Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL

Volume 4, Issue 1, 2021, Pages 9–24

Available online at www.agricuta.edu.eg

DOI: https://dx.doi.org/10.21608/aasj.2021.67619.1058

Chia gel as fat substitute for producing low fat cake

Kadry M. M., Salama A., Ammar M. S.*

Food Science and Technology Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt

Abstract

The increased demands of healthy natural foods represent a challenge for food processors. This work aimed to study the effect of fat substituting with chia (*Salvia hispanica* L.) gel in producing low-fat cake. Fat was substituted with chia gel containing chia seed with the levels of 25, 50, 75 and 100% which named CG-25, CG-50, CG-75 and CG-100 respectively. The results reveal that chia seeds are a good source of nutrients since it contains 24.95 g/100 g protein, 36.27 g/100 g lipid and ash 5.11 g/100 g (on dry basis) as well as had high caloric value (563.91 kcal/100 g). Regarding the physiochemical properties, cake volume was decreased as substitution level increased (above 50%). Similarly, the cake's specific volume was decreased by increasing of fat substitution level with chia gel. Cake hardness was increased as the substitution level increased, since cake sample CG-25 was more firm than control sample but was less firm than cake sample CG-100. The crust and crumb color of cake samples containing chia gel became darker than that of control sample. The highest ($P < 0.05$) contents of moisture and protein were recorded for cake sample which formulated with fully substitution of shortening with chia gel (38.90 and 15.75%, respectively) while the lowest contents of the same parameters were observed in control sample (36.48 and 12.01%, respectively). As well as contents of carbohydrates, ash and fibers were increased (from 29.82 to 38.96; 2.06 to 2.41 and 1.58 to 1.72 g/100 g., respectively) as the substitution level of fat increased. On contrary, lipids content was significantly ($P < 0.05$) decreased as the level of substitution increased, so cake sample CG-100 exhibited a great reduction ratio (79.7%) in lipid content in relation to control sample. Also, the results indicated that the highest caloric value was recorded for control sample (343.99 kcal. /100g), while the cake sample CG-100 exhibited the lowest caloric value (254.66 kcal. /100g). Fatty acids profile was changed by substitution of shortening with chia gel, the decrement ratios of saturated and monounsaturated fatty acids for cake sample CG-100 were 84.17 and 82.46%., respectively, whereas the increment ratio of polyunsaturated fatty acids was 44.62%. Also, sensorial results indicated that no significant effects were observed between different cake samples and control sample in most qualities and they generally were acceptable. Finally, low fat cake can be produced by fat substitution by chia gel with keeping good physiochemical properties and nutritional quality, as well as consumer acceptability.

Keywords: cake, chia seeds, chia mucilage, fat substitution, physiochemical properties, sensory evaluation.

*Corresponding author: Ammar M. S.,
E-mail address: mohammedammar15@azhar.edu.eg

1. Introduction

Fat reduction in food is a major concern in our days, as market demands increase for lower fat products. This is related to indices showing a duplication of the population with overweight and obesity in the last 30 years, accounting in 2008 more than 1400 million adults (WHO, 2014).Fat substituting by other ingredients is a great challenge, especially in bakery products, which contain elevated levels of fat. Cakes are the second common bakery products after breads which are consumed everywhere, but they contain high fat content (17 g/100 g). Fat plays important role in producing pound cakes, since it impact cake higher volume and softness which due to the air incorporation during batter preparation and inhibition of gas-bubble coalescence, which resulting in a finer and softer crumb structure (Bennion and Bamford, 1997; Bobbio and Bobbio, 2003). In addition, fats and emulsifiers retard gelatinization of starch via slowing water transfer into the starch granule, by formation of complexes between polar lipids and amylose during baking, which finally improves tenderness, moisture content and flavor of cakes and extending shelf-life (Pizarro *et al.*, 2013). So that the absent of fat or fat reducing cause several problems in pound cakes, such as low volume, denser crumb, firmer eating qualities, and loss of flavor, compared to conventional cakes (Cauvain and Young, 2006). So, in bakery products, such breads and cakes, the ingredients used as fat substitutes should play the same role as the fat, i.e., promote aeration of the dough/batter, lubrication during the mixing phase, improve the final texture of the product and increase the volume (Rios *et al.*, 2014). Over the years, different ingredients have been used for replacement of fat in foods, such as gums, fibers or mucilage. Chia forming a gelatinous mass (called chia gel or chia mucilage) when soaked in water due to the presence of high amount of mucilage and gums. This gel is composed essentially of soluble fiber (polysaccharides about 71.22%) and corresponds to about 6% of chia seed (Reyes-Caudillo *et al.*, 2008; Muñoz *et al.*, 2012), appearing to be contained in the seed coat or the adjacent layer become visible when fully hydrated, not being easily separated from the seed (Segura-Campos *et al.*, 2014). The gel formed has qualities that allow it using in food applications such as yoghurt, cereals, juices or cakes in different countries all over the world as thickener, gel former and chelator (Ali *et al.*, 2012; Capitani *et al.*, 2012). Due to its structure, chia gel acts like soluble fiber and it is known to have excellent water holding properties. Thus, chia gel might provide hydration, viscosity development and conservation of freshness, especially for baked goods, therefore, presenting a potential as fat substitute particularly in bakery products (Vázquez-Ovando *et al.*, 2009). Furthermore, chia and its gel be useful for the gut health because soluble fiber prolongs the gastro-intestinal transit time that aids in improving digestion (Suri *et al.*, 2016). So, this work aimed to producing low fat cake by partially/ fully substitution of fat (shortening) with chia gel and study its effect on physiochemical properties, nutritional and sensory quality of the produced cake.

2. Materials and methods

2.1 Materials

Chia (*Salvia hispanica* L.), white and brown seeds used in this study were obtained from Abu Auf market, Nasr City, Cairo, Egypt. Ingredients of cake: Soft wheat flour (72% extraction) was obtained from The Egyptian-French Company for Trade and Mills (Helwan, Cairo, Egypt). Sugar (sucrose), salt, skim milk powder, fresh whole eggs, shortening, baking powder and vanilla were purchased from the local market, Nasr City, Cairo, Egypt. Chemicals: All chemicals, reagents and solvents used in the analytical methods in present study (analytical grade) were obtained from El-Gamhouria Trading Chemicals and Drugs Company, Cairo, Egypt.

2.2 Methods

2.2.1 Technological methods

2.2.1.1 Chia gel extraction

Chia gel was extracted by the method of Boreno *et al.* (2010) as follows: Chia seeds were soaked in tap water with ratio of 1 seed: 9 water w/w, mixed and rested for 30 min before using. Chia seeds (10%) were left in the gel and incorporated into the cake batter.

2.2.1.2 Preparation of cake samples

Control cake was prepared without chia mucilage while other cake samples were prepared by replacing shortening by 25, 50, 75 and 100% of chia gel (CG) which contains chia seeds. Cakes were prepared according to the method described by Khalifa *et al.* (2015) by using the formulas shown in Table (1) as follows: The shortening was melted thoroughly then sugar and salt were mixed vigorously with shortening, shortening/chia gel or chia gel. The fresh whole egg was mixed with vanillia and whipped until got puff and smooth like-cream texture. Additionally, wheat flour was mixed individually with baking powder and skim milk powder then added gradually to whipped egg mixture. This mixture was mixed gently until got homogenous batter using Hand mixer (MK-H4-W, Panasonic Co, Malaysia). After getting appropriate texture the batter was poured into cups and baked at 180˚C ± 5˚C in an electrical oven (Vipinho 0448, Perfecta, Curitiba, Brazil) for 30 - 35 min.

2.2.2 Analytical Methods

2.2.2.1 Physical characteristics of cake samples

2.2.2.1.1 Weight, volume and specific volume of cake samples

The average weight (g) of cake samples was determined individually within one hour after baking using a semi-analytical balance PB 3002 (Mettler Toledo, Greifensee, Swiss). The volume (cm^3) was determined by rapeseed displacement. While Specific volume (cm^3/g) was calculated according to the method of AACC (2010) using the following equation:

$$\text{Specific volume } (cm^3/g) = \text{volume } (cm^3) \text{ / weight } (g)$$

2.2.2.1.2 Crumb hardness

Crumb hardness of cake samples was measured at 0, 3 and 5 days after baking using a TA-XT2i texture analyzer (Stable Micro Systems, Surrey, UK). For this analysis, cakes were sliced using an electric knife (Moulinex) and the crust was removed. The tests were conducted according to the method of AACC (2010) (74-09.01). Crust and crumb color: crust and crumb color were conducted using a colorimeter (Minolta Chroma Meter CR-400). The experiment followed the L* a* b* color space system or CIE-L* a* b*, defined by the CIE (International Commission on Illumination) in 1976. This evaluates values for L* (lightness); a*, which indicates a hue that moves from green (-) to red (+); and b*, which indicates a hue that goes from blue (-) to yellow (+) (Minolta, 1994).

Table (1): Ingredients recipe of cake samples.

Ingredients (g)	Treatments*				
	Control	CG-25	CG-50	CG-75	CG-100
Wheat flour (72%)	250	250	250	250	250
Fresh egg	110	110	110	110	110
Sugar	125	125	125	125	125
Salt	3.50	3.50	3.50	3.50	3.50
baking powder	12.50	12.50	12.50	12.50	12.50
Vanilla	2.00	2.00	2.00	2.00	2.00
Skim milk powder	25.00	25.00	25.00	25.00	25.00
Shortening	53.50	40.125	26.75	13.375	0.00
Chia gel (CG)	0.00	13.375	26.75	40.125	53.50

*Control, 100 % Shortening; CG-25, 75% shortening /25% CG; CG-50, 50 % shortening/ 50 % CG; CG-75, 25 % shortening/ 75 % CG and CG-100, 100 % CG.

2.2.2.2 Chemical properties of raw materials and cake samples

2.2.2.2.1 Gross chemical composition

Contents of moisture, crude protein, ether extract and ash were determined according to the methods described by AOAC (2012). Dietary fiber content was determined by the total dietary fiber assay procedure AOAC (1991). Nitrogen Free Extract (NFE) representing the total carbohydrates was calculated by subtracting the sum of percentages of crude protein, crude fat, ash and moisture from 100 according to Aurand (2013) using the following equation:

$$\text{Total carbohydrates} = 100 - (\%\text{ protein} + \%\text{ fat} + \%\text{ ash} + \%\text{ moisture})$$

2.2.2.2.2 Caloric value

The caloric value (kcal. / 100 g) of cake samples was calculated theoretically according to the method described by Mudambi and Rao (1989) using the following equation:

$$\text{Caloric value} = (\text{g of protein} \times 4) + (\text{g of lipid} \times 9) + (\text{g of carbohydrate} \times 4)$$

2.2.2.2.3 Fatty acids profile

Fatty acids profile of the lipids extracted from cake samples was obtained according to the method of AACC (2010).

2.2.2.3 Sensory evaluation of cake samples

The tested cake samples were submitted to sensory evaluation after 2 hr. of baking by using 20 panelists from the staff of Food Science and Technology Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt. Each panelist was asked to rate the liking of quality attributes (visual appearance, crust color, crumb color, texture, taste, odor and overall acceptability) of each sample using a 9-point hedonic scale (1= dislike extremely and 9 = like extremely) according to the method of Pyler (1973).

2.2.2.4 Statistical analysis

Means of physical and chemical properties obtained from three replicates while sensory evaluation means obtained from 20 panelists were analyzed by (ANOVA) using the SPSS statistical package program, and differences among the means were compared using the Duncan's Multiple Range test at significant level of 0.05 (SPSS, 1998).

3. Results and Discussion

3.1 Proximate composition and caloric value of the chia seeds

The results in Table (2) indicate that the moisture content of chia seeds was low (5.79%). This helps in keeping the quality of seeds during storage under proper condition. At this level of moisture, the micro-organisms growth and the biochemical reactions are usually inhibited. It is also increased from dry matter of chia seeds up to 94%. These results are closely similar to that obtained by Suri *et al.* (2016) who reported that moisture content of chia seeds is 5.80 %. The same Table shows that chia seeds are a good source of nutrients since it contains 24.95 g/100 g protein and 36.27 g/100 g lipid (on dry basis), these results are like those found by Ayerza and Coates (2004). Similarly, Monroy-Torres *et al.* (2008) reported that chia seeds are a rich source of protein (19–27%), this content is greater than that found in other traditional grains, such as wheat (14%), barley (9.2%), oats (15.3%), corn (14%), and rice (8.5%). Also, Table (2) reveals that total dietary fiber content of chia seeds is 30.78 g/100 g which is in accordance with the previous studies which reported that chia seeds are a source of dietary fiber (about 35%) which is higher than that of other seeds, such as amaranth (7.3%), quinoa (7.0%), and corn (8.3%) as reported by da Silva *et al.* (2017) and Srichuwong *et al.* (2017). The caloric value of chia seeds is 563.91 kcal/100 g. It was higher than that reported by Michele and Myriam (2014), since they reported that caloric value of chia seeds is 519.9 kcal/100 g and nearly to that mentioned by Mohammed *et al.* (2019), whom recorded caloric value of chia seeds about 562.25 kcal/100 g. The high caloric value of chia seed is associated with its high level of lipids.

Table (2): Proximate chemical composition (g/100 g) and caloric value of the chia seeds (kcal.100 g^{-1}).

Components (g/100 g)	Chia seeds (CS)	
	on wet basis	on dry basis
Moisture content	5.79	-
Total proteins [(a)]	23.50	24.95
Total lipids	34.74	36.27
Total carbohydrates [(b)]	31.15	33.06
Ash content	4.82	5.11
Total dietary fiber	30.78	32.67
Caloric value (kcal.100g^{-1})	531.26	563.91

[(a):] N=6.25; [(b):] by difference. (n=3).

3.2 Fatty acids composition of chia seeds

Table (3) shows five fatty acids that were detected in the fat isolated from chia seeds. They are palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1 ω-9), linoleic acid (C18:2 ω-6) and *α*-linolenic acid (C18:3 ω-3). Also, the table shows that polyunsaturated fatty acids in the chia seed's fat amounted to approximately 79.18%, which consisted mainly of α-linolenic acid (59.46%) and α-linoleic acid (19.72%), while monounsaturated fatty acid (oleic acid) amounted to approximately 7.32%, while it contain low content of saturated fatty acid (11.38%). These results are in agreement with those reported by Marineli *et al*. (2014) in their study on Chilean chia seed oil. In addition, chia seeds showed low ratio ω-6/ω-3 (0.33) which in agreement with that obtained by Marineli *et al*. (2014), who recorded a ratio of ω-6/ω-3 about 0.29 in Chilean chia oil.

3.3 Effect of fat substituting with chia gel on Physical properties of cake samples

3.3.1 Effect of fat substituting with chia gel on weight, volume and specific volume of cake samples

Physical properties (weight, volume and specific volume) are very important quality criteria for cake samples, which strongly influence consumer preference, and they directly related to the type and amount of fat, since fat promotes aeration of the batter and stabilizes the air bubbles formed during batter mixing (Felisberto *et al*., 2015). Table (4) presents the effect of fat substituting with chia gel containing chia seeds on the physical properties of cake samples. From the results weight of cake samples formulated by substituting shortening with chia gel were not statistical different than that formulated without chia gel (control sample). As shown in Table (4) cake volume was affected when fat was replaced with CG, since as substitution level increased (above 50%) cake volume was decreased, because the low aeration of the cake batter which is agree with the findings of (Borneo *et al*. 2010; Min *et al*., 2010; Rodríguez-García *et al*., 2014; Zahn *et al*., 2010) who reported smaller volume and lower weight loss in low fat cakes /muffins.

Table (3): Fatty acids composition of the chia seeds oil (mg/100 g oil).

Fatty acids (mg/100 g oil)	Chia seeds (CS)
SFA:	
Palmitic acid (C16:0)	7.76
Stearic acid (C18:0)	3.62
MUFA:	
Oleic acid (C18:1 ω -9)	7.32
PUFA:	
α-Linoleic acid C18:2 ω -6)	19.72
α-Linolenic acid C18:3 ω -3)	59.46
Σ SFA	11.38
Σ PUSFA	79.18
ω-6/ω -3 Ratio	0.33

CS: chia seeds; SFA: saturated fatty acid; USFA: unsaturated fatty acid; MUFA: mono unsaturated fatty acid; PUFA: poly unsaturated fatty acid.

Table (4): Effect of fat substituting with chia gel on physical properties of cake samples.

Treatments*	Weigh (g)	Volume (cm^3)	Specific Volume (cm^3/g)
Control	40.60^a	124^a	3.05^a
CG-25	40.65^a	120^a	2.95^{ab}
CG-50	40.69^a	118^{ab}	2.89^b
CG-75	40.80^a	110^b	2.69^{bc}
CG-100	40.85^a	106^b	2.59^c

*Control, 100 % Shortening; CG-25, 75% shortening /25% CG; CG-50, 50 % shortening/ 50 % CG; CG-75, 25 % shortening/ 75 % CG and CG-100, 100 % CG. Values with different letters in the same column are significantly different ($p<0.05$). (n= 3).

Similarly, the cake's specific volume was decreased with the increasing of fat substitution level with chia gel. The lowest value of specific volume was corresponding to the high concentration of chia gel (CG-100) while the highest (P

< 0.05) value was observed for control sample. Cake sample CG-25 which contain the lowest chia gel was characterized with high specific volume, which is closely to that of control sample, 3.05, 2.95 (cm^3/g), respectively. The reduction of cake's specific volume may be due to the decreasing in the batter stability as the fat content is reduced, since fat stabilizes the air bubbles and maintains more air during baking (Rodríguez-García *et al*., 2014).

3.3.2 Effect of fat substituting with chia gel on crumb hardness, crust and crumb color of cake samples

Fat has a positive effect on bakery products texture, color and important to keep cake softer for a long period. Table (5) shows the effect of fat replacing with chia gel on crumb hardness (texture) of cake samples. It can be observed that the reduction of fat content by substituting with chia gel increased the hardness of cake samples as compared to control which is related to the drop in the specific volume of cake containing chia gel. The fat substitution with chia gel resulted in increasing the cake hardness, which increased as the substitution increased, since CG-25 cake sample was less firm when compared to CG-100 cake sample. The reduction of fat resulted in a lower aeration capacity, worse crumb structure and, consequently, greater hardness which agrees with results of Lakshminarayan *et al*. (2006) who found that reduction of cake's fat content made it less soft and required more force to compress. Similar results were obtained by Chung *et al*. (2010) in muffins, since reduction of fat content caused an increase in hardness, which was associated with a decrease in both air incorporation and cake-specific volume.

Table (5): Effect of fat substituting with chia gel on crumb hardness, crust color and crumb color of cake samples.

Parameters	Crumb hardness (g)			Crust color			Crumb color		
Treatments*	Storage days			L*	a*	+b*	L*	a*	+b*
	0	3	5						
Control	106.66^b	196.66^c	248.33^c	58.47^a	9.88^a	20.70^a	60.54^a	0.099^c	13.85^a
CG-25	107.00^b	198.33^c	266.66^b	58.13^a	9.85^a	20.00^a	60.00^a	0.138^{bc}	13.21^a
CG-50	110.35^{ab}	215.00^{bc}	278.50^b	57.79^a	9.86^a	19.47^{ab}	59.60^a	0.159^b	12.90^{ab}
CG-75	115.43^a	228.33^b	305.00^a	56.70^a	9.84^a	18.98^b	58.40^a	0.205^{ab}	12.16^b
CG-100	118.33^a	266.50^a	323.60^a	56.00^a	9.85^a	18.81^b	58.00^a	0.240^a	11.90^b

Control, 100 % Shortening; CG-25, 75% shortening /25% CG; CG-50, 50 % shortening/ 50 % CG; CG-75, 25 % shortening/ 75 % CG and CG-100, 100 % CG; L: brightness; a*: redness and +b* yellowness; Values with different letters in the same column are significantly different (p<0.05). (n=3).

Also, Table (5) shows that a gradual increase in hardness of the cake crumb was observed as storage time increased for all samples. Crumb hardness values were increased from 106.66 to 118.33g at zero-time to 248.33 to 323.60g at the fifth day of storage at room temperature for control and CG-100 cake samples respectively. These results in agreement with those of Fernandes *et al.* (2017) since they observed that cake firmness increases in proportion to the amount of mucilage added. Color is one of the most important characteristics in the appearance of a cake, since this combined with the texture and flavor, and contributes to the consumer's preference for the product (Felisberto *et al.*, 2015). The values for L^*, a^* and b^* for the crust color of the cake samples ranged from 58.47 to 56.00, 9.88 to 9.85 and 20.70 to 18.81 respectively (Table 5). The highest values for these parameters were observed for control sample. As expected, due to its own color, chia gel influenced all the color parameters evaluated. In addition, CG contributed to making the crumb color darker which may be due to the presence of chia seeds in chia gel (lower L*), with a less yellow color (lower b*) and tending more to red (higher a*). According to the results shown in Table (5), the values for L*, a* and b* for the crumb color of the cake samples ranged from 60.54 to 58.00, 0.099 to 0.240 and 13.85 to 11.90, respectively. These results agree with those reported by Pizarro *et al.* (2013) and Pertuzatti *et al.* (2015) since they observed a reduction in the color values of cake formulated with addition of chia flour, probably because of its dark color, affecting the crust and crumb color of cakes.

3.4 Effect of fat substituting with chia gel on chemical properties of cake samples

3.4.1 Effect of fat substituting with chia gel on proximate chemical composition and caloric value of cake samples

Table (6) presents the proximate chemical composition of control cake and tested cake samples containing chia gel at different levels. Moisture content in is one of the desirable sensory characteristics in bakery products, being usually related to a mild product (Dadkhah *et al*., 2012). The data in Table (6) shows that the moisture content of cake samples increased as the fat substitution level increased. Cake treatments formulated with chia gel had higher moisture content compared to control cake which could be explained by the chi gel high water holding capacity. The highest ($P < 0.05$) moisture content was recorded for cake sample which formulated with fully substitution of shortening with chia gel (38.90%) while the lowest moisture content was recorded for control sample (36.48 %). These results were on the line with results of Filiberto *et al*. (2015) who studied the technological effects of adding chia gel to cakes to reduce fat and reported increase of moisture content as a function of substitution fat with chia gel. In the same way, cake samples formulated to contain chia gel presented higher protein content than control cake because of presence of chia seeds in chia gel, the increase in protein content was proportion to the level of fat substitution, the highest ($P < 0.05$) protein content was observed to cake sample in which shortening was completely substituted with chia gel (15.75%), while the lowest protein content was recorded for control sample (12.01%). These results agree with those of Borneo et al. (2010) who found high protein content when oil replaced by chia gel in cake. Regarding, the lipid content substituting of shortening with chia gel containing chia seeds resulted in decreasing lipid level of cakes which is decreased as the level of substitution increased, so cake sample CG-100 which formulated with fully substituting of shortening by chia gel exhibited a significant ($P < 0.05$) reduction ratio (79.7%) of lipids in relation to control sample. The obtained values agree with that obtained by Borneo et al. (2010) who showed a fat reduction ratio of 57% in cakes by adding chia gel. Moreover, the contents of carbohydrates, ash and fibers were significantly ($P < 0.05$) increased as the substitution level of fat increased, (from 29.82 to 38.96; 2.06 to 2.41 and from 1.58 to 1.72 g/100 g respectively). In contrary, the caloric values of cake samples were decreased as the substitution level increased because fat is the major source of energy in cake which is decreased with replacing with chia gel, the highest caloric value was recorded for control sample (343.99 kcal. / 100g), while the lowest caloric value was observed to cake sample in which shortening was completely substituted with chia gel (254.66 kcal. /100g).

Table (6): Effect of fat substituting with chia gel on proximate chemical composition (g/100 g on dry basis) and caloric value of cake.

Treatments*	Moisture content	Total proteins*	Total lipids*	Ash content*	Total dietary fiber*	Total carbohydrates*	Caloric Value ($kcal.100g^{-1}$)
Control	36.48^{b}	12.01^{c}	19.63^{a}	2.06^{c}	1.58^{b}	29.82	343.99
CG-25	36.76^{b}	12.95^{bc}	17.71^{b}	2.09^{bc}	1.62^{b}	30.49	333.15
CG-50	37.39^{ab}	13.75^{b}	14.24^{c}	2.10^{b}	1.69^{ab}	32.52	313.24
CG-75	37.95^{ab}	14.55^{ab}	10.28^{d}	2.20^{ab}	1.71^{a}	35.02	290.8
CG-100	38.90^{a}	15.75^{a}	3.98^{e}	2.41^{a}	1.72^{a}	38.96	254.66

*Control, 100 % Shortening; CG-25, 75% shortening /25% CG; CG-50, 50 % shortening/ 50 % CG; CG-75, 25 % shortening/ 75 % CG and CG-100, 100 % CG; Values with different letters in the same column are significantly different ($p<0.05$). (n = 3).

3.4.2 Effect of fat substituting with chia gel on Fatty acid profile of cake

The analysis of the fatty acid profile of cake samples was showed in Table (7). The table shows that fatty acid profile was changed by substitution of shortening with chia gel, the decrement ratios of saturated and monounsaturated fatty acids in cake formulated with fully substituting of shortening were 84.17% and 82.46%., respectively, whereas the increment ratio of polyunsaturated fatty acids was 44.62% than control sample because of presence of chia seeds in chia gel. These results were supported by the findings of Pizarro *et al*. (2013) who evaluated the fatty acid profiles of pound cakes formulated with 15 g chia and 20% hydrogenated vegetable fat per 100 g flour and observed an increase in the amount of linoleic acid.

Table (7): Effect of fat substituting with chia gel on fatty acids profile (g/100 g of total lipids) of cake samples.

Fatty acids	Treatments*				
	control	CG-25	CG-50	CG-75	CG-100
SFA					
Palmitic acid (C16:0)	38.56	30.40	22.44	14.32	5.33
Stearic acid (C18:0)	5.42	5.17	4.49	3.07	1.62
MUFA					
Oleic acid (C18:1 ω-9)	37.69	30.26	23.17	16.73	6.61
PUFA					
α-Linoleic acid (C18:2 ω-6)	10.92	11.99	12.26	13.49	15.67
α-Linolenicacid (C18:3 ω-3)	0.78	1.08	1.42	3.01	5.46
ΣSFA	43.93	35.57	26.93	17.39	6.95
ΣPUSFA	11.70	13.07	13.68	16.50	21.13
ω-6/ω -3 Ratio	14/1	11/1	9/1	4/1	3/1

*Control, 100 % Shortening; CG-25, 75% shortening /25% CG; CG-50, 50 % shortening/ 50 % CG; CG-75, 25 % shortening/ 75 % CG and CG-100, 100 % CG; SFA: saturated fatty acid; USFA: unsaturated fatty acid; MUFA; monounsaturated fatty acid; PUFA: poly unsaturated fatty acid.

Similarly, Coelho and Mercedes (2015) reported an increase in linoleic and linolenic acid contents by adding chia to wheat doughs. Furthermore, a significant decrease in ω-6/ ω-3 ratio was observed in cake samples formulated with incorporation of chia gel especially in cake sample formulated with complete substitution of shortening with chia gel (CG-100 sample) (3/1) comparing with control sample (14/1), which is essential for proper brain functions and has beneficial effects in cardiovascular diseases and in prevention of arthritis as reported by Pizarro *et al*. (2014).

3.5 Effect of fat substituting with chia gel on sensory properties of cake samples

Table (8) presents the scores of the sensory analysis of tested cake samples that were developed with fat substitution by chia gel at different levels as compared to control sample (without substitution). It can be observed that all sensory attributes presented scores between 8 and 9, showing that cake samples were evaluated as ‘‘liked extremely”. The overall acceptability was greater than 8.00, which confirms that the cake samples are considered as acceptable by the panelists as reported by Spehar and Santos (2002), who reported that a product is considered sensorial acceptable, when it obtained a minimum score of 70%. Table (8) reveals that cake formulated with fully substitution of shortening with chia gel exhibited lower scores with no significant different for all the parameters when compared to other cake samples containing chia gel (except crumb color and texture), but it significantly (P < 0.05) differed in overall acceptability as compared to control sample.

Table (8): Effect of fat substituting with chia gel on sensory properties of cake samples.

Treatments*	Crust color*	Crumb color*	Texture*	Visual Appearance*	Taste*	Odor*	Overall acceptability*	Purchase intention a
Control	8.58a	8.58a	8.95a	8.53a	9.00a	8.50a	9.00a	4.93a
CG-25	8.59a	8.59a	8.90a	8.53a	8.95a	8.50a	9.00a	4.80a
CG-50	8.53a	8.35a	8.85a	8.50a	8.90a	8.47a	8.53a	4.75a
CG-75	8.47a	8.26ab	8.50ab	8.50a	8.50a	8.33a	8.50ab	4.50a
CG-100	8.33a	8.00b	8.00b	8.00a	8.50a	8.30a	8.00b	4.30a

*Control, 100 % shortening; CG-25, 75% shortening /25% CG; CG-50, 50 % shortening/ 50 % CG; CG-75, 25 % shortening/ 75 % CG and CG-100, 100 % CG;; *: Hedonic scale ranging from 1 = "disliked extremely" to 9 = "liked extremely"; a: Hedonic scale ranging from 1 = "would certainly not buy" to 5 = "would certainly buy"; Values with different letters in the same column are significantly different (p<0.05). (n = 20).

Regarding consumption of cake samples by panelists, the result obtained for the purchase intent was very satisfactory, with a similar value for all types of cakes, showing that cake samples were evaluated as ‘‘would certainly buy”. The results for purchasing intention varied between 4 and 5 (would certainly buy) for the product, showing no statistical difference between treatments and mean that about 80% of the panelists would certainly buy the cake, representing a positive purchasing intention. In general, it can be observed that the cake samples produced by substitution of shortening with chia gel showed good sensory acceptance which indicates that it is possible to produce low fat cakes, with a good consumer acceptability by substituting shortening with chia gel.

4. Conclusion

Finally, it could conclude that cake can produced by substitution shortening with chia gel containing chia seeds with keeping good physiochemical properties and nutritional quality, as well as consumer acceptability.

References

AACC (2010), American Association of Cereal Chemists International approved methods of analysis, AACC International, USA.

Ali, N. M., Yeap, S. K., Ho, W. Y., Beh, B. K., Tan, S. W. and Tan, S. G. (2012), "The promising future of chia, *Salvia hispanica* L.", *BioMed Research International*, Vol. 2012, Article ID 171956.

AOAC (1991), *Official methods of analysis association of official Agricultural chemists*, 15th Edition, The Association of Official Analytical Chemists, Washington, D.C., USA.

AOAC (2012), *Official methods of analysis association of official Agricultural chemists*, 19th Edition, The Association of Official Analytical Chemists, Washington, D.C., USA.

Aurand, L. W. (2013), *Food composition and analysis*, Springer Science and Business Media, New York, USA.

Ayerza, R. and Coates, W. (2004), "Composition of chia (*Salvia hispanica*) grown in six tropical and sub-tropical ecosystems of South America", *Tropical Science,* Vol. 44, pp. 131–135.

Bennion, E. B. and Bamford, G. S. T. (1997), *The technology of cake making*, 6th ed., Blackie London, England.

Borneo, R., Aguirre, A. and Leon, A. E. (2010), "Chia (*Salvia hispanica* L) gel can be used as egg or oil replacer in cake formulations", *Journal of the American Dietetic Association*, Vol. 110, pp. 946–949.

Capitani, M. I., Spotorno, V., Nolasco, S. M., and Tomás, M. C. (2012), "Physicochemical and functional characterization of by-products from chia (*Salvia hispanica* L.) seeds from Argentina", *Food Science and Technology*, Vol. 45, pp. 94–102.

Chung, H. J., Lee, S. E., Han, J.A. and Lim, S. T. (2010), "Physical properties of dry heated octenyl succinylated waxy corn starches and its application in fat-reduced muffin", *Journal of Cereal Science*, Vol. 52, pp. 496–50.

Coelho, M. S. and Salas-Mellado, M. M. (2015), "Effects of substituting chia (*Salvia hispanica* L.) flour or seeds for wheat flour on the quality of the bread", *Food Science and Technology*, Vol. 60, p. 729–736.

da Silva, B. P., Anunciação, P. C., Matyelka, J. C. S., Della Lucia, C. M., Martino, H. S. D., and Pinheiro-Sant'Ana, H. M. (2017), "Chemical composition of Brazilian chia seeds grown in different places", *Food Chemistry*, Vol. 221, pp. 1709–1716.

Dadkhah, A., Hashemiravan, M. and Seyedain-Ardebili, M. (2012), "Effect of shortening replacement with nutrim oat bran on chemical and physical properties of shortened cakes", *Annals of Biological Research*, Vol. 3, pp. 2682–2687.

Felisberto, M. H. F., Wahanik, A. L., Gomes-Ruffi, C. R., Clerici, M. T. P. S., Chang, Y. K. and Steel, C. J. (2015), "Use of chia (*Salvia hispanica* L.) mucilage gel to reduce fat in pound cakes", *Food Science and Technology*, Vol. 63, pp. 1049–1055.

Khalifa, I., Barakat, H., Hamdy, A. and Soliman. A. (2015), "Physico-Chemical, Organolyptical and Microbiological Characteristics of Substituted Cupcake by Potato

Processing Residues", *Food and Nutrition Sciences*, Vol. 6, pp. 83–100.

Lakshminarayan, S. M., Rathinam, V. and Krishna Rau, L. (2006), "Effect of maltodextrin and emulsifiers on the viscosity of cake batter and on the quality of cakes", *Journal of the Science of Food and Agriculture*, Vol. 86, pp. 706–712.

Marineli, R. S., Moraes, E. A., Lenquiste, S. A., Godoy, A. T., Eberlin, M. N. and Maróstica, M. R. J. (2014), "Chemical characterization and antioxidant potential of Chilean chia seeds and oil (*Salvia hispanica* L.) ", *Food Science and Technology*, Vol. 59, pp. 1304–1310.

Michele, S. C. and Myriam, M. S. (2014), "Chemical characterization of chia (*Salvia hispanica* L.) for use in food products", *Journal of Food and Nutrition Research*, Vol. 2, pp. 263–269.

Min, B., Bae, I. Y., Lee, H. G., Yoo, S. H. and Lee, S. (2010), "Utilization of pectin enriched materials from apple pomace as a fat replacer in a model food system", *Bioresource Technology*, Vol. 101, pp. 5414–5418.

Minolta. (1994), *Precise color communication: color control from feeling to instrumentation*, Minolta Co Ltd, Osaka, Japan.

Mohammed, O. B. R., Abd El-Razek, A. M., Bekhet, M. H. H. and Moharram, Y. G. (2019), "Evaluation of Egyptian Chia (*Salvia hispanica* L.) Seeds, Oil and Mucilage as Novel Food Ingredients", *Egyptian Journal of Food Science*, Vol. 47 No. 1, pp. 11–26.

Monroy-Torres, R., Mancilla-Escobar, M. L., Gallaga-Sol´ orzano, J. C., Medina-Godoy, S. and Santiago-Garc´ıa, E. J. (2008), "Protein digestibility of chia seed", Revista Salud Pública y Nutrición, Vol. 9, pp. 1–9.

Mudambi, R. S. and Rao, M. S. (1989), *Food Science*, New Age International, Chennai, India, pp. 227.

Muñoz, L. A., Cobos, A., Diaz, O. and Aguilera, J. M. (2012), "Chia seeds: Microstructure, mucilage extraction and hydration", *Journal of Food Engineering*, Vol. 108, pp. 216–224.

Paul, A. A. and Southgate, D. A. (1979), *The composition of foods*, 4th ed., Elsevier /North. Holland Biomedical Press, Amsterdam, Netherlands.

Pertuzatti, P. B., Esteves, S. M. R., Alves, J. E., Lima, L. C., and Borges, J. E. (2015), "Sensory evaluation of bakery and confectionery products prepared through semi-industrial and artisanal processes", *American Journal of Food Science and Technology*, Vol. 3 No. 4A, 32–36.

Pizarro, P. L., Almeida, E. L., Coelho, A.

S., Samm´an, N. C., Hubinger, M. D. and Chang, Y. K. (2014), "Functional bread with n-3 alpha linolenic acid from whole chia (*Salvia hispanica* L.) flour", *Journal of Food Science and Technology*, Vol. 52, pp. 4475–4482.

Pizarro, P. L., Almeida, E. L., Samman, N. C. and Chang, Y. K. (2013), "Evaluation of whole chia (*Salvia hispanica* L.) flour and hydrogenated vegetable fat in pound cake", *Food Science and Technology*, Vol. 54, pp. 73–79.

Pyler, E. J. (1973), *Baking science and Technology*, Vol. 1 (Chapter 3), Siebel Publishing Co., Chicago, USA.

Reyes-Caudillo, E., Tecante, A., and Valdivia-López, M. A. (2008), "Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (*Salvia hispanica* L.) seeds", *Food Chemistry*, Vol. 107, pp. 656–663.

Rios, R.V., Pessanha, M. D. F., Almeida, P. F., Viana, C. L. and Lannes, S. C. S. (2014), "Application of fats in some food products", *Food Science and Technology*, Vol. 34 No. 1, pp. 3–15.

Rodríguez-García, J., Salvador, A. and Hernando, I. (2014), "Replacing fat and sugar with inulin in cakes: bubble size distribution, physical and sensory properties", *Food Bioprocess Technology*, Vol. 7, pp. 964–974.

Segura-Campos, M. R., Acosta-Chi, Z., Rosado-Rubio, G., Chel-Guerrero, L., and Betancur-Ancona, D. (2014), "Whole and crushed nutlets of chia (*Salvia hispanica*) from Mexico as a source of functional gums", *Food Science and Technology*, Vol. 34 No. 4, pp. 701–709.

Spehar, C. R. and Santos, R. L. B. (2002), "Quinoa BRS Piabiru: alternativa para diversificar os sistemas de produção de grãos", *Pesquisa Agropecuária Brasileira*, Vol. 37, pp. 889–893.

SPSS (1998), *Statistical Package for the Social Sciences, for windows*, Release, 9.0.0, standard Version SPSS. Inc., Armonk, New York, USA.

Srichuwong, S., Curti, D., Austin, S., King, R., Lamothe, L., and Gloria-Hernandez, H. (2017), "Physicochemical properties and starch digestibility of whole grain sorghums, millet, quinoa and amaranth flours, as affected by starch and non-starch constituents", *Food Chemistry*, Vol. 233, pp. 1–10.

Suri, S., S. Passi and J. Goyat. (2016), *Chia Seed (Salvia Hispanica L.) – a New Age Functional Food*, 4th International Conference on Recent Innovations in Science Engineering and Management, India International Centre, New Delhi, India, pp. 286–299.

Valdivia-L´opez, M. A. and Tecante, A.

(2015), "Chia (*Salvia hispanica*): A review of native mexican seed and its nutritional and functional properties", Advances in food and nutrition research (1st ed., Vol.75). USA: Elsevier Inc.

Vázquez -Ovando, A., Rosado-Rubio, G., Chel-Guerrero, L., and Betancur-Ancona, D. (2009), "Physicochemical properties of a fibrous fraction from chia (*Salvia hispanica* L.) ", *LWT e Food Science and Technology*, Vol. 42 No. 1, 168e173.

WHO (2014), *Obesity and overweight*, World Health Organization, available at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

Zahn, S., Pepke, F. and Rohm, H. (2010), "Effect of inulin as a fat replacer on texture and sensory properties of muffins", *International Journal of Food Science and Technology*, Vol. 45, pp. 2531–2537.