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Production of low-calorie shortening from high internal phase emulsion gel and its application in the food system

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ABSTRACT

The current research was conducted to produce a gel emulsion with reduced saturated and Trans fatty acids that can be used as shortening. Hydrocolloids of guar gum, κ-carrageenan, CMC, and maltodextrin were used to prepare gel emulsion. For emulsion stability, PGPR (1%) was used as an emulsifier. In the first phase of the research, for the production of gel emulsion using guar gum from 0 to 0.25%, κ-carrageenan from 0 to 2%, CMC from 0 to 3%, and maltodextrin from 0 to 20%, different formulations were determined by Design Expert software and by Response surface method and optimal design, and samples formulations were produced. Sensory and hardness evaluation tests were performed and regression models for predicting hardness (sensory) responses, overall acceptance, and hardness were presented and the optimal formulation was determined. In the second phase of the research, the optimal formulation of gel emulsion at the levels of 25, 50, 75, and 100% was used to produce biscuits, and the physicochemical, sensory, and peroxide value were investigated. The results showed that by replacing 50% of shortening with biscuit gel emulsion with less amount of fat and saturated fatty acid and without Trans and in terms of physicochemical and sensory properties, it is obtained similar to the sample containing shortening.

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1- Introduction

Shortening is one of the most widely used raw materials in confectionery and bakery industries. Shortenings have high amounts of saturated and trans fatty acids, and consuming high amounts of these types of fatty acids is harmful to health and increases the risk of chronic diseases, including heart disease [1]. According to the recommendation of the Food and Agriculture Organization of the FAO[1] and the World Health Organization (WHO).[2] The consumption of saturated and trans fatty acids should reach less than 10% and less than 1%, respectively [2 and 3]; Therefore, it is very important to produce fat substitutes with minimum saturated fatty acids and no trans fatty acids. Due to the technological role and rheological characteristics of solid fats, their complete removal and replacement with liquid oils is very difficult and requires structural modification [4]. One of the new technologies for texture modification is the use of the process of gelling emulsions with liquid oils [5]. Emulsion gels are formed through the gelation of the continuous phase to a certain extent [6]. Torres et al. (2017) prepared emulsion gels using sunflower oil, starch and octenyl succinic anhydride modified starch. Their results showed that emulsion droplets stabilized with octenyl succinic anhydride-modified starch can act as a gelling agent [7]. In general, emulsion gels prepared from a polysaccharide often have a weak gel structure and low water holding capacity; While the use of two or a combination of polysaccharides increases the performance of the gel. The use of gel emulsion in confectionery and bakery products leads to a reduction in oil migration, a reduction in saturated and trans fatty acids, and the stability of emulsions [8]. Pandey et al. (2016) prepared a gel emulsion for drug delivery using xanthan and guar gums as well as sorbitan monostearate as an emulsifier [9]. Patel et al. (2014), using carrageenan, xanthan and locust bean gum, prepared a dense gel emulsion that kept the continuous phase of oil between them and made the system stable [10]. Gutierrez et al. (2023) examined the sensory characteristics and shelf life of cookies produced with alginate gel-olive oil emulsion over 21 days and the results showed a 40% reduction in fat and 70% reduction in saturation compared to the control sample. [11]. Wang et al. (2023), investigated the textural and rheological properties of oleogel based on hydroxypropylmethylcellulose and methylcellulose and showed that the emulsion-based oleogel effectively prevented the accumulation of oil droplets [12]. By replacing part of the vegetable oil in margarine with 20% potato maltodextrin and waxy corn maltodextrin gels, Hadnado et al. (2011) showed that replacing 15% of the fat in margarine with maltodextrin gel had the same performance characteristics as the control sample. The results of this research showed that the replacement of fat by maltodextrin gels increases the rheological properties including the degree of thixotropy, yield stress, apparent viscosity and elastic modulus, as well as increasing tissue stiffness [13]. Replacement of shortening with gel containing canola oil in cookies was investigated by Zhang et al. (2015). In this research, Candelilla wax was used as a gelling agent in two concentrations of 3 and

1- Food and Agriculture Organization

2-World Health Organization

6%. The results showed that the amount of unsaturated fatty acids in the formulation containing gel increased compared to the formulation containing shortening, and the sensory and spreadability characteristics were similar to the control sample [14]. Martinez et al. (2015) substituted sunflower oil-cellulose ether emulsion for butter in muffins and showed that dough containing butter and dough containing gel emulsion have different viscoelastic properties. The acceptability of muffins containing gel emulsion was slightly lower due to the stiffness of the texture [15]. Giacomozzi et al. (2018) used oleogels containing monoglyceride and sunflower oil to replace margarine in muffins. The results showed that muffins containing oleogel showed more spreadability, higher specific volume and hardness similar to the control sample [16]. The purpose of this research is to produce a low-fat gel emulsion using guar sesame oil, κ-carrageenan, CMC and maltodextrin, as well as its use in biscuits as a healthier alternative (less saturated fat and no trans) for shortening.

2- Materials and methods

2-1- Materials

In this research, 4 hydrocolloids were used to gel the emulsion. Guar seed gum was obtained from Condio, Germany, κ-carrageenan gum was obtained from BASF, Germany, maltodextrin with C Sib brand, from Pars Sta (Tehran, Iran) and CMC from Sinochem, China. Sesame oil, smooth confectionary oil and flour used in preparing biscuits were purchased from local stores. To protect the oxidation of sesame oil, α-tocopherol (Sigma-Aldrich, USA) was used in the formulation. Lecithin emulsifier was obtained from Cargill, America, and other chemical materials and solutions were obtained from Merck, Germany.

2-2- Preparation of fat replacement gel emulsion samples

To prepare the gel emulsion, first the aqueous phase by dissolving guar gum (X_1): 0-25, κ-carrageenan (X_2): 2-0 ، CMC(X_3): 3-0 and maltodextrin (X_4): 0-20 (according to the formulation provided by the software), citric acid (0.01%), potassium sorbate (0.1%) and salt (0.1%) in water at temperature$^{C\circ}$ 60 and the oil phase by dissolving polyglycerol polyresinoleate emulsifier[3] (1 percent) in sesame oil (20 percent) at temperature$^{C\circ}$ 70-65 were prepared. To protect the oil from oxidation, the natural antioxidant α-tocopherol (0.05%) was used. Then, the water phase and the oil phase were mixed using a homemade mixer (Sunny, China) at a temperature of$^{C\circ}$ 60 were mixed. By cooling the sample, an oily gel emulsion was obtained and they were kept in the refrigerator until the tests were performed.

2-3- Biscuit production

Biscuits dough formulation was prepared using equal amounts of all raw materials and different amounts of oil, shortening and gel emulsion according to table 1, the dough was cut into 5 mm thick rectangular molds with dimensions of 45 x 60 mm and in Avon C^0 180 was baked for 20 minutes [17].

[3]3- PGPR: Poly Glycerol Poly Ricinoleate

Table 1 Biscuit formulation containing emulsion gels

Ingredients	control	oil	Emulsion gel			
			100%	75%	50%	25%
flour	45.45	45.45	45.45	45.45	45.45	45.45
shortening	19.69	-	-	4.92	9.84	14.77
oil	-	19.69	-	-	-	-
Emulsion gel	-	-	19.69	14.77	9.84	4.92
sugar	15.15	15.15	15.15	15.15	15.15	15.15
egg	18.18	18.18	18.18	18.18	18.18	18.18
improver	1.23	1.23	1.23	1.23	1.23	1.23
salt	0.3	0.3	0.3	0.3	0.3	0.3

2-4- Features of sesame oil

The characteristics of sesame oil were determined according to standard No. 1752 (Edible oils and fats - refined sesame oil - characteristics and test methods) [18].

5-2- Examining the characteristics of gel emulsion

Sensory evaluation was done according to the method of Yilmaz et al. (2015) and texture analysis was done according to the method of Lemur et al. (2010) [19, 20].

6-2- Investigating the physical and chemical characteristics of biscuits

The prepared biscuits were kept for six months to evaluate the peroxide index. The fat percentage of the samples according to Iran National Standard No. 37 (biscuits, characteristics and test methods) [21], water activity by the Novasina Sprint device, Switzerland), moisture, tissue stiffness by the three-point bending test, the color of the biscuits using the Huntlab device (VA) .Colorflex, 0.45, USA) and sensory test was measured by the method of Soudah et al. (2007) [22].

The fatty acid profile of the samples was determined by gas chromatography (Agilant, 7890A, USA) equipped with a flame ionization detector. Sample preparation was done according to Iranian national standard number 2-13126 [23].

2-7-Statistical analysis

In the first phase, the goal was to optimize the low-fat gel emulsion formulation using guar gum, κ-carrageenan gum, CMC and maltodextrin with the ability to be used as a shortening substitute. The maximum limit for each of the hydrocolloids was determined by the pretreatments. Then using the optimal design[4] with four guar independent variables (X_1): 0-25, κ-carrageenan (X_2): 2-0 ،CMC(X_3): 3-0 and maltodextrin (X_4): 0-20 different formulations (25 combinations with 5 repetitions) were prepared. Statistical analysis (ANOVA) was performed using Design of Experiment software. The appropriateness of the model using the

[4]- I-Optimal

coefficient of explanation R^2, lack of fit and number*p* The result was analyzed by ANOVA. The parameters are statistically significant at the 5% probability level Investigation and optimal formulation was determined and used as an alternative to shortening in biscuit formulation. All tests were performed with three repetitions. Data analysis was done in the form of completely randomized design and in the sensory analysis section in the form of completely randomized blocks. The data obtained from the tests were compared with the LSD test after analysis of variance. SAS software (Ver. 9.13) was used for data analysis.

3. Results and Discussion

3-1- The effect of different hydrocolloids on sensory stiffness

Stiffness is one of the important features for shortening and similar products; which can be evaluated by sensory methods as well as devices [24]. Sensory firmness of gel products is defined as the force required to change the shape of the product [19]. According to the results of variance analysis; The estimated regression model for significant sensory stiffness (>0.05).*p*) Was. Significant factors (>0.05).*p*) regression analysis were chosen to write the reduced quadratic model for sensory stiffness, which is based on the coded values, in the form of the following equation:

$$y = 6.99 + 1.47x_1 .87x_2 + .02x_3 + 048x_4 + 0.58x_1 x_2 + 1.24x_1 x_3 - .23x_1 x_4 - 1. x_2 x_3 - 0.73x_2 x_4 - 0.64x_3 x_4 + 0.49x_1^2 - 0.62x_2^2 - 1.61x_3^2 - 0.81x_4^2$$

As seen in Figure 1, all hydrocolloids used have a significant effect (>0.05*p*) were on sensory hardness. Polysaccharides often cause emulsion stability by changing and increasing the viscosity of the aqueous phase [25]. Increasing the amount of hydrocolloid can increase the apparent viscosity, storage modulus and drop in oil-in-water emulsions [26]. The interaction effect of guar gum and κ-carrageenan as well as guar seed gum and CMC on stiffness is significant (<0.05*p*) and it was positive. The smooth regions of guar gum are able to bind to the helical regions of carrageenan and CMC and form strong and elastic gels, with less liquefaction during cooling [27, 28]. The interaction effect of maltodextrin with other gums on hardness is significant (>0.05).*p*) and it was negative.

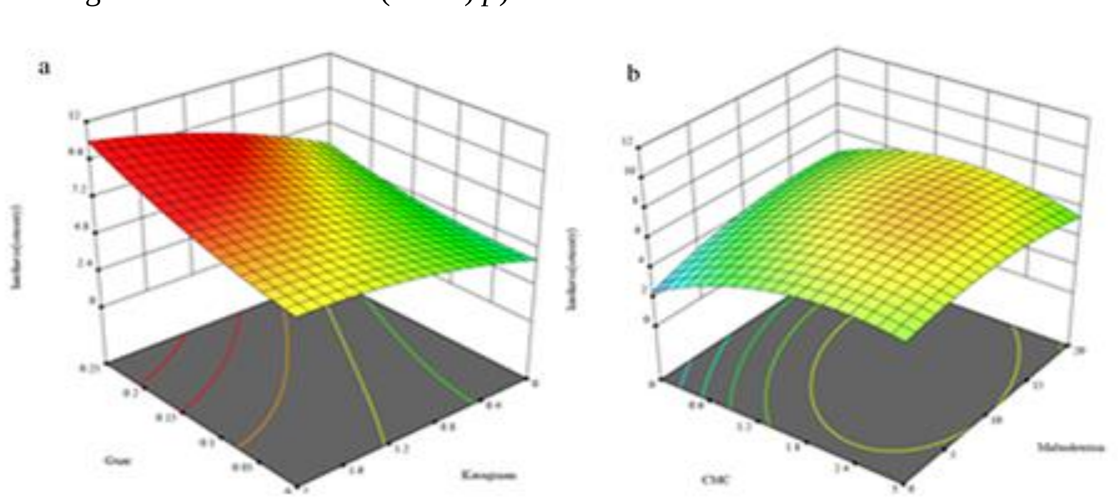

Fig 1. The change in hardness (sensory) of emulsion gel with (a) Guar and Karaginan (b) CMC and Maltodextrin

2-3- The effect of different hydrocolloids on the general acceptance of samples

The estimated equation for predicting the results of the overall acceptance of the samples by considering the significant factors (<0.05*p*) and based on the coded values are:

$$y = 5.93 - 0.66x_1 . 13x_2 + .87x_3 + 035x_4 - 1.49x_1 x_2 - 1.41x_1 x_3 - .78x_1 x_4 + 0. x_2 x_3 - 1.07x_2 x_4 + 0.23x_3 x_4 - 2.78x_1^2 - 0.12x_2^2 + 0.48x_3^2 - 0.18x_4^2$$

The results of the analysis showed that overall acceptance increased with the increase in the amount of κ-carrageenan, CMC and maltodextrin. While guar gum has a significant effect (>0.05).*p*) and it was negative on the general acceptance of the samples. Figure 2 shows that the maximum overall acceptance can be achieved with the minimum amount of maltodextrin and the maximum amount of κ-carrageenan.

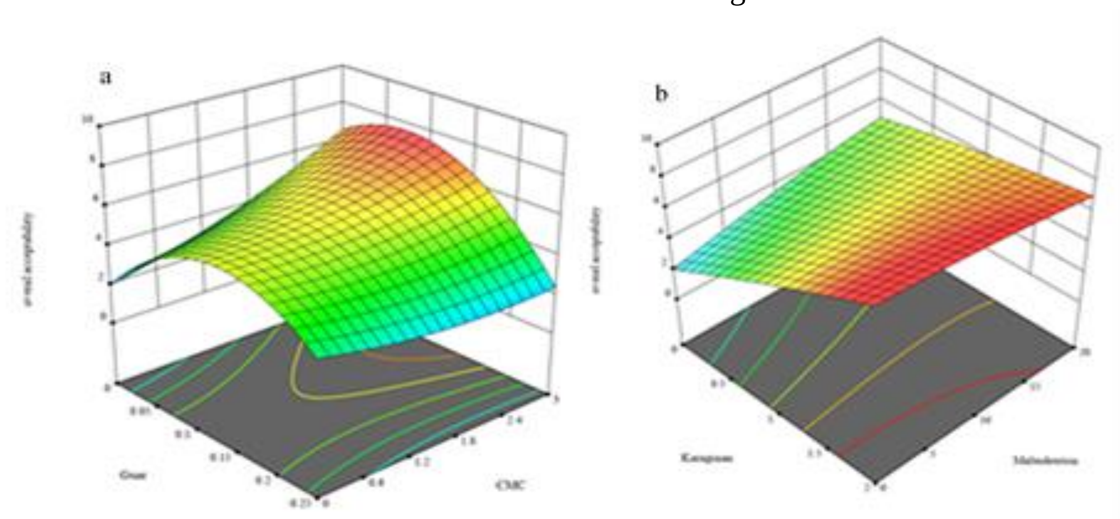

Fig 2. The change in overall acceptability of emulsion gel with (a) Guar and CMC (b) Karaginan and Maltodextrin

3-3- The effect of different hydrocolloids on device stiffness

The maximum force applied by the histometer device to compress the sample was considered as device stiffness. Estimated model for device stiffness considering significant factors (>0.05).*p*) and based on the coded values are:

$$y = 166.96 + 46.93x_1 + 71.10x_2 + 50.82x_3 + 17.06x_4 + 17.44x_1 x_2 + 35.53x_1 x_3 - 22.46x_1 x_4 - 27.51x_2 x_3 + 3.04x_2 x_4 + 1.56x_3 x_4 + 14.11x_1^2 - 16.97x_2^2 - 41.48x_3^2 - 15.48x_4^2$$

Device stiffness had a high positive correlation (0.94) with sensory stiffness responses. As seen; The mechanical stiffness of the samples was significantly (>0.05).*p*) increased linearly with increasing amounts of all hydrocolloids, which agreed with the results of sensory hardness. According to the combined effect of κ-carrageenan and CMC (Figure 3), the stiffness of the device was maximum in the maximum amount of κ-carrageenan (2%) and equal amount of CMC (2%). As the CMC value increased, the device stiffness decreased. The interaction effect of guar gum and maltodextrin is significant (>0.05).*p*) and it was negative.

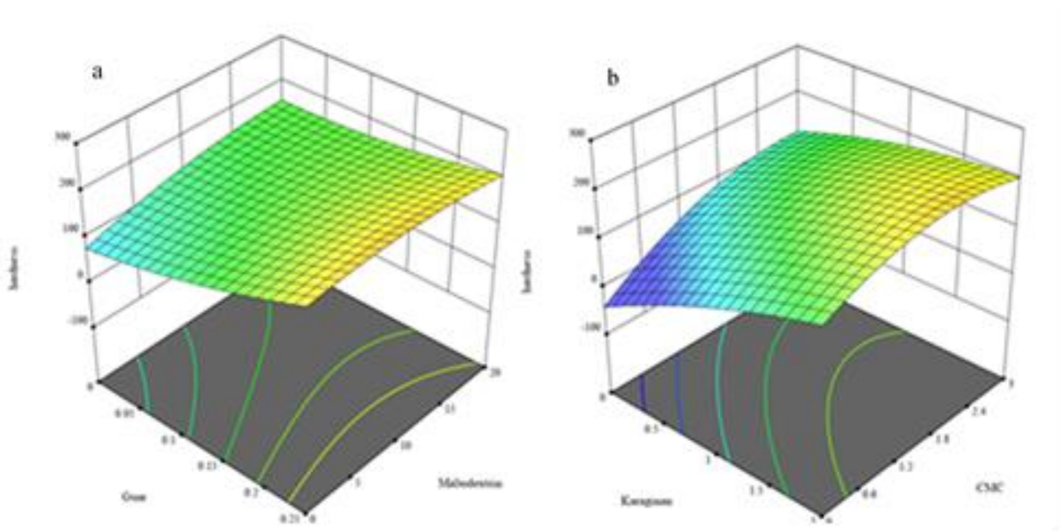

Fig 3. The change in hardness of emulsion gel with (a) Guar and Maltodextrin (b) Karaginan and CMC

The interaction effect of guar gum and κ-carrageenan as well as guar gum and CMC on stiffness is significant (<0.05*p*) and it was positive. Similar results have been reported for the synergistic effect of κ-carrageenan and xanthan, which ultimately leads to the formation of a stronger and more elastic gel [28, 29].

3-4- Model optimization and validation

In order to eliminate formulas with inappropriate stiffness (too soft or too stiff), the optimal range of sensory and device stiffness responses was determined based on samples with high overall acceptance, and this range was considered as a measure of the suitability of stiffness. After verifying the validity of the regression models and adjusting the desired parameters, the optimal gel emulsion formula includes 0.77% guar gum, 1.65% κ-carrageenan, 1.86% CMC and 14.89% maltodextrin, preparing and replacing shortening in biscuits. used.

5-3- Features of sesame oil

As can be seen in Table 2, the values obtained for the characteristics of sesame oil correspond to the relevant standards [18]. The amount of saturated and unsaturated fatty acids of the used sesame oil is 15.35 and 84.54, respectively (Table 3).

Table 2 Properties of sesame oil

	Result	**Limit**
Moisture (%)	**0.1**	**Max 0.1**
Peroxide	**1.51**	**Max 5**

value(eqo2/kg)		
Free fatty acid	**0.09**	**Max 0.1**
iodine index	**105**	**103-118**

Table 3 Sesame oil fatty acid profile

g/100g	**Fatty acid**
C12:0	**-**
C14:0	**0.17±0.01**
C16:0	**9.25±0.04**
C16:1	**0.32±0.03**
C17:0	**0.08±0.01**
C17:1	**0.05±0.03**
C18:0	**5.53±0.02**
C18:1	**41.21±0.04**
C18:2	**42.12±0.04**
C18:3	**0.47±0.01**
C20:0	**0.32±0.02**
C20:1	**0.37±0.05**
C22:0	**-**
Saturated fat	**15.35±0.03**
Unsaturated fat	**84.54±0.01**

6-3- Investigating the physicochemical characteristics of biscuits containing gel emulsion

Features of biscuits after baking include six formulations containing 100% sesame oil, containing 100% shortening, samples containing shortening and 25%, 50%, 75% and 100% gel emulsion. are (Table 4). The amount of fat, water activity, moisture, tissue firmness and color of the samples are shown in Table 4. The amount of fat in the samples containing gel emulsion has decreased compared to the sample containing shortening. This reduction was 5.5%, 8.3%, 10.5% and 12.2% in samples containing 25%, 50%, 75% and 100% shortening, respectively. The highest amount of water activity was observed in the sample containing shortening and there was a significant difference between the samples containing gel (<0.05).*p*) There was not. As the results show, samples containing oil and 100% gel emulsion have the highest strength and samples containing 25% gel emulsion. They had the lowest strength and the softest texture. In the study conducted by Jang et al. (2015), the amount of force required to break biscuits containing oleogel (candelilla wax as a gelling agent and sunflower oil as an oily phase) was investigated after baking during a bending test, and the results indicated a softer texture in The samples containing oleogel were shorter than the sample containing shortening [14]. As the results show, the sample containing shortening has the highest Indicator*L (light) and the sample containing oil have the lowest amount of this index. 100% samples Has the highest index b* (blue-yellow). The high index and more yellowness is due to the emulsion of the gels in these samples. In terms of index*a (green-red) also, 25% samples They have more redness than other samples. In the study conducted by Yilmaz and Ogutcho (2015), the color of biscuits containing shortening was compared with the color of biscuits containing oleogel (sunflower wax and hazelnut oil). The findings of these researchers also indicate that the brightness index is high and the index is low*b was in the sample containing shortening and the samples containing oleogels had more red color [30].

Table 4 Physicochemical characteristics of biscuits containing gel emulsion

Treatments	Fat (%)	a_{In}	Moisture (%)	Hardness(N)	color		
					L*	a*	b*
shortening	**18±0.05**	**0.355±0.01^a**	**9.61±0.01^a**	**13.05±0.01^d**	**71.8±0.04^a**	**9.77±0.02^d**	**29.85±0.05^f**
oil	**15±0.04**	**0.283±0.02^b**	**7.35±0.02^b**	**15.36±0.03^b**	**65.33±0.04$^{It is}$**	**5.51±0.01$^{It is}$**	**32.14±0.04$^{It is}$**
25% emulsion gel	**17±0.05**	**0.169±0.02^c**	**4.12±0.01^d**	**10.05±0.01^f**	**67.25±0.05^d**	**11.68±0.03^a**	**36.85±0.03^d**
50% emulgel	**16.5±0.04**	**0.168±0.03^{cd}**	**4.95±0.03^c**	**12.78±0.02$^{It is}$**	**68.12±0.03^c**	**10.21±0.04^b**	**38.23±0.05^c**
75% emulgel	**16.1±0.05**	**0.167±0.01^{cd}**	**4.93±0.02^c**	**14.15±0.01^c**	**68.18±0.02^b**	**10.19±0.05^b**	**39.22±0.02^b**
100% emulgel	**15.8±0.05**	**0.165±0.01^d**	**4.92±0.02^c**	**17.21±0.01^a**	**68.19±0.04^b**	**10.01±0.05^c**	**39.97±0.05^a**

Means within the same rows with different common letters differ significantly (P<0.05)

7-3- Investigating sensory characteristics of biscuits containing gel emulsion

As the results in Table 5 show, in terms of color, no significant difference was observed between the samples. (05/0 > *p*). In terms of texture, shortening sample, 25%

and 50% samples had the highest scores. In terms of overall acceptance, the shortening sample and the 50% sample showed the highest score. In the study conducted by Patel et al. (2014), oleogels containing shellac and canola oil replaced margarine in cakes. The findings of these researchers also showed that cakes containing oleogel have a significant difference in terms of sensory characteristics (<0.05).*p*) with cakes containing margarine did not [31].

Table 5 Sensory characteristics of biscuits containing gel emulsion

Treatment	color	Texture	Taste & flavor	Overall acceptance
shortening	**10.00 ± 0.05^{a}**	**9.64 ± 0.03^{b}**	**9.89 ± 0.04^{a}**	**10.00 ± 0.01^{a}**
oil	**9.84 ± 0.05^{ab}**	**8.12 ± 0.02^{c}**	**8.78 ± 0.04^{b}**	**9.02 ± 0.05^{d}**
25% emulsion gel	**9.84 ± 0.03^{ab}**	**9.83 ± 0.05^{a}**	**9.79 ± 0.01^{a}**	**9.12 ± 0.02^{c}**
50% emulgel	**9.77 ± 0.04^{b}**	**9.52 ± 0.02^{b}**	**8.62 ± 0.02^{b}**	**9.24 ± 0.02^{b}**
75% emulgel	**10.00 ± 0.05^{a}**	**9.31 ± 0.03^{bc}**	**9.22 ± 0.03^{ab}**	**9.21 ± 0.03^{b}**
100% emulgel	**9.86 ± 0.01^{ab}**	**9.21 ± 0.04^{bc}**	**8.45 ± 0.03^{c}**	**$8.41\pm0.02^{\text{It is}}$**

Means within the same rows with different common letters differ significantly (P<0.05)

8-3-Examining the profile of fatty acids of biscuits containing gel emulsion

As seen in Table 6, samples containing gel with 50%, 75% and 100% replacement were free of trans fatty acids; But the samples with 25% replacement still have some trans fatty acids due to the higher amount of shortening. As can be seen, the reduction of saturated fatty acids in samples with 50%, 75% and 100% replacement was 8.8%, 14.5% and 15.3%, respectively. In the study conducted by Giaranti et al. (2015), 50% of the butter in the cookie formulation was replaced with emulsions containing gel (inulin and olive oil). The results showed that the reduction rate of saturated fatty acids was 24% [17].

Table 6 Fatty acid profile of biscuits containing gel emulsion

Fatty acid	Biscuit				
	Shortening	**25%**	**50%**	**75%**	**100%**
C12:0	**0.15±0.01**	**0.21±0.01**	**0.21±0.01**	**0.14±0.01**	**0.13±0.02**
C14:0	**0.82±0.01**	**1.15±0.04**	**0.91±0.03**	**0.74±0.02**	**0.73±0.04**
C16:0	**44.50±0.03**	**41.74±0.05**	**41.21±0.05**	**35.13±0.05**	**34.46±0.04**

C16:1	**-**	**0.09±0.01**	**0.08±0.01**	**0.18±0.04**	**0.18±0.04**
C17:0	**0.02±0.01**	**0.04±0.01**	**0.05±0.01**	**0.04±0.01**	**0.11±0.01**
C17:1	**-**	**0.04±0.01**	**0.05±0.01**	**0.05±0.01**	**0.05±0.01**
C18:0	**6.75±0.05**	**5.96±0.05**	**6.69±0.03**	**8.80±0.04**	**8.85±0.05**
C18:1	**37.01±0.04**	**40.36±0.04**	**40.37±0.04**	**41.55±0.05**	**41.54±0.04**
C18:1(T)	**4.51±0.03**	**1.26±0.03**	**-**	**-**	**-**
C18:2	**5.64±0.03**	**8.91±0.03**	**9.62±0.03**	**13.01±0.05**	**13.12±0.04**
C18:3	**0.11±0.01**	**0.22±0.01**	**0.24±0.01**	**0.21±0.01**	**0.23±0.01**
C20:0	**0.2±0.02**	**0.04±0.01**	**0.09±0.01**	**0.20±0.02**	**0.33±0.01**
C20:1	**-**	**-**	**-**	**0.18±0.03**	**0.23±0.01**
C22:0	**0.25±0.01**	**0.14±0.02**	**0.15±0.01**	**-**	**-**
Saturated fat	**52.69±0.05**	**49.28±0.05**	**48.05±0.05**	**45.05±0.05**	**44.61±0.05**
Unsaturated fat	**47.27±0.04**	**50.88±0.05**	**51.62±0.03**	**55.18±0.04**	**55.35±0.04**

9-3- Checking the peroxide index of biscuits containing gel emulsion during storage

The highest amount of peroxide index (Table 7) during storage was related to the sample containing oil and the samples containing gel emulsion significantly (>0.05)*p*) had lower peroxide index than the sample containing oil and shortening, which shows the protective effect of gel emulsion against oil oxidation and antioxidant. In the research conducted by Yilmaz and Ogutcho (2014), the properties of oleogel containing olive oil and two gelling agents including beeswax and sunflower wax were compared with margarine. One of the investigated characteristics was the oxidative stability by examining the peroxide index during 90 days. Their studies showed that the peroxide index in oleogels containing gelling agents was lower than the control sample [32].

Table 7 Biscuit peroxide index containing gel emulsion, during storage

Treatment	**Peroxide value(mEq/Kg) (day)**			
	0	**60**	**120**	**360**
shortening	**1.35±0.02^{b}**	**1.42±0.01^{b}**	**1.51±0.03^{b}**	**1.62±0.03^{b}**
oil	**1.88±0.03^{a}**	**1.96±0.04^{a}**	**2.21±0.02^{a}**	**2.32±0.02^{a}**

25% emulsion gel	**1.24±0.01[d]**	**1.32±0.03[c]**	**1.38±0.01[d]**	**1.44±0.04[c]**
50% emulgel	**1.30±0.04[c]**	**1.38±0.04 [b]**	**1.48±0.03[c]**	**1.54±0.01[b]**
75% emulgel	**1.33±0.02[b]**	**1.39±0.03 [b]**	**1.51±0.04[b]**	**1.58±0.03[b]**
100% emulgel	**1.34±0.03[b]**	**1.42±0.05 [b]**	**1.55±0.02[b]**	**1.61±0.01[b]**

Means within the same rows with different common letters differ significantly ($P<0.05$)

4- General conclusion

Considering the need to consume foods with less fat content and the need to reduce saturated fatty acids and eliminate trans fatty acids from the diet, an emulsion gel was produced using sesame oil and hydrocolloids with the potential to be used as a low-calorie shortening, and their physical-chemical characteristics were investigated. became The optimal formulation had good sensory and mechanical stiffness and good overall acceptance and had a good potential to be used as a low-calorie shortening. Optimal gel emulsion with different levels replaced shortening in biscuit dough. Saturated fatty acids in biscuits containing gel emulsion were significantly reduced compared to the control sample. In addition, biscuits containing gel emulsion at replacement levels of 50, 75 and 100% were free of trans fatty acids. According to the results of sensory and texture tests, replacing shortening in biscuit dough up to 50% leads to the creation of desirable characteristics in the product (reduction of fat content and healthier fat profile) compared to the control sample.

5- Resources

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تولید شورتنینگ کم‌کالری با استفاده از امولسیون ژل با درصد بالای فاز داخلی و کاربرد آن در سیستم غذایی

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چکیده

پژوهش حاضر، باهدف تولید امولسیون ژل با اسیدهای چرب اشباع و ترانس کاهش‌یافته باقابلیت مصرف به‌عنوان شورتنینگ، انجام شد. از هیدروکلوئیدهای گوار، κ-کاراگینان ، CMC و مالتودکسترین برای تهیه امولسیون ژل، استفاده شد. برای پایداری امولسیون، از امولسیفایر PGPR (۱ درصد) استفاده شد. در فاز اول پژوهش، برای تولید امولسیون ژل با استفاده از صمغ گوار۰ تا ۰/۲۵ درصد، κ-کاراگینان ۰ تا ۲ درصد، CMC ۰ تا ۳ درصد و مالتودکسترین ۰ تا ۲۰ درصد، با نرم‌افزار Design Expert و به‌وسیله روش سطح پاسخ و طرح بهینه، فرمولاسیون‌های مختلفی ارائه و نمونه‌ها تولید شدند. آزمون‌های ارزیابی حسی و سفتی دستگاهی انجام گرفت و مدل‌های رگرسیونی برای پیش‌بینی پاسخ‌های سفتی، پذیرش کلی و سفتی دستگاهی ارائه و فرمولاسیون بهینه تعیین شد. در فاز دوم پژوهش، فرمولاسیون بهینه امولسیون ژل در سطوح ۲۵، ۵۰، ۷۵ و ۱۰۰٪ برای تولید بیسکویت مورداستفاده قرار گرفت و ویژگی‌های فیزیکوشیمیایی، حسی و اندیس پراکسید موردبررسی قرار گرفت. نتایج نشان داد با جایگزینی ۵۰٪ شورتنینگ با امولسیون ژل می‌توان بیسکویتی با میزان چربی و اسید چرب اشباع کمتر و بدون ترانس و ازنظر خصوصیات فیزیکوشیمیایی و حسی مشابه با نمونه حاوی شورتنینگ به دست آورد.