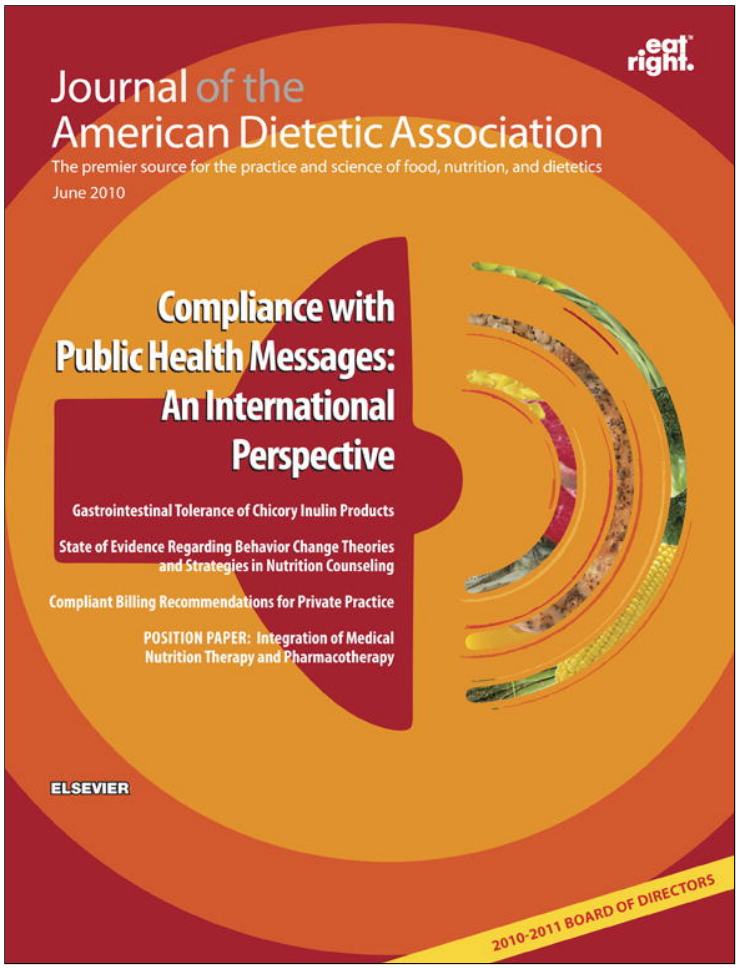

American Dietetic Association

RESEARCH

Research and Professional Briefs

Chia (*Salvia hispanica* L) Gel Can Be Used as Egg or Oil Replacer in Cake Formulations

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ABSTRACT

This study determined the overall acceptability, sensory characteristics, functional properties, and nutrient content of cakes made using chia (*Salvia hispanica* L) gel as a replacement for oil or eggs. Chia gel was used to replace 25%, 50%, and 75% of oil or eggs in a control cake formulation. Seventy-five untrained panelists participated in rating cakes on a seven-point hedonic scale. Analysis of variance conducted on the sensory characteristics and overall acceptability indicated a statistically significant effect when replacing oil or eggs for color, taste, texture, and overall acceptability ($P<0.05$). Post hoc analysis (using Fisher's least significant difference method) indicated that the 25% chia gel cakes were not significantly different from the control for color, taste, texture, and overall acceptability. The 50% oil substituted (with chia gel) cake, compared to control, had 36 fewer kilocalories and 4 g less fat per 100-g portion. Cake weight was not affected by chia gel in the formulation, although cake volume was lower as the percentage of substitution increased. Symmetry was generally not affected. This study demonstrates that chia gel can replace as much as 25% of oil or eggs in cakes while yielding a more nutritious product with acceptable sensory characteristics.

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Risk of cardiovascular disease, type 2 diabetes, and colorectal cancer has been increasing in developed countries (1). Risk of such illnesses increases with obesity (2). Diet and lifestyle can be modified to prevent and lower the risks associated with excess body weight. Despite cultural differences in food consumption and cuisines worldwide, there is epidemiologic evidence that diets which promote health are high in dietary fiber, relatively high in n-3 fatty acids, and low in saturated fat, *trans* fat, and dietary cholesterol (3). Notably, diets that promote a healthy lifestyle are those rich in fruits and vegetables, legumes, whole grains, and fish (4-6). One strategy for lowering fat consumption is to develop low-fat products. However, fat contributes to the appearance, texture, flavor, and mouthfeel in foods (7). These sensory properties tend to suffer with the replacement of fats in processed foods. Suitable materials to be used as fat replacers are difficult to find (8) because they need to provide, at least partially, many of the properties that contribute to the overall acceptability of a food product. Research in this area indicates that carbohydrates or a mix of carbohydrates and emulsifiers may act as fat replacers and produce acceptable food products (9).

The seeds of *Salvia hispanica* L, commonly known as chia seeds, were an important staple food for Mesoamericans in pre-Columbian times (10). Chia has been cultivated in Mexico for thousands of years, and recent evaluation of its properties and possible uses has shown that it has a high nutritional value with high contents of linolenic acid, dietary fiber, and protein (11). Chia seeds are small with three unequal semiaxes (largest axis average 2 to 2.25 mm) (12). A popular drink is still made in Mexico by mixing chia seeds with water or lemon juice, and chia flour is used in a variety of different food preparations (13). Chia seeds have an oil content of 25% to 35%, are rich in n-3 polyunsaturated fatty acids (14), have a protein content of 17% to 24%, and a fiber content of 18% to 22% (15,16). Recently, a fiber-rich fraction was obtained by dry-fractionation of chia seeds (oil-extracted) with 55.46% of total dietary fiber content, of which 53.45% was insoluble dietary fiber and 3.01% was soluble dietary fiber (17). Also, chia seeds are promising as a source antioxidants due to the presence of polyphenols (18). Chia has received attention, among several alternative crops, for industrial production by the Northwestern Argentina Regional Project in the favorable growing conditions in the northwestern part of the country (19).

The objective of this study was to evaluate how replacing eggs or oil in a cake formulation with chia gel would affect the nutritional content, basic functional properties, and sensory characteristics of the product, compared to the full oil/egg (control) recipe.

Table 1. Nutrition content of cakes prepared using 25%, 50%, and 75% oil or egg replacement with chia gel[a]

Cake data	Control	Egg Substitution[a]			Oil Substitution[a]		
		25%	50%	75%	25%	50%	75%
Ingredient (g/100 g)							
Cake flour[b]	27.5	27.5	27.5	27.5	27.5	27.5	27.5
Sugar[c]	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Milk[d]	16.5	16.5	16.5	16.5	16.5	16.5	16.5
Eggs[e]	13.8	10.3	6.9	3.5	13.8	13.8	13.8
Chia gel[f]	0.0	3.5	6.9	10.3	2.1	4.2	2.1
Sunflower oil[g]	8.4	8.4	8.4	8.4	6.3	4.2	2.1
Double-acting baking powder[h]	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Nutrient content per 100 g serving							
Energy (kcal)	335	331	328	325	317	299	282
% energy from fat	28.4	28.0	27.6	27.2	24.3	19.7	14.5
Fat (g)	10.7	10.5	10.3	9.9	8.7	6.7	4.6
Saturated fat (g)	1.7	1.6	1.5	1.4	1.5	1.3	1.1
Total n-3 fat (mg)	27.5	86.9	145	203	64.4	101	138
Total n-6 fat (mg)	5,931	5,911	5,891	5,872	4,563	3,195	1,826
Ratio of n-6/n-3	216	68	41	29	71	32	13
Cholesterol (mg)	60.7	47.5	31.2	16.6	60.7	60.7	60.7
Carbohydrate (g)	55.4	55.5	55.6	55.8	55.5	55.6	55.7
Protein (g)	5.0	4.6	4.2	3.8	5.0	5.0	5.1
Dietary fiber (g)	0.7	0.8	0.9	1.1	0.7	0.8	0.9

[a]On the control formula, egg content or oil content was substituted with chia gel by 25%, 50%, and 75%.
[b]White, 10% protein, enriched, Molino San José, Córdoba, Argentina.
[c]Granulated (white cane), Ingenio Fronterita, Tucumán, Argentina.
[d]Whole, 3.25% milkfat, La Serenisima, Buenos Aires, Argentina.
[e]Whole eggs (True Value, Wal-Mart, Inc, Córdoba, Argentina) were opened, shells discarded, pooled, mixed, and weighed.
[f]Prepared by weighting 1 part (weight) chia seeds and 9 parts (weight) of water. Mix is allowed to stand for 30 min for gel formation; seeds were left in the gel and incorporated into the batter. Chia seeds distributed by Grandiet, Córdoba, Argentina.
[g]Molino Cañuelas, Córdoba, Argentina.
[h]Yuspe, Córdoba, Argentina.

MATERIALS AND METHODS

Materials

Cake flour (white, 10% protein, enriched, Molino San José, Córdoba, Argentina); granulated sucrose (Ingenio Fronterita, Tucumán, Argentina); sunflower oil (approximately 65% linoleic acid, Molino Cañuelas, Córdoba, Argentina); liquid 3.25% milkfat whole milk (La Serenisima, Buenos Aires, Argentina); fresh whole eggs (True Value, Wal-Mart, Inc, Córdoba, Argentina); dried chia seeds (Grandiet, Córdoba, Argentina); and a double-acting baking powder (Yuspe, Córdoba, Argentina) were all obtained locally.

Cake Preparation

All formulas used for cake preparation are reported in Table 1. Oil or eggs (within the control formula) were substituted with chia gel at levels of 25%, 50%, and 75%. Before cake preparation, chia gel was made by soaking chia seeds (one part by weight) with tap water (nine parts by weight) for 30 minutes. The exact amount of chia gel was prepared for each formulation (Table 1). Chia seeds were left in the gel and incorporated into the cake batter. All the other ingredients were weighed separately (eggs opened by hand, shells discarded, pooled, mixed, and measured by weight).

A single-bowl mixing procedure was used. All weighed ingredients were pooled, premixed for 1 minute (speed 3), and mixed for 10 minutes (speed 5) using a Kitchen-Aid Professional Mixer (Model KPM5, Kitchen Aid, Inc, St Joseph, MI). Two hundred grams of batter was weighed in a round Teflon-coated (DuPont, Wilmington, DE) metallic pan (120 mm diameter, 45 mm height) and baked (six pans each time) in a gas-fired oven for 25 minutes at 200°C. After baking, cakes were allowed to cool (20 minutes), removed from pans, and cooled (1 hour). Cakes for sensory analysis were stored in coded plastic bags. Sensory evaluation took place 4 to 6 hours after cooling.

Functional Measurements

Cakes were weighed after 1 hour of cooling. Cake volume was measured by the seed displacement method (20). Symmetry was evaluated using method 10-91 of the American Association of Cereal Chemists (21). The symmetry evaluation method is based on measuring cake height at three specific points. The symmetry value is calculated as twice the central zone height minus the lateral zone heights (high symmetry values indicate cakes mainly rise in the central part).

Nutritional Evaluation

Nutrition analysis was performed using a spreadsheet (Excel, Microsoft Inc, Redmond, WA) with appropriate

Table 2. Functional and sensory properties of cakes made with chia gel as egg or oil replacer

Characteristic	Egg Substitution[a]				Oil Substitution[a]		
	Control	25%	50%	75%	25%	50%	75%
	← mean ± standard deviation →						
Functional[b]							
Weight (g)	181 ± 1^{x}	183 ± 2^{x}	180 ± 2^{x}	180 ± 3^{x}	181 ± 2^{x}	181 ± 2^{x}	180 ± 1^{x}
Volume (cm^3)	625 ± 25^{x}	625 ± 15^{x}	466 ± 33^{y}	383 ± 42^{z}	600 ± 20^{x}	500 ± 49^{y}	400 ± 45^{z}
Central height (mm)	63 ± 2^{x}	62 ± 1^{x}	54 ± 2^{y}	49 ± 2^{y}	59 ± 2^{x}	49 ± 3^{y}	47 ± 1^{y}
Symmetry (mm)	38 ± 1^{x}	40 ± 2^{x}	38 ± 3^{x}	31 ± 3^{y}	38 ± 2^{x}	36 ± 3^{x}	35 ± 3^{x}
Sensory[c]							
Color	6.2 ± 0.7^{x}	6.5 ± 0.4^{x}	5.1 ± 1.1^{y}	5.0 ± 1.1^{y}	6.0 ± 0.7^{x}	5.1 ± 1.1^{y}	5.0 ± 1.0^{y}
Taste	5.9 ± 1.0^{x}	6.0 ± 0.9^{x}	5.3 ± 1.0^{y}	5.0 ± 0.9^{y}	5.9 ± 0.6^{x}	4.8 ± 1.4^{y}	4.5 ± 0.9^{y}
Texture	6.0 ± 0.8^{x}	6.2 ± 0.4^{x}	5.3 ± 0.9^{y}	4.5 ± 1.1^{y}	5.8 ± 1.0^{x}	4.8 ± 0.7^{y}	4.2 ± 1.2^{y}
Acceptability	6.1 ± 0.5^{x}	6.0 ± 0.7^{x}	5.2 ± 1.0^{y}	4.0 ± 1.3^{y}	6.0 ± 0.9^{x}	4.8 ± 1.2^{y}	4.1 ± 1.3^{y}

[a]For details on cake preparation formulas, see Table 1.
[b]Average of six determinations (3 cakes made on 2 different days).
[c]Cakes were evaluated of a 7-point hedonic scale: 1=dislike extremely, 2=dislike moderately, 3=dislike slightly, 4=neither dislike nor like, 5=like slightly, 6=like moderately, and 7=like extremely.
[xyz]Values followed by a different letter within each row (x, y, z) indicate (for each of oil or egg substitution group) statistically different means.

formulas. All input data were taken from the US Department of Agriculture National Nutrient Database for Standard Reference, Release 21 (2008, US Department of Agriculture, Beltsville, MD).

Sensory Evaluation

Seventy-five untrained adults (college students, age range 20 to 30 years) who consumed cake as part of their typical diet pattern participated in the study. No information was collected on socioeconomic status or sensory preferences for cakes. For testing, each round cake was sliced in four (along the two perpendicular diameter axes) and then each fourth sliced again in four from border to center. Slicing was done by hand using an appropriate knife. Crust was not removed for testing. Each panelist evaluated four samples at a time (one control and one at each of the three substitution levels). The samples were evaluated for the degree of liking of color (visual), taste (mouth), texture (mouth), and overall acceptability. Participants used a 7-point hedonic scale (1=dislike extremely, 4=neither dislike nor like, and 7=like extremely). They completed paper ballots that contained the hedonic scales and instructions. Participants were instructed to rate each sample individually and not to rate samples against each other.

The test was conducted in a 9×9 m room on a table (4×2 m). Panelists were comfortably seated during testing. Room temperature was controlled (20°C to 22°C) and illumination (white) was appropriate. Six panelists sat at a time (one at each end of the table and two on each side of the table). Each panelist received a white plastic plate with four samples each coded with a three-digit random number. Water (20°C to 22°C) was provided for palate cleansing. Participants were instructed not to communicate between themselves. This study was approved by the Institutional Review Board of Centro de Excelencia en Productos y Procesos Córdoba.

Statistical Analyses

All analyses were made in triplicate. Means and standard deviations were calculated and reported. Further analysis was carried out using an analysis of variance using statisical software (Excel, Microsoft, Inc, Redmond WA) at an α-level of .05. A multiple comparisons test (Fisher's least significant difference) was performed using Excel to determine which means were statistically significantly different (95% confidence).

RESULTS AND DISCUSSION

Table 1 reports the nutrition analysis of cake formulations. 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. The 50% oil substituted cake has 36 fewer kcal per 100-g portion than the control and 19.7% of energy from fat (a reduction of around 62% in actual energy derived from fat). The effect on energy reduction and on energy from fat in the cakes where eggs were substituted by chia gel was less intense than the effect of substituting oil by chia gel (50% egg substituted cakes have 7 fewer kcal than control, and a reduction in energy from fat of only 4.7%).

An improvement in the quality of the fat profile in the cakes was observed as eggs or oil was substituted with chia gel. As the degree of substitution of oil or eggs increased, there was less saturated fat (see Table 1), from 1.7 g saturated fat for control to 1.4 g for 50% egg substituted formula and 1.1 g for 75% oil substituted formula. Also, the ratio of n-6 to n-3 fatty acids improved as the substitution increased. Substituting eggs with chia gel caused the ratio of n-6 to n-3 fatty acids to decrease from a value of 215.7 (control) to 28.9 (75% substitution). When oil was substituted with chia gel, the ratio decreased to 13.2 (75% oil substitution). Cholesterol content decreased as eggs were substituted with chia gel (Table 1).

As shown in Table 2, substituting oil or eggs within the cake formulation (with chia gel) did not greatly affect the

functional properties of the cake. In fact, cake weight was not statistically different from control at any substitution level (Table 2), which means that the yield of cake would not be affected with the use of chia gel. However, cake volume, an important cake functional characteristic, was affected when oil or eggs were replaced with chia gel (Table 2) ($P<0.05$). As substitution increased (above 50%), cakes yielded less volume upon baking, which means that the product is less aerated and denser. Symmetry of the product remained unchanged ($P<0.05$) when substitution levels increased (except for at the 75% egg substitution level).

The analysis of variance of the sensory evaluation results (Table 2) showed that there was a statistically significant effect when replacing oil or eggs with chia gel for acceptability, color, texture, and taste ($P<0.05$). Post hoc analysis indicated that the differences appeard when the percentage of substitution was 50% or 75%, and that there was no significant statistical difference between the control formula and the cake made with 25% egg or 25% oil substitution ($P<0.05$; see Table 2). Despite the statistical differences observed (Table 2), the sensory results indicated that the average preference ratings for the 50% and 75% egg or oil substitution generally ranged from neutral ("like nor dislike") to "like slightly," which indicates that panelists did not dislike the products that contained chia gel. Control cake formulation obtained the highest score for all sensory characteristics evaluated (Table 2).

For a fat replacer to be successful it should improve or at least preserve the functional characteristics and sensory feelings of the food in which it will be used. In this case, the fat replacer should maintain the functional characteristics of the product (ie, cake weight, cake volume, and symmetry) and preserve the taste, texture, and color of the cake as compared to the traditional formula (control). This study showed that substituting eggs or oil within the cake formulation with chia gel up to a level of 25% maintained the functional and sensory characteristics of the product. Further research is needed to optimize functional and sensory properties of cakes containing chia gel. Perhaps less-aggressive fat reductions or combinations of oil/egg substitution in the same formula may yield products with acceptable functional and sensory characteristics.

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