Journal of Home Economics

Volume 26, Number (1), 2016

Journal of Home Economics

http://homeEcon.menofia.edu.eg

ISSN 1110-2578

Effect of substituting chia (*Salvia hispanica* L.) seeds flour and gel for wheat flour and egg on the quality of cookies and cake

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Abstract: The present study aims to determine the nutrient content, functional properties and sensory characteristics of cookies and cakes made from flour substituted partially by chia seeds (*Salvia hispanica* L) flour and gel as follow: 1) partial replacement of wheat flour by 25% chia seed flour and 2) total replacement of eggs by chia gel, in comparing with traditional cookies and cake formulation as control samples. Results revealed that overall acceptability of control samples recorded the highest value followed by samples with chia gel then 25% whole chia flour blending. Significant increase ($p<0.05$) in weight, diameter and height were observed in cookies samples blended with 25% whole chia flour. Meanwhile, significant increase ($p<0.05$) in volume and specific volume were observed by the whole replacement of egg with chia gel in cookies samples in comparing with the control ones. Significant differences ($p<0.5$) were observed amongst cake samples in weight, volume and specific volume. Cake samples with completely egg substitution with chia gel recorded the highest weight and volume. The partial substitution of wheat flour by 25% chia seed flour caused significant increasing ($p<0.05$) in protein, ash, fat and total energy and significant decreasing ($p<0.05$) in moisture and carbohydrate in both cookies and cake samples in comparing with control ones. On the other hand total replacement of eggs by chia gel in cookies caused a significant increasing ($p<0.05$) in all chemical composition parameters except carbohydrate which decreased by adding chia flour comparing with the control samples. Protein, carbohydrate and total energy values were decreased by substitution egg in cakes with chia gel. Also, cookies and cake samples substituted with chia flour or gel recorded higher values in protein, amino acid content, amino acid scores (AAS), essential amino acid index (EAAI), biological value (BV) and protein efficiency ratio (PER) than the control samples. In conclusion, the substitution of cookies and cake flour and eggs with chia seeds flour and gel were affected on their nutritive value, functional properties and sensory characteristics. Thus, we recommended to use chia seeds flour and gel in our daily meals and dishes in general and in particular for the people who suffering from healthy problems as the result of consumption food products containing egg.

Key words: *Salvia hispanica L.*, nutritive value, functional properties, amino acids, protein quality, sensory characteristics

Introduction

Thousands years ago chia seeds (*Salvia hispanica* L.) has been planted in Mexico. Several studies of cheia seeds 'features has proved that it has a great importance in the nutrient field, because of the high content of linolenic acid, dietary fiber, and protein (**Peiretti and Gai, 2009**). It has been known that the chia seed is full of oil, protein, dietary fiber, minerals and polyphenolic compounds (**Capitani, *et al.*, 2012**). Also, the chia flour is substantial with protein , and is accomplished with all eight essential amino acids. Also, it is full of iron, vitamin C, omega- 3-fatty acids, and antioxidants, which are considered very useful to have healthy skin, hair and nail. In spite of adding such an active ingredient to get nutritional advantages, it was great challenge to achieve the goal of enriched food products with certain characteristics like being fresh, sensory, appearance, conditions of storage, easy preparation and safe moods (**Drusch and Mannino, 2009**).

The chia seed contain oil content about 25 to 35% and full of n-3 polyunsaturated fatty acids (**Taga *et al.*, 1984**), it also have a protein content about 17% to 24%, and a fiber content of 18% to 22% (**Ayerza and Coates, 2000**).These seeds are full of polyunsaturated fatty acids, specially , the omega-3 (50-57 g/100 g) and omega-6 (17-26 g/100 g) fatty acids (**Reyes-Caudillo et al., 2008**). Those great researches have proved noticeable nutritional features of the chia seeds, because of its its high oil content, protein, antioxidants, minerals and dietary fiber, chia seeds are recommended for exhaustion (**Ixtaina *et al.*, 2008**). High proportion of omega-3/omega-6 is confirmed for health, and may cause an improvement of chronic diseases. It can also develop the proportion of dietary by rising the omega-3 fatty acids ,which is important for brain functions and for handing cardiovascular disease, arthritis and cancer (**Simopoulos and Cleland, 200**3).the structure of the seeds looks so charming,as being a significant source of protein, beside high quantities of natural antioxidants such as phenolic compounds ,involving chlorogenic and caffeic acids, quercetin, and kaempferol, also as high dietary fiber content (>30% of the total weight) (**Martínez *et al.*, 2012**).

Many authors reported that the advantages of chia seeds are qualified and important for health and nutrition because of their bioactive contents which are proved to elevate health benefit (**Vuksan *et al.*, 2010**), by developing biological markers concerning dyslipidemia, inflammation, cardiovascular disease, glucose homeostasis, and insulin resistance, without any side effects. Chia seeds can be used as a complete seed or grinded, or grounded. In food, oil extracted from those seeds can be used also (**Capitani *et al.,* 2012**). Chia seeds are also used as a nutritional supplements in the United States, Latin America, and Australia, as well in the production of bars, breakfast cereals, and cookies (**Martínez *et al.,* 2012**).

The manufacture of baking is developing rapidly, and the products became very likable among all people. It is obvious that fast snakes that have likable advantages like the wide consumer base, and long shelf-life, and suitable eaten fineness (**Hooda and Jood, 2005**).It is well known that bakery products are exhausting largely and become an essential strain of food all over the world. One of the most famous bakery products is cake that is exhausting by people all over the world (**Kotsianis *et al.,* 2002**). Cookies, now admitted universally, and consuming in developing countries, cookies are made from wheat flour in conventional ways (**Shaha *et al.,* 2014).**

It is hard to find suitable materials to replace fat materials, as they are in a need to supply at least many of the contents that help in the final agreement of a food product (**Hahn, 1998**). In this field, research proved that carbohydrates or a mix of carbohydrates and emulsifiers could be presented as a fat replacers and generate good food products (**Roller and Jones, 1996**).The total dietary fiber (TDF), has also a technological functionalities like a fat-binding, gel-forming, chelating and texturizing agent (**Esposito *et al.,* 2005**).The chia seeds have the unexpected function to forma a gelly like mass when absorbed in water. This is because of the existence of high amount of mucilages and gums. Researches have proved that chia seeds have the ability to absorb water up to 12 times their weight (**Munoz *et al.,* 2012).** Chia seeds have many significant physiochemical and functional features, that makes it more useful in food manufactures. Chia performs like a good absorber, gel forming, chelator, foam enhancer, foam enhancer, emulsifier, suspension formers, clarifying agent and as a dehydrating agent. Thus, in commerce and trading it can be widely used in producing products full of omega-3, protein, soluble and insoluble fiber and phenolic contents. So, chia is proved to be a functional food that helps in making the health of masses better (**Suri1 *et al.,* 2016**).

In this study, we attempted to develop new cereal-based products and evaluate how replacing wheat flour or eggs in cookies and cake formulation with whole chia flour or chia gel would affect the nutritional content, basic functional properties, sensory and physical characteristics of products, to reduce the consumption of flour and eggs compared to the full egg/wheat flour (control) recipes.

Materials and Methods

Materials

Chia seeds (*Salvia hispanica* L.) were obtained from National Research Center, Giza, Egypt. Other ingredients including wheat flour, sugar, oil, baking powder, milk vanilla, salt and eggs were purchased from local market, Mansoura City, Egypt. All chemicals, solvents and buffers in analytical grad were purchased from Al-Gomhoryia Company for Trading Drugs, Chemicals and Medical Instruments, Cairo, Egypt.

Methods

Chia flour and gel preparation

Whole chia flour was prepared by grinding whole chia seeds in a food processor grinder (Alarby Toshiba, Benha, Egypt) and then shifted through a 250 *μm* sieve, to obtain fine flour. Some part of grounded chia flour was soaked in water for 5 hour to form a firm gel to be used as an egg replacer in the preparation of cookies and cakes according to **Borneo *et al.*, (2010).**

Cookies preparation

The cookies were prepared according to the procedure described by **McWatters *et al.*, (2003)** with slight modifications. The basic ingredients used were 100 *g* of flour blend, 30*g* of hydrogenated vegetable fat, 50 *g* of sugar, 20 *g* of hydrated chia gel, 10*g* cocoa powder, 1 *g* salt, 0.5 *g* sodium bicarbonate, 0.5 *g* of ammonium bicarbonate and 0.5 *g* of baking powder. The dry ingredients were weighed and mixed thoroughly in a bowl by an electronically operated beater for 3-5 *min*. At first creaming was done by beating, shortening and sugar for incorporation air until the mixes become fluffy and smooth, then other ingredients with flour blend were kneaded. Care was taken for prevention of gluten network formation. The dough was rolled thinly on a sheeting board to a uniform thickness (8.0 *mm*) and cut out using a round scorn cutter to a diameter of 35.0 *mm*. The cut out dough pieces were baked on greased pans at 160°C for 15 *min* in a baking oven. The prepared cookies were cooled to room temperature (30 ± 2°C) and packed in high density polyethylene bags. The details of the nomenclature of the prepared cookies were as follow: 1) cookies control sample prepared with 100% wheat flour and egg, 2) wheat flour (within the control formula) was substituted with 25% chia flour (CF) in cookies, and 3) egg (within the control formula) was completely substituted with chia gel (CG) in cookies.

Cake preparation

Cake samples were prepared such as mentioned by **Sudha *et al*., (2007)**. The formula included 100 *g* flour blend, 100 *g* sugar, 120 *g* egg, 25 *g* shortening, 40 *g* refined vegetable oil, 0.5 *g* baking powder and 1.5 *g* salt. Cake batter was prepared in a Hobart mixer (N-50) using flour batter method, wherein, the flour, shortening, salt and baking powder were creamed together to get a fluffy cream; eggs and sugar were whipped together until semi-firm foam resulted. The sugar–egg foam was mixed with the creamed flour and shortening, after which the vegetable oil was added in small portions. Cake batter was poured into a wooden pan and baked at 160 °C for 1 *h*. Cakes were cooled to room temperature. The details of the nomenclature of the prepared cookies were as follow: 1) cake control sample prepared with 100% wheat flour and egg, 2) wheat flour (within the control formula) was substituted with 25% chia flour (CF) in cake and 3) egg (within the control formula) was substituted with 100% chia gel (CG) in cake

Analytical Methods

Chemical composition: Moisture, ash, crude protein, fat and crude fiber contents were determined according to the methods outlined in **A.O.A.C., (2000).** Carbohydrates were calculated by difference as mentioned as follows: Carbohydrates = 100 – (% moisture + % protein + % fat + % ash + % crude fiber).

Sensory evaluation: Sensory characteristics of cookies and cake samples were evaluated according to **Hoojjat and Zabik (1984)** where each formula was subjected to sensory analysis by 20 panelists. Each panelist was asked to assign scores 0-10 for color, flavor, taste, texture, appearance and overall acceptability.

Baking quality

Baking quality of cookies: Diameter of cookies samples was measured by Boclase (HL 474938, STECO, Germany). Also, thickness, weight, volume, specific volume of samples was determined according to standard methods **(A.A.C.C., 2000).** The spread ratio (Diameter/thickness) was calculated.

Baking quality of cakes: Volume (cm^3) and weight (*gm*) of three cake samples of each treatment were recorded. Specific volume (gm/cm^3) was calculated by dividing of the volume to weight according to the method described in **(A.A.C.C, 2000).**

Color determinations: Objective evaluation of biscuit surface color of biscuits samples was measured according to the methods of **Sapers and Douglas, (1987).** Hunter L*(luminosity) ,a*(red intensity), and b*(yellow intensity) parameters were measured with a color difference meter using a spectrocolorimeter (Tristimulus Color Machine) with the CIE lab color scale (Hunter, Lab Scan XE - Reston VA, USA) in the reflection mode. The instrument was standardized with white tile of Hunter Lab Color Standard (LX No.16379): X= 72.26, Y= 81.94 and Z= 88.14 (L*= 92.46; a*= -0.86; b*= -0.16)

Determination of Amino Acids: Amino acids content of samples was determined according to **Millipore co-operative (1987)** using HPLC system. The apparatus used is Spectra-physics Analytical, Inc. Aoogg– 600 with spectra focus optical scanning detector and spectra system UV 2000 detector and ultrasphere C18 Beckman column. The analysis was carried out using a gradient of two solvents A and B at 40°C and flow rate 1 ml / min. Separated amino acids were detected at wave length, 254 nm.

Protein quality: Essential amino acids index (EAAI) and biological value (BV) was calculated as described by **Dessouki and Hassanin (1995)**. Amino acid score (AAS) was calculated for essential amino acid by using **(Anon, 1985).** AAS = [AA/16 gN ÷ AA of (FAO/WHO)]. Protein efficiency ratio (PER): The protein efficiency ratio of the test was based on their amino acid content according to **Alsmeyer *et al.*, (1974)**. However the following equation was used:

$PER_1 = 0.684 + 0.456$ leucien – 0.047 proline

$PER_2 = 0.468 + 0.454$ leucien – 0.105 tyrosine

$BV = 49.09 + (10.53\ PER_2)$

Grams consumed to cover the daily requirements of protein and essential amino acid for children (6 – 10 years) was calculated by using RDA **(Anon, 1989).**

$$GDR\ of\ protein = 63 * 100 / (protein\ \%).$$

Percent of satisfaction of protein and essential amino acids, when consumed 250 g from given beverage (PS / 250) were calculated by using RDA **(Anon, 1989)**.

Essential amino acid, which showed the highest GDR value, is called restricting amino acid (RAA).

Statistical evaluation

The obtained results were evaluated statistically using analysis of variance as reported by **McClave and Benson (1991).**

Results and Discussion

Gross chemical composition of raw materials

Table (1) shows a comparison between chemical composition contents of wheat flour and chia flour. Wheat flour recorded 12.63± 0.35, 9.3±0.15, 0.64±0.01, 1.36±0.05, 3.70±0.26, 72.32±0.31 and 338.92±0.61 in moisture ,protein ,ash fat ,total fiber ,carbohydrates and energy, respectively meanwhile ,chia flour recorded 6.73±0.20, 22.16±0.87, 3.73±0.20, 32.39±0.12, 31.00±0.62, 3.97±1.59 and 396.1±3.93 for the same previous parameters, respectively. It could be observed that chia flour had high contents of protein, ash, fat and total fibers 22.16±0.87, 3.73±0.20, 32.39±0.12 and 31.00±0.62 respectively as compared to those of wheat flour. In the same context, **Pizarro *et al.*, (2013)** mentioned that whole chia flour had higher protein, lipid and dietary fibre contents, showing that WCF is an important source of these components. The values obtained for the proximate composition of the WCF were in agreement with the composition reported in the literature, as follows: 9-23 g protein/100 g (**Coates and Ayerza, 1996**), 25-35 g lipids/ 100 g (**Álvarez-Chávez *et al.*, 2008 and Ixtaina *et al.*, 2011**) and 18-41 g fibre/100 g (**Ayerza and Coates, 2000 and Reyes-Caudillo *et al.*, 2008**). The wheat flour had 12.41% moisture, 9.31% protein, 9.8% dry gluten, 0.74% ash and 1.55% fat, whereas chia seed flour was found to be very high in protein 17.83%, fat 21.96%, ash 4.92%, fiber 41.38% and moisture content of

3.37% (**Divyashree *et al.*, 2016**). Chia seed and its whole flour showed a high amount of lipids (32.48–33.90 % in dry matter) (**Iglesias-Puig and Haros, 2013**). With the exception of moisture, the amounts of lipids, proteins, minerals and dietary fibre were significantly higher in chia than in wheat flour. Also chia seeds have a lipid content of about 25-39 %, of which 60-70 % is n-3 fatty acids (**Peiretti and Gai, 2009**).

Table (1): Gross chemical composition of raw materials

Parameters	Samples	
	Wheat flour	Chia flour
Moisture (%)	12.63±.35	6.73±0.20
Protein (%)	9.33±0.15	22.16±0.87
Ash (%)	0.64±0.01	3.73±0.20
Fat (%)	1.36±0.05	32.39±0.12
Total fiber (%)	3.70±0.26	31.00±0.62
Carbohydrates (%)	72.32±0.31	3.97±1.59
Total energy (*kcal*)	338.92±0.61	396.1±3.93

*Each value represents the mean ± SE.

Sensory properties of cookies and cake fortified with chia seeds flour or chia gel

Data represented in Table (2) show the effect of substitution 25% wheat flour by chia flour and the replacement of egg by chia gel in cookies or cake samples in comparing with the controls. Results show that color, texture, crispness, taste and aroma values decreased significantly ($p<0.5$) by the addition of chia flour or chia gel in cookies samples as compared to the control. Data show that the control recorded the highest overall acceptability value (9.55± 0.78) followed by cookies with 100% chia gel replacement by egg (7.35±0. 95), then cookies samples with 25% chia flour addition which recorded 6.01±0.55. Also, It could be noticed from the some table that color, taste, odor, texture and appearance of values decreased significantly ($p<0.5$) by the addition of chia flour or chia gel in cake samples in comparing with the control .Overall acceptability of control recorded the highest value (19.35±0.87) followed by cake sample with 100% chia gel (17.12±1.33), then cake sample with 25% chia flour addition as recorded 14.75±1.53.

There was a statistically significant effect when replacing oil or eggs with chia gel for acceptability, color, texture, and taste (*P*_0.05). Control cake formulation obtained the highest score for all sensory characteristics evaluated **(Borneo *et al.*, 2010).** It is possible to incorporate WCF into pound cake formulations and obtain a product with good technological and sensory performances (**Pizarro *et al.*, 2013**). panelists like the cookies with 30% chia flour as much as the control sample, but the cookies with 50% chia flour is also liked and the sensory results was not significantly different from the control cookies samples ($p<0.05$) (**Shah *et al.*, 2014**). With the increase of the level of chia flour, the sensory scores for color, aroma, texture, taste and OAA of biscuits decreased and the texture of biscuits is harder (**Divyashree *et al.*, 2016**).

Baking quality of cookies and cake fortified with chia seeds flour or chia gel

Data in Table (3) and (4) showed the baking quality of cookies and cake samples prepared by the partial replacement of wheat flour with 25% chia flour or whole replacement of egg with 100% chia gel. As shown in Table (3), control samples recorded the highest spread ratio value (0.97±0.13) followed by cookies samples with 100% chia gel (0.82±0.11), then cookies samples fortified with 25% chia flour (0.33±0.10). Significant increase ($p<0.05$) in weight, diameter and height were observed in cookies samples fortified with 25% chia flour as recorded 8.61±0.28, 4.21±0.14 and 1.41±0.11, respectively. Meanwhile significant increase ($p<0.05$) in volume and specific volume were observed by the whole replacement of egg by chia gel in cookies samples in comparing with the control as recorded (29.5±0.18 and 3.59±0.13), respectively.

Results in Table 4 show the baking quality values of cake samples in weight (*g*), volume (*cm*) and specific volume. Significant differences ($p<0.5$) were observed between samples in weight, volume and specific volume. Data show 100% egg substitution with chia gel cakes recorded the highest weight (195.42±0.23) *gm* and volume (340.25±0.14) *cm* followed by control cake samples which recorded 171.56±0.40 *gm* for weight and 352.5±0.17 *cm* for volume, whereas cake samples fortified with 25% chia flour recoded 162.21±0.36 *gm* for weight and 320.5±0.21 *cm* for volume.

Table (3): Baking quality of cookies fortified with chia seeds flour or chia gel

Samples	Weight (gm)	Volume (cm)	Specific volume	Diameter	Height	Spread Ratio
Cookies (control)	7.38±0.25[c]	16.5±0.20[c]	2.24±0.24[c]	1.15±0.14[c]	1.12±0.12[c]	0.97±0.13[a]
25% WF substitution with CF	8.61±0.28[a]	25.25±0.21[b]	2.93±0.23[b]	4.21±0.17[a]	1.41±0.11[a]	0.33±0.10[c]
100% Egg substitution with CG	8.22±0.36[b]	29.5±0.18[a]	3.59±0.13[a]	1.46±0.12[b]	1.19±0.10[b]	0.82±0.11[b]

*WF, wheat flour; CF, chia flour; CG, chia gel. Each value represents the mean ± SE. Means with the different letters in the same row are significantly different (P≤ 0.05).

Table(4): Baking quality of cake fortified with chia seeds flour or chia gel

Samples	Weight (gm)	Volume (cm)	Specific volume
Cake (control)	171.56±0.40[b]	325.5±0.17[b]	1.90±0.24[b]
25% WF substitution with CF	162.21±0.36[c]	320.5±0.21[c]	1.98±0.18[a]
100% Egg substitution with CG	195.42±0.23[a]	340.25±0.14[a]	1.74±0.21[c]

*WF, wheat flour; CF, chia flour; CG, chia gel. Each value represents the mean ± SE. Means with the different letters in the same row are significantly different (P≤ 0.05).

Cake weight was not affected by chia gel in the formulation, although cake volume was lower as the percentage of substitution increased when substituting oil or eggs within the cake formulation (with chia gel) ***(Borneo et al., 2010***). The specific volume remained high with WCF concentrations in the range from 0 to 15 g/100 g flour mixture and HVF concentrations in the range from 16 to 20 g/100 g flour mixture (***Pizarro et al., 2013).***

It is evident that the increase in the addition of chia flour results an increase in weight of the biscuits. The control biscuits weighed 6.86 g when compared to 9.23 g of composite flour biscuits 20% chia seed flour (***Divyashree et al., 2016***). The increase in weight of biscuits may be due to increase in density of biscuits (***Francine et al. 2011***) and also due to ability of chia seed flour to retain oil during biscuit baking (***Rufeng et al. 1995***). The diameter of the biscuit decreased and thickness increased as the level of incorporation of chia flour increased. The decrease in diameter and increase in thickness affected the spread ratio of biscuits which decreased from 10.55 to 6.89 (***Divyashree et al., 2016***). Good quality cookies or biscuits should have a high spread ratio (***Miller and Hoseney, 1997***).

Color characteristics of cookies and cake fortified with chia seeds flour or chia gel

Color characteristics were measured in the surface and the bottom of cookies samples and the data obtained represented in Table (5). It could be notice that the partial replacement of wheat flour with 25% chia flour and the total replacement of eggs by chia gel caused a significant decreasing ($p<0.5$) in luminosity, red intensity, and yellow intensity in the bottom and the surface of cookies in comparing with the control. Luminosity and yellow intensity values of the cookies bottom increased significantly ($p<0.5$) (48.25±0.03 and 23.39±0.02) ,whereas red intensity value decreased (4.55±0.04) by replacing whole egg with chia gel as compared to those of cookies samples fortified with 25% chia flour. Meanwhile, luminosity, red intensity and yellow intensity of the cookies surface increased significantly (41.82±0.02, 13.21±0.02 and 28.85±0.01), respectively by replacing egg with chia gel in cookies as compared to those of the surface of cookies samples fortified with 25% chia flour as recorded 36.66±0.05, 10.33±0.01 and 21.98±0.03), respectively.

On the other hand L, a and b values decreased significantly ($p<0.5$) in the crust and crumb of cake samples by the partial replacement of wheat flour with 25 % chia flour or the whole replacement of egg with chia gel in cake samples in comparing with the control. Luminosity and yellow intensity recorded higher values 50.31±0.03 and 29.91±0.01 in the crust of cake samples prepared by replacing whole egg with chia gel than those of cake samples fortified with 25% chia flour which recorded 45.78±0.04 and 28.13±0.02, respectively, whereas the crumb of cake samples fortified with 25% chia flour recorded higher values in red and yellow intensity (5.82±0.01 and 21.26±0.02) as compared to those of the crumb of cake samples prepared by replacing egg with chia gel as recorded 5.31±0.02 and 20.71±0.04, respectively.

The addition of 15 g whole chia flour/ 100 g flour mixture decreased the values of color characteristics and compared to cake with no WCF addition (***Borneo et al., 2010***). Wheat flour can be fully replaced by whole chia flour in gluten free baking, but major disadvantage is the colour of the flour, which is slightly blackish or brownish. The colour of the cookies became increasingly dark by using high proportion of chia flour by

Table (5): Color parameters of cookies and cake fortified with chia seeds flour or chia gel.

Samples	Bottom			Surface		
	L*	a*	b*	L*	A*	B*
			Chia cookies			
Cookies (control)	54.03±0.01[a]	7.02±0.02[a]	34.06±0.01[a]	39.73±0.01[b]	17.65±0.01[a]	30.74±0.06[a]
25% WF substitution with CF	38.40±0.04[c]	5.34±0.02[b]	20.97±0.06[c]	36.66±0.05[c]	10.33±0.01[c]	21.98±0.03[c]
100% Egg substitution with CG	48.25±0.03[b]	4.55±0.04[c]	23.39±0.02[b]	41.82±0.02[a]	13.21±0.02[b]	28.85±0.01[b]
			Chia cakes			
Samples	Crust			Crumb		
	L*	a*	b*	L*	a*	B*
Cake (control)	61.84±0.02[a]	15.03±0.02[a]	41.08±0.01[a]	68.01±0.01[a]	4.28±0.01[c]	33.52±0.01[a]
25% WF substitution with CF	45.78±0.04[c]	13.45±0.01[b]	28.13±0.02[c]	44.73±0.03[c]	5.82±0.01[a]	21.26±0.02[b]
100% Egg substitution with CG	50.31±0.03[b]	12.15±0.01[c]	29.91±0.01[b]	45.68±0.05[b]	5.31±0.02[b]	20.71±0.04[c]

*WF, wheat flour; CF, chia flour; CG, chia gel. Each value represents the mean ± SE. Means with the different letters in the same row are significantly different (P≤ 0.05).

replacing wheat flour by whole chia flour (***Shah et al., 2014***). L* (Luminosity) of the biscuits decreased from 68.41 in control biscuits to 51.24 with the addition of 20% chia seed flour. The redness (a*) value of biscuits increased and yellowness (b*) value decreased with the increasing level of replacement of wheat flour (***Shivani & Sudha, 2011 and Divyashree et al., 2016)***.

Chemical composition of cookies and cake fortified with chia seeds flour or chia gel

Data in Table (6) represent the effect of partial replacement of refined wheat flour by 25% chia seeds flour and the total replacement of eggs by chia gel in comparing with control cookies & cake formulation on chemical composition. As shown in the table, the partial replacement of

Table (6): Chemical composition of cookies and cake fortified with chia seeds flour or chia gel.

Samples	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Carbohydrates (%)	Energy (*kcal*)
Chia cookies						
Cookies (control)	2.85±0.06[b]	8.41±0.19[b]	0.05±0.01[c]	23.27±0.80[a]	65.40±0.87[a]	504.72±3.84[a]
25% WF substitution with CF	2.28±0.06[b]	10.90±0.25[a]	0.54±0.01[a]	24.60±2.35[a]	61.54±2.63[a]	511.72±11.61[a]
100% Egg substitution with CG	4.21±0.65[a]	8.50±0.04[b]	0.39±0.02[b]	25.57±1.68[a]	61.32±1.54[a]	509.39±9.96[a]
Samples	Chia cakes					
	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Carbohydrates (%)	Energy (*kcal*)
Cake (control)	21.24±0.23[ab]	7.60±0.30[b]	0.34±0.02[b]	39.85±0.32[a]	30.96±0.20[a]	512.93±2.09[a]
25% WF substitution with CF	20.23±0.20[b]	9.00±0.10[a]	0.74±0.02[a]	41.22±1.46[a]	28.95±1.15[a]	521.47±7.22436[a]
100% Egg substitution with CG	22.02±0.62[a]	6.70±0.30[c]	0.66±0.09[a]	40.63±1.56[a]	29.98± 2.39[a]	512.42±5.59[a]

*WF, wheat flour; CF, chia flour; CG, chia gel. Each value represents the mean ± SE.
Means with the different letters in the same row are significantly different (P≤ 0.05).

wheat flour by 25% chia seed flour caused significant increasing (p<0.5) in protein, ash ,fat & energy and significant decreasing (p<0.5) in moisture and carbohydrate in both cookies and cake samples in comparing with control.

On the other hand total replacement of eggs by chia gel caused a significant increasing (p<0.5) in cookies in regarding chemical composition parameters except carbohydrate which decreased by adding chia flour comparing with the control. Whereas data in the same Table show that protein, carbohydrate and energy values decreased by replacing egg in cakes with chia gel as recorded 6.70±0.30, 29.98±2.39 and 512.42±5.59, respectively. meanwhile, moisture ,ash and fat increased significantly (p<0.5) as recorded 22.02±0.62, 066±0.09 and 40.63±1.56, respectively in 100% chia gel cakes comparing with those of 100% egg cakes (control) which recorded 21.24±0.23, 0.34±0.02 and 39.85, respectively. Control cake contained 335 kcal, 10.7 g total fat, 1.7 g saturated fat, and 28.4% energy from fat per 100-g cake (**Borneo *et al.*, 2010**). The increased ash content of 7.33g/100g flour in cookies sample with 50% chia flour was due to high percentage of mineral content present in chia flour. As the 0% chia control sample contained the lowest protein, lipids and dietary fiber contents, with an increasing trend with the 30% and 50% addition of chia which indicated that chia can significantly increase protein, lipids and fiber contents in the cookies like product **(Reyes-Caudillo *et al.*, 2008 and Shah *et al.*, 2014**).

Amino acids contents of cookies and cakes substituted with chia seeds flour or chia gel

Data in Table (7) show that the percentage of essential amino acid contents (EAA) recorded 35.780, 45.628 and 31.531% for the cookies control samples, cookies with 25% wheat flour substitution by chia flour and cookies with 100% egg substitution by chia gel, respectively. However, EAA percentage recorded 41.727, 40.993 and 39.832 for cake control, 25% wheat flour substitution by chia flour cake and 100% egg substitution by chia gel cake, respectively. On the other hand, the percentage of nonessential amino acid contents (NEAA) recorded 64.219, 54.37 and 68.468% for cookies control samples, cookies fortified with 25% chia flour and cookies with 100% egg substitution by chia gel, respectively, whereas NEAA percentage recorded 58.285, 59.006 and 60.167 % for cake control samples, cake fortified with 25 chia flour and cake with100% egg substitution by chia gel, respectively. It could be noticed that partial replacement of wheat flour with 25% chia flour decreased total amino (TAA) acid values in cookies samples (87.49 *g/100g*), whereas increased total amino acid value in cake samples (98.647*g*) as compared to those of cake control (77.877*g*). Meanwhile the total replacement of egg with 100% chia gel increased TAA values in cookies samples (91.579*g*) and cake samples (82.35*g*) as compared to those of cookies and cake controls.

The average protein content varies from 15 *per cent* to 23 *per cent* according to the location where the seeds have been grown (**Ayerza and Coates, 2001**). Chia seeds (*per 100g*) contain higher amount of protein (16.54 *g*) as compared to other grains like wheat (11.8 *g*), oats (13.6 *g*), barley (11.5 *g*), rice (6.8 *g*) and corn (11.1 *g*) (**USDA, 2016 and Gopalan *et al.*, 2007**). Average amino-acid composition of chia seeds Amino acid (*g*

Table: (7) Amino acids contents of cookies and cakes fortified with chia seeds flour or chia gel

	Cookies (control)	25% WF substitution with CF	100 % egg substitution with CG	Cake (control)	25% WF substitution with CF	100 % egg substitution with CG
Essential amino acids (EAA)						
Threonine	2.619	2.477	2.941	2.631	3.888	2.537
Valine	4.047	4.128	4.35	4.210	5.555	4.029
Iso-leucine	3.214	3.302	4.00	4.210	3.888	4.149
Leucine	6.071	5.688	7.764	7.105	7.555	7.164
Phenylalanine	4.880	4.403	5.294	4.210	5.111	4.328
Histidine	2.023	2.201	2.352	1.842	2.333	1.940
Lysine	2.380	2.660	2.470	3.157	3.888	2.686
Arginine	3.690	4.862	4.705	3.289	5.444	4.029
Methionine	2.380	2.844	2.00	1.842	2.777	1.940
Tryptophan	-	-	-	-	-	-
TEAA	31.304	32.565	28.876	32.496	40.439	32.802
EAA (%)	35.780	45.628	31.531	41.727	40.993	39.832
Non Essential amino acids						
Aspartic	4.642	5.688	5.764	5.921	7.333	5.970
Serine	4.404	3.302	4.823	3.684	5.66	3.283
Glutamic	25.595	10.275	31.176	18.684	25.444	22.238
Glycine	3.095	3.027	3.882	3.157	3.555	3.432
Alanine	3.452	3.211	3.529	3.289	4.333	3.283
Tyrosine	3.452	3.027	3.529	3.157	4.555	3.134
Proline	9.166	7.064	8.00	5.657	5.44	6.268
Cystine	2.380	3.211	2.00	1.842	1.888	1.940
TNEAA	56.186	38.805	62.703	45.391	58.208	49.548
NEAA (%)	64.219	54.37	68.468	58.285	59.006	60.167
TAA	87.49	71.37	91.579	77.877	98.647	82.35

WF, wheat flour; CF, chia flour; CG, chia gel.

per 100g) according to **USDA National Nutrient Databas (2016)** recorded 2.143, 3.500, 0.709, 0.436, 0.801, 1.371, 0.588, 0.970 and 0.407 for Arginine, Glutamic acid, Threonine, Tryptophan, Isoleucine, Leucine, Methionine, Lysine and Cystine, respectively. While, Phenylalanine, Tyrosine, Histidine, Valine, Alanine, Glycine, Aspartic acid, Proline and Serine recorded 1.016, 0.536, 0.531, 0.950, 1.044, 0.943, 1.689, 0.776 and1.049, respectively.Chia seeds contain all the essential amino acids, particularly lysine, leucine, isoleucine and valine (**Lin *et al.,* 1994**). The protein content of chia seed was found to be 23.4%. Seeds were found to contain niacin, riboflavin, and thiamin at a concentration of 83, 2 and 14 μg/g seed, respectively (**Bushway *et al.,* 1981**). Chia seeds protein content is higher (19–23%) than most of the traditionally utilised grains, including wheat (14%), corn (14%), rice (8.5%), oats (15.3%) and barley (9.2%). Chia seeds contain all of the essential amino acids, in particular leucine, lysine, valine, and isoleucine (4.15, 2.99, 2.85, and 2.42 g/100 g proteins, respectively) (**Sandoval-Oliveros and Peredes-Lopez, 2012**).

Essential amino acids (EAA) of cookies and cakes fortified with chia seeds flour or chia gel comparing with hen's egg

Data in Table (8) compared essential amino acid (EAA) contents of cookies & cake samples control and its treatments to hen's egg protein as a reference. Data show that cake control samples and cake samples with 100% egg substitution by chia gel had a high content of iso lysine as compared to those of hen's egg protein. Also, data show that all samples had a higher content of lysine those of than hen's egg protein except cookies control samples which had a low content of the same amino acid comparing with those of hen's egg protein. Methionine +cysteine recorded high values in cookies control samples, cookies fortified with 25% chia flour, cake samples fortified with 25% chia flour, and cake samples fortified with 100% chia gel as compared to those of hen's egg. It could be noticed that all samples had a higher contents of phenylalanine +tyrosine than hen's egg protein, whereas the cake sample fortified with 25% chia flour recorded higher content of therionine as compared to those of hen's egg protein. These variances in EAA is actually due to the differences levels of chia flour and chia gel which added to cookies or cake samples during processing and its effect in amino acid composition of these products.

The amino acid composition of defatted flour showed that chia seeds are a good source of sulfur, aspartic, and glutamic amino acids (**Sandoval-Oliveros and Paredes-López, 2013**). The profile of amino acids in chia seeds has been reported previously by **Ayerza and Coates (2005*)*** which is in general agreement with that of this study.

Essential amino acids (EAA) of cookies and cakes fortified with chia seeds flour or chia gel in relative to FAO/WHO protein pattern

Results in Table (9) show the essential amino acid (EAA) of cookies & cake samples as controls and their treatments in relative to FAO/WHO protein reference pattern. Data show that cookies control samples recorded high contents of methionine + cysteine and phenylalanine + tyrosine, however low contents of lysine, leucine+ isoleucine, therionine and valine were detected as compared to those of FAO/WHO protein reference pattern. Cookies fortified with 25% chia flour recorded high content of phenylalanine +tyrosine, whereas cookies fortified with 100% chia gel recorded high content of leucine + isoleucine, methionine + cystine and phenylalanine + tyrosine as compared to those of FAO/WHO protein reference pattern. On the other hand, data show that cake control sample, recorded high contents of leucine + isoleucine, meth + cyst and phenylalanine + tyrosine, however low contents of lysine, therionine and valine were found as compared to those of FAO/WHO protein reference pattern. It could be noticed that all samples had the lowest content of lysine as compared to FAO/WHO protein reference pattern, so the first restricting amino acid (RAA) in all cookies and cake samples was lysine.

Table (8): Essential amino acids (EAA) of cookies and cakes blended with chia seeds flour or chia gel in comparing with hen's egg (mg)

EAA	Hen's egg	Cookies (control)	25% WF substitution with CF	100 % egg substitution with CG	Cake (control)	25% WF substitution with CF	100 % egg substitution with CG
Valine	14.687	12.879	13.005	12.664	13.008	14.205	12.627
Iso-leucine	11.889	10.228	10.403	11.645	13.008	9.942	13.003
Leucine	18.348	19.320	17.920	22.603	21.953	19.319	22.452
Methionine + Cystine	11.756	15.148	19.076	11.645	11.383	11.929	12.160
Phenylalanine + Tyrosine	20.351	26.515	23.408	25.687	22.762	24.718	23.386
Lysine	13.396	7.574	8.380	7.191	9.754	9.942	8.418
Threonine	9.572	8.334	7.804	8.562	8.129	9.942	7.951

* WF, wheat flour; CF, chia flour; CG, chia gel.

Low levels of lysine were observed in chia seeds (**Sandoval-Oliveros and Paredes-López, 2013**). The abundance of sulfur amino acids suggests that they may be intimately involved in maintaining the tertiary and quaternary structure of the proteins, and the presence of high levels of glutamic acid has been of interest in the food industry due to the potential of this amino acid to stimulate the central nervous and immunologic systems in humans (**Paredes-Lopez, 1991**). The potential of aspartic acid rich foods in the hormonal regulation for the proper functioning of the nervous system has been reported. In general, the protein quality of chia has been demonstrated to be higher than that of some cereals and oilseeds; this may represent an important nutraceutical contribution to foods that contain chia seeds and isolated globulins as ingredients (**Derbyshire *et al.*, 1976**).

Table (9): Essential amino acids (EAA) of cookies and cakes fortified with chia seeds flour or chia gel in relative to FAO/WHO protein pattern

Amino Acids	Lysine	Leucine + Iso-leucine	Methionine + Cystine	Phenylalanine + Tyrosine	Threonine	Valine	RAA
Scoring pattern FAO/ WHO (adults)	5.50	11.00	3.50	6.08	4.40	4.69	
Cookies (control)	2.380	9.285	4.76	8.332	2.619	4.047	Lysine
% from FAO/ WHO	43.27	84.409	136.00	137.03	59.522	86.289	
25% WF substitution with CF	2.660	8.99	6.055	7.43	2.477	4.128	Lysine
% from FAO/ WHO	48.363	81.727	173	122.203	56.295	88.017	
100 % egg substitution with CG	2.470	11.764	4.00	8.823	2.941	4.35	Lysine
% from FAO/ WHO	44.909	106.945	114.285	145.115	66.840	92.750	
Cake (control)	3.157	11.315	3.684	7.367	2.631	4.210	Lysine
% from FAO/ WHO	57.4	102.863	105.257	121.167	59.795	89.765	
25% WF substitution with CF	3.888	11.443	4.665	9.666	3.888	5.555	Lysine
% from FAO/ WHO	70.690	104.027	133.285	158.980	88.363	118.443	
100 % egg substitution with CG	2.686	11.313	3.88	7.462	2.537	4.029	Lysine
% from FAO/ WHO	48.836	102.845	110.857	122.730	57.659	85.906	

* WF, wheat flour; CF, chia flour; CG, chia gel; RAA, restricting amino acids

Essential amino acids composition; calculated GDR and PS (mg) of cookies and cakes fortified with chia seeds flour or chia gel

Data concerning essential amino acid composition (g/100g sample), grams consumed to cover the daily requirement for adults (GDR) and percent of satisfaction of daily need of adults (PS/150*g*) of cookies and cake samples as controls and their treatments are shown in Table (10). The composition of EAA of all cookies and cake (g/100g sample) was lower than the RDA grams for adults, GDR of lysine which as restricting amino acid (RAA) were 504.00, 347.586 and 480.00 for cookies control samples, cookies fortified with 25% chia flour, cookies fortified with 100% chia gel, respectively. Whereas GDR of lysine (RAA) recorded 420.0, 288.0 and 560.0 for cake control samples, cake fortified with 25% flour and cake fortified with 100% chia gel, respectively. Also it could be noticed that PS/150*g* of RAA of the cookies control, cookies fortified with 25% chia flour and cookies fortified with 100% chia gel, cake control, cake fortified

with 25% chia flour and cake fortified with 100% chia gel were 29.761, 43.154, 31.25, 35.714, 52.083 and 26.785%, respectively. Cake fortified with 25% chia flour recorded the lowest GDR of RAA and the highest value of PS/150*g* followed by cookies fortified with 25% chia flour, then cake control samples, then cookies fortified with 100% chia gel, then cookies samples, then cake fortified with 100% chia gel which gained the highest value of GDR and the lowest value of PS/150*g*.

Chia seeds are higher in protein content and amino acid content than most traditionally utilized grains; chia seeds have a good balance of amino acid this represent an excellent alternative source of protein for human consumption (**Monroy-Torres *et al.,* 2008**). In the case of the seed flour, the coverage of the amino acid requirement for infants was about 100% satisfactory for the sulfur amino acids; the coverage for the remaining essential amino acids ranged from 52 to 76%. On the other hand, the required coverage was much better for adults; the essential amino acids in seed flour varied from 66 to 126%. The globulin fraction exhibited ranges of coverage of requirements wider than those of seed flour, 27−210% for infants and 34−288% for adults; the lowest values corresponded to lysine in view of the known limitations of cereals in this amino acid and its partial destruction during the protein fraction isolation (**Sandoval-Oliveros and Paredes-López, 2013**)

Protein quality of cookies and cakes fortified with chia seeds flour and gel

Data concerning the protein quality of cookies and cake samples as controls and their treatments are shown in Table (11). Data show that the amino acid score (AAS) values were over 1.0 for all individual essential amino acids (EAA) in all cookies and cake samples. This indicated that protein of the cookies or cake samples produced by (25% substitution wheat flour by chia flour & 100% substitution egg by chia gel) consider a complete protein and have high nutritional value of protein when compared to FAO/WHO protein reference pattern. It could be observed that cookies fortified with 100% chia gel scored the highest protein quality as indicated by the highest value of essential amino acid index (EAAI) (90.788) and biological value (BV) (87.229) in comparing with cookies control which recorded 83.445 and 79.226 for EAAI and PV, respectively.

On the other hand, results show that cake fortified with 25% chia flour scored the highest protein quality as indicated by the highest value of EAAI (88.827) and BV (85.092), followed by cake fortified with 100% chia gel which recorded 88.556 and 84.797 for EAAI and BV, respectively in comparing with protein quality of cake control. Data in the same table show that the protein efficiency ratio recorded high values for cookies and cake samples fortified with chia flour or chia gel comparing with cookies and cake control samples.

The protein quality of chia has been demonstrated to be higher than that of common cereals and oil seeds **(Weber *et al.*, 1991; Reyes-Caudillo *et al.*, 2008)**, which is in accordance with our results. In a study performed by **Sandoval-Oliveros and Paredes-López (2013**), the percentage of essential amino acids was about 50% (46.5%), which is much higher than the corresponding values reported for soybean (41.0%) and safflower (38.1%); this is an important aspect in favor of the quality of the chia seed proteins (**Paredes-Lopez, 1991**).

Conclusion

The substitution of cookies and cake flour and eggs with chia seeds flour and gel were affected on their nutritive value, functional properties and sensory characteristics. Thus, we recommended to use chia seeds flour and gel in our daily meals and dishes in general and in particular for the people who suffering from healthy problems as the result of consumption food products containing egg.

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Journal of Home Economics

مجلة بحوث الاقتصاد المنزلى
مجلد ٢٦ – العدد (٤) - ٢٠١٦

http://homeEcon.menofia.edu.eg **ISSN 1110-2578**

تأثير استبدال دقيق بذور وجل التشيا (*Salvia hispanica* L.) لدقيق القمح والبيض على جودة الكوكيز والكعك

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صممت الدراسة الحالية بهدف تقدير الخواص الحسيه والطبيعية والتغذويه لكل من الكوكيز والكيك المصنع باستخدام دقيق أو جل بذور التشيا والمصنعه بطريقتين: الأولى الإستبدال الجزئي لدقيق القمح (استخلاص ٧٢%) بدقيق التشيا بنسبة ٢٥%، والثانية الإستبدال الكلي للبيض بجل التشيا مقارنة بعينات الكوكيز والكيك كعينات ضابطة. ولقد أثبتت النتائج حصول العينات الضابطة على أعلى درجات القبول العام ثم تلتها العينات التى تم فيها إستبدال البيض كاملا بجل التشيا ثم المضاف إليها ٢٥% دقيق بذور التشيا. بالنسبه لعينات الكوكيز أوضحت النتائج حدوث زيادة معنوية في الوزن والطول والقطر للعينات المدعمه بنسبة ٢٥% من دقيق التشيا بينما حدثت زيادة معنويه في الحجم والحجم النوعي عند استبدال البيض كلياً بجل التشيا مقارنة بالعينات الضابطة. أما بالنسبه لعينات الكيك فقد لوحظ حدوث فروق معنويه في الوزن والحجم والوزن النوعي، في حين أدى الإستبدال الكامل للبيض بجل التشيا إلى زيادة حجم ووزن الكيك مقارنةً بالعينات الضابطة. أظهرت النتائج أن الإستبدال الجزئي لدقيق القمح بنسبة ٢٥% من دقيق التشيا إلى حدوث زيادة معنوية في كل من البروتين والرماد والدهون والطاقة في حين أدى إلى إنخفاض معنوي في الرطوبة والكربوهيدرات لكل من عينات الكوكيز والكيك. كما أدى الإستبدال الكلي للبيض بجل التشيا إلى زيادة معنويه في جميع المكونات الكيميائية فيما عدا الكربوهيدرات والطاقة لعينات الكوكيز مقارنةً بالعينات الضابطة، بينما إنخفضت نسبة كل من البروتين والكربوهيدرات والطاقة بهذا الإستبدال في عينات الكيك مقارنة بالعينات الضابطة. وأخيرا.. أثبتت النتائج أن عينات الكوكيز والكيك المدعمة بدقيق وجل بذور التشيا ذات محتوى عالي من مجموع الأحماض الأمينية، ومؤشر الأحماض الأمينيه الأساسيه، ومؤشر جودة البروتين، بالإضافه إلى معدل كفاءة البروتين. وخلاصة القول فإن إستبدال دقيق القمح والبيض فى الكوكيز والكعك بدقيق وجل بذور التشيا قد أثر إيجابيا على قيمتها الغذائية وخواصها الوظيفية وخصائصها الحسية. لذلك فنحن نوصى بإستخدام دقيق وجل بذور التشيا فى وجباتنا وأطباقنا اليومية بصفة عامة وللأشخاص الذين يعانون من مشاكل صحية نتيجة تناول المنتجات الغذائية المحتوية على البيض.

الكلمات المفتاحية: التشيا ، القيمة الغذائية، الخواص الوظيفية، الأحماض الأمينية، جودة البروتين، الخصائص الحسية.