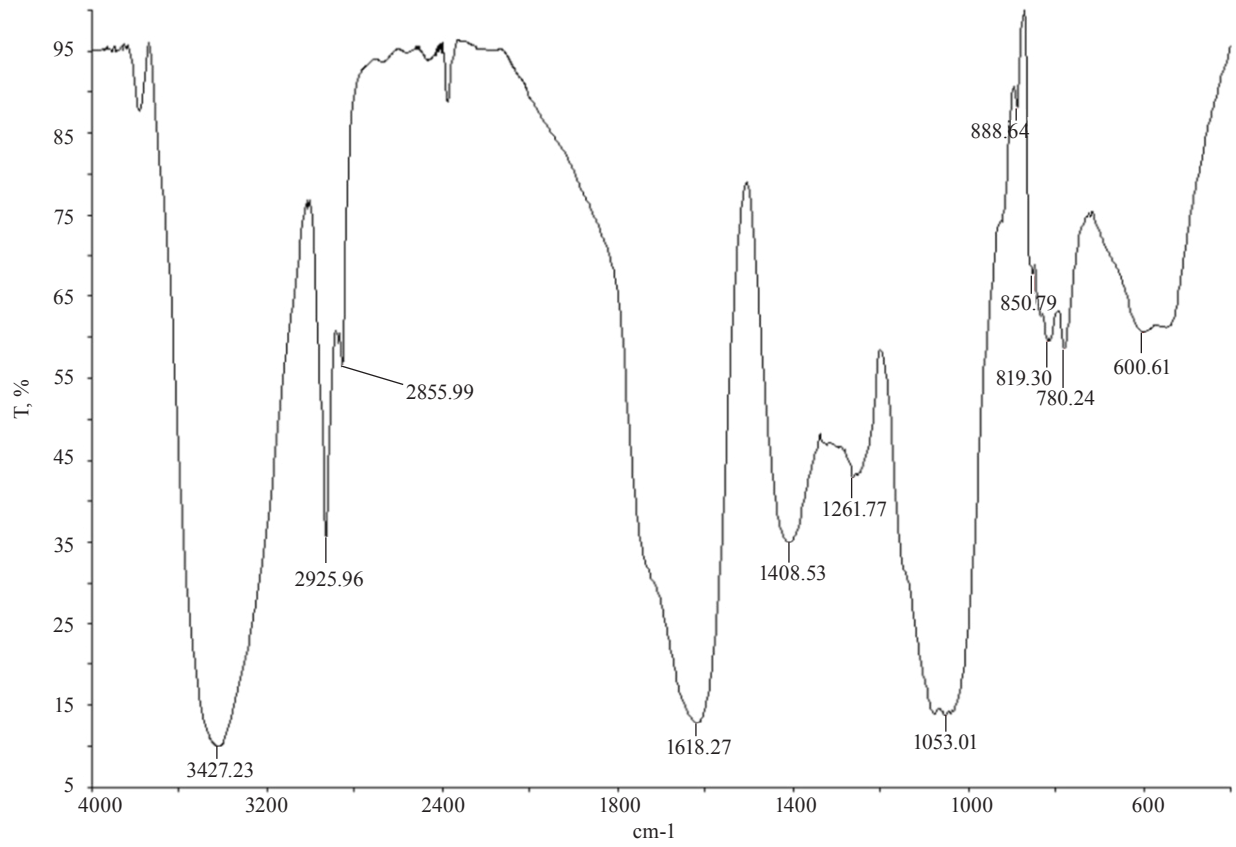
Overall, both samples displayed similarity in spectra. However, there were some differences between two spectra with sharp peaks at a wavenumber of 1200–1000 cm^{-1} and small absorption bands at around 850–400 cm^{-1} . They are associated to the intermolecular bonding of functional groups in polysaccharides [31].

Fatty acid compositions. Fatty acid composition of kolompeh samples is presented in Table 2.

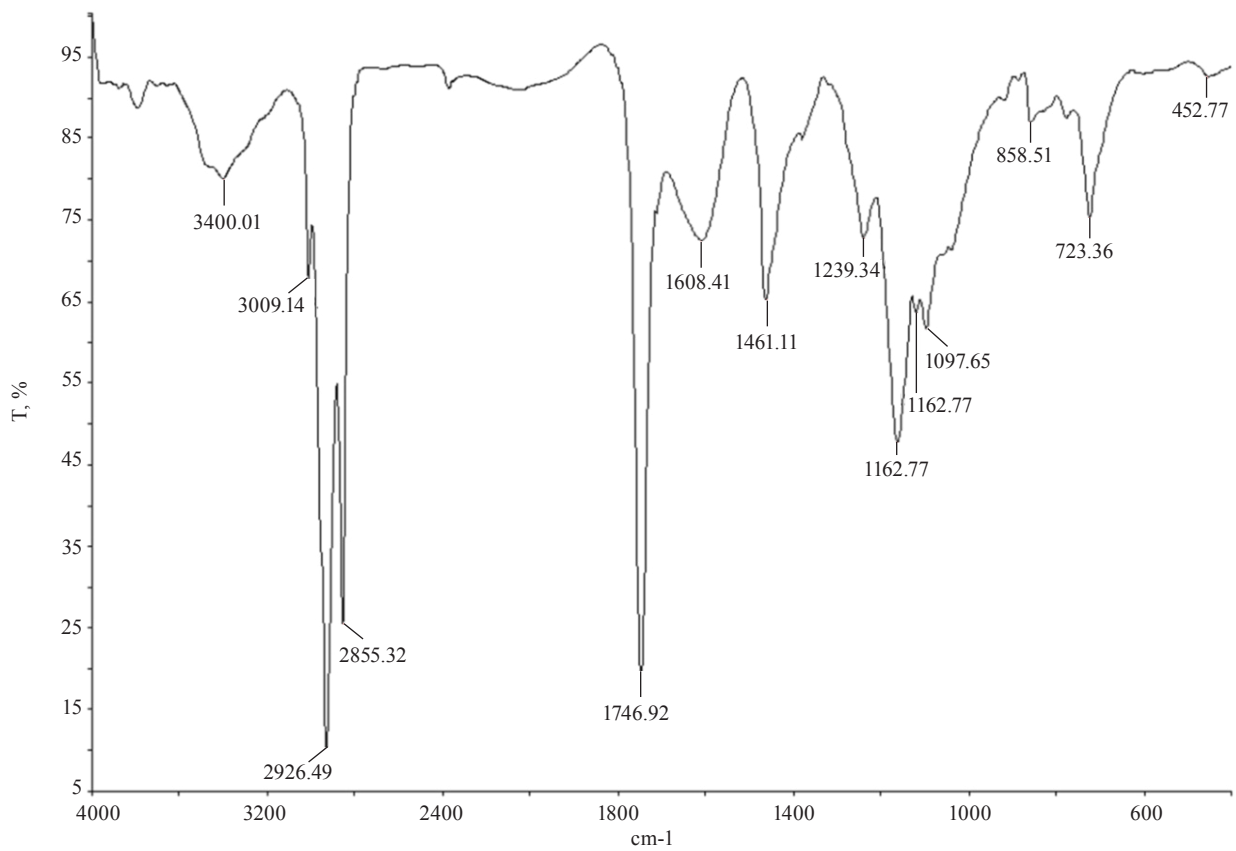
According to the GC fatty acids profile, linoleic and oleic acids were detected as the main fatty acids in kolompeh with the extracts. The product with black caraway powder also was rich in unsaturated fatty acids, with a high amount of linoleic acid (44.15%). Similar results were observed in the sample with no black caraway, with linoleic and oleic acid content of 44.86 and 37.32%, respectively. As Egorova *et al.* reported, linoleic acid is the most important fatty acid of caraway [32].

In the control sample, the main saturated and unsaturated fatty acids were represented by palmitic acid (35.45%) and oleic acid (37.34%), while linolenic acid was found at low concentrations (19%). Further, the analysis of fatty acid profile showed lack of lauric and palmitoleic acids in kolompeh containing black caraway extract, which is in accordance with the results of Laribi *et al.* [33].

In addition, a trace of lauric acid was found in the encapsulated extract sample, which may be due to petroselinic acid contained in some types of caraway seed oil. Petroselinic acid is a main component for oleochemical processes that converts easily into lauric and adipic acid [34]. All samples were rich in unsaturated fatty acids, compared to the saturated



(a)



(b)

Figure 2 Fourier transform infrared spectra of BCE (a) and EBCE (b)

Table 2 Fatty acid composition of kolompeh samples

Fatty acid, %	Samples				
	with EBCE	with BCE	with BCP	FBC	Control
Lauric acid (C12:0)	1.77	–	2.31	–	–
Myristic acid (C14:0)	2.36	2.77	0.39	1.47	1.24
Palmitic acid (C16:0)	11.12	10.73	11.58	11.64	35.45
Palmitoleic acid (C16:1)	0.18	–	–	–	–
Stearic acid (C18:0)	3.98	4.04	3.15	4.13	8.34
Oleic acid (C18:1)	36.13	37.03	37.82	37.32	37.34
Linoleic acid (C18:2)	43.38	44.99	44.15	44.86	16.76
Linolenic acid (C18:3)	0.29	0.36	0.40	0.12	0.19
Arachidonic acid (C20:0)	0.54	0.10	0.10	0.17	0.30
Behenic acid (C22:0)	0.24	0.08	0.08	0.30	0.38

EBCE is encapsulated black caraway extract

BCE is black caraway extract

BCP is black caraway powder

FBC is without (free) black caraway

analogues, which is related to sesame oil in their composition. Sesame seed oil belongs to the oleic–linoleic acid group [35]. Thus, as expected, oleic and linoleic acids were prevalent fatty acids in the kolompeh samples containing sesame oil.

Arachidonic, stearic and behenic acids were also found in trace amounts in the kolompeh containing black caraway extract and powder, which is in agreement with Nzikou *et al.* [36]. However, the samples with sesame oil were characterised by a low content of palmitic acid compared to the control.

Hardness. Figure 3 demonstrates the hardness of the samples during storage.

The results illustrated that the hardness of the products under study was decreasing during storage, except for kolompeh without black caraway, which had no significant differences in hardness. The highest and lowest hardness by the end of storage had the samples with the powder and encapsulated extract, respectively. All the samples, excluding the kolompeh with the powder, displayed lower hardness than the control. This phenomena may be related to the high density of black caraway powder [2].

In spite of the fact that the use of plant extracts in kolompeh still has not been investigated, there are data about increasing hardness of samples during storage. Budryn *et al.* mentioned that covalent interaction of polyphenols and proteins resulted in an enhancement in hardness, which was contrary to the results of this study [37]. To our opinion, there are two causes for this.

First, the presence of mono and di-glycerides in sesame oil, with their emulsifying properties, caused a reduction in the hardness of the product. Thus, they are able to make starch complex and delay staling [38]. The second cause for enhancing of hardness is related to the presence of saccharides limiting interactions between polyphenols and proteins [37]. The reducing of hardness in the kolompeh with the extract can be explained by rivalry between fibres and polyphenols and wheat starch in the dough. In addition, the sample with EBCE was softer than that with BCE because of encapsulation, which protected the sample against the direct exposure of polyphenols and starch.

Colour. Table 3 illustrates the colour properties of kolompeh samples during storage.

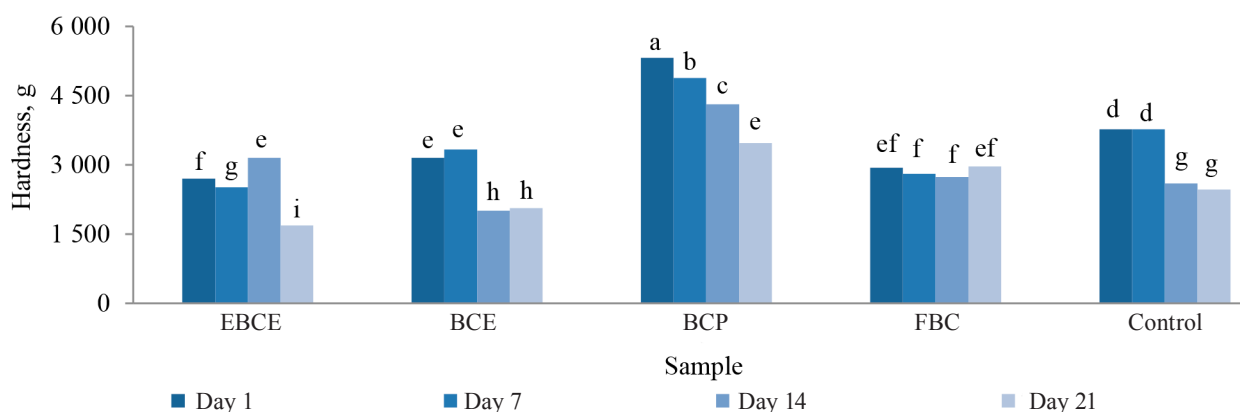
**Figure 3** Hardness of kolompeh samples during storage

Table 3 Colour characteristics of kolompeh samples on day 1, 7, 14, and 21 of storage

Sample	Colour parameter	1	7	14	21
EBCE	L*	43.3 ± 52.1 ^a	53.2 ± 42.2 ^a	49.2 ± 44.9 ^{ab}	48.3 ± 1.3 ^a
	a*	-7.0 ± 46.6 ^c	2.0 ± 88.5 ^a	-0.0 ± 0.1 ^b	5.0 ± 22.8 ^{ab}
	b*	24.1 ± 23.9 ^a	27.2 ± 44.3 ^{ab}	33.0 ± 11.8 ^b	35.1 ± 11.1 ^a
BCE	L*	57.3 ± 88.8 ^a	65.1 ± 22.5 ^a	71.4 ± 22.3 ^a	63.3 ± 88.6 ^a
	a*	-3.0 ± 41.8 ^a	2.1 ± 88.1 ^a	1.0 ± 66.3 ^{ab}	5.0 ± 88.6 ^a
	b*	26.2 ± 36.2 ^a	31.1 ± 55.8 ^{ab}	41.2 ± 11.3 ^a	35.2 ± 11.5 ^a
BCP	L*	58.3 ± 34.8 ^a	58.3 ± 62.3 ^a	55.4 ± 87.8 ^b	45.1 ± 23.9 ^b
	a*	-5.0 ± 74.8 ^b	-3.0 ± 33.5 ^b	2.0 ± 55.3 ^a	1.0 ± 44.4 ^b
	b*	26.2 ± 30.6 ^a	24.1 ± 44.3 ^b	37.1 ± 66.5 ^{ab}	32.2 ± 21.1 ^a
FBC	L*	60.1 ± 94.1 ^a	74.4 ± 22.3 ^a	71.2 ± 88.8 ^{ab}	71.2 ± 88.5 ^a
	a*	-5.1 ± 56.2 ^b	-1.0 ± 77.1 ^b	0.0 ± 1.1 ^{ab}	1.0 ± 33.4 ^b
	b*	26.2 ± 19.3 ^a	30.1 ± 33.2 ^{ab}	32.0 ± 44.9 ^b	34.1 ± 33.5 ^a
Control	L*	43.1 ± 82.4 ^a	43.2 ± 44.1 ^a	43.1 ± 11.5 ^{ab}	45.0 ± 43.9 ^b
	a*	-8.0 ± 19.5 ^c	2.0 ± 33.7 ^a	0.0 ± 0.1 ^b	5.1 ± 11.8 ^a
	b*	24.0 ± 9.7 ^a	29.1 ± 44.1 ^{ab}	34.0 ± 22.1 ^b	33.1 ± 44.2 ^a

*Means with different letters are significantly different ($P < 0.05$). Each value is expressed as Mean ± SD. Test was conducted in triplicate

Colorimetric analysis showed that the L* value of all the samples, except BCP, increased during the storage period (21 days). The encapsulated sample had a lower lightness compared to the others, which might be probably due to a more intense yellow colour of canola oil used as a wall material in the encapsulation process [39]. In addition, as expected, the sample without caraway (FBC) was lighter than the others. The differences were probably due to the presence of black caraway (extract or powder) in kolompeh that impacted on its lightness.

On day 14, the kolompeh with BCE had the highest L* value, while EBCE, BCE and control samples exhibited a reduction of redness. The similar results were obtained in bread fortified by cumine seeds powder by Sayed Ahmad *et al.*, who found that the lightness of bread depended on the amount of cumin [40]. The increasing in the yellowness could be related to reaction between amino acids (flour) and sugars (date), known as Maillard reaction [40].

Sensory assessment. Table 4 represents the sensory attributes of the kolompeh samples on day 1, 7, 14 and 21 of storage.

We evaluated such sensory characteristics as colour, aroma, flavour, tenderness, and general acceptability. On day 1, the kolompeh with black caraway powder had the lowest score in colour among the other samples, however no significant differences were observed between them ($P > 0.05$). The addition of black caraway (extract and powder) affected adversely the flavour, aroma, and tenderness of kolompeh.

According to the results, the sensory attributes of all samples reduced during storage. As for the kolompeh with encapsulated extract, its colour, aroma and flavour remained unchanged compared to day 1 of storage, which is a positive point of the protective effect of encapsulation. The aroma of the samples containing extract or powder of black caraway decreased by the end

of storage, which was due to the loss of some volatile compounds.

In addition, the results revealed that the tenderness of kolompeh with encapsulated extract of black caraway did not change significantly during storage, and was similar to that of the control. However, considerable changes in the texture of BCE, BCP and FBC samples were observed ($P < 0.05$).

Table 4 Sensory evaluation of kolompeh samples during storage

Sensory attribute	Time, days	Sample				
		with EBCE	with BCE	with BCP	FBC	Control
Colour	1	4.6 ^a	4.0 ^{ab}	3.6 ^b	4.4 ^a	4.2 ^a
	7	4.1 ^a	2.2 ^b	2.6 ^b	2.4 ^a	4.0 ^a
	14	3.8 ^a	2.2 ^c	2.6 ^{bc}	2.8 ^b	3.8 ^a
	21	3.7 ^a	1.6 ^{cd}	2.0 ^c	2.4 ^b	3.6 ^a
Aroma	1	4.0 ^{ab}	3.6 ^{ab}	3.4 ^b	3.8 ^{ab}	4.0 ^a
	7	4.0 ^a	2.4 ^b	2.4 ^b	2.2 ^b	4.2 ^a
	14	3.7 ^a	2.4 ^c	3.0 ^b	3.0 ^b	3.6 ^a
	21	3.6 ^a	2.2 ^c	2.0 ^c	2.8 ^b	3.6 ^a
Flavour	1	4.4 ^a	3.0 ^b	3.0 ^b	4.0 ^a	4.0 ^a
	7	4.0 ^a	2.2 ^b	2.2 ^b	2.2 ^b	4.4 ^a
	14	3.9 ^a	2.2 ^b	2.6 ^b	2.4 ^b	3.8 ^a
	21	3.8 ^a	2.2 ^{cd}	2.6 ^{bc}	3.0 ^b	3.6 ^a
Tenderness	1	4.3 ^a	3.2 ^b	3.4 ^b	4.2 ^a	4.4 ^a
	7	4.0 ^a	2.0 ^b	2.0 ^b	2.4 ^a	4.0 ^a
	14	3.8 ^a	2.4 ^b	2.8 ^b	2.8 ^b	3.8 ^a
	21	3.8 ^a	2.0 ^c	2.2 ^{bc}	2.6 ^b	3.8 ^a
Overall acceptability	1	4.1 ^{ab}	3.4 ^c	3.6 ^{bc}	4.0 ^{ab}	4.2 ^a
	7	4.1 ^a	2.0 ^b	2.2 ^b	2.4 ^b	4.4 ^a
	14	4.0 ^a	2.4 ^{bc}	2.6 ^b	2.6 ^b	4.0 ^a
	21	3.7 ^a	1.8 ^c	1.8 ^c	2.6 ^b	3.6 ^a

*Means with different letters are significantly different ($P < 0.05$). Each value is expressed as Mean ± SD. Test was conducted in triplicate

Overall, the sample with encapsulated extract of black caraway demonstrated a higher score in the sensory parameters. Our results were in agreement with those of Sayed Ahmad *et al.* who fortified protein bread with cumin and caraway powder [40]. Their study showed the improvement of sensory properties in the bread, however, bitter aftertaste was felt, which was dependent on an amount of cumin and caraway powder.

CONCLUSION

In this study, we evaluated the effect of sesame oil and different forms of black caraway extract on the physicochemical and sensory properties of kolompeh. The results showed that caraway had IC_{50} of $124.1 \mu\text{g}\cdot\text{mL}^{-1}$. Thus, the kolompeh with encapsulated black caraway extract showed the high oxidative stability. In addition, the EBCE microcapsule had global and monotonous morphology, and FTIR spectroscopy confirmed the well encapsulated black caraway extract.

The GC results indicated that the kolompeh samples with sesame oil were rich in unsaturated fatty acids. Oleic and linoleic acid were identified as the major fatty acid in their fatty acid composition. Sesame oil and encapsulation of black caraway had a great influence on the hardness of the samples containing encapsulated extract, which had the lowest hardness among all treatments.

Furthermore, the kolompeh with black caraway encapsulated extract had lower lightness compared

to the other samples, probably due to more intense yellow colour of canola oil. However, the sample without caraway was lighter than the others, which was attributed to black caraway colour. In addition, the encapsulation protected the colour, aroma, and flavour of black caraway extract.

According to the sensory assessment, the kolompeh with encapsulated extract was preferred by panelists. Nevertheless, the addition of the extract and powder of black caraway influenced adversely the flavour and aroma of kolompeh. Overall, this research revealed that black caraway extract had a considerable potential for using it as an ingredient and thus for improving the physicochemical and sensory properties of kolompeh.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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