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Production and Quality Evaluation of Low Calorie Cake

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ABSTRACT

The aim of this study was to produce low calorie cake, by replacing Fat or sugar or fat and sugar together (fat-sugar) in cake with different levels (0, 25, 50 and 75%) of artichoke (as fat replacer), Equal, a commercial sweetener (as a sugar replacer) and artichoke-Equal (as fat and sugar replacer). The physical properties of batter and chemical, physical and sensory properties of cakes were evaluated. The caloric values of prepared cakes were lower than that of control. Specific gravity of the batter prepared with 25% replacers level was improved. Cakes prepared with replacers at the 25% level had higher heights, volumes, specific volume and compressibility than those of the control. There were no significant differences in heights, volumes, specific volume and compressibility between control cake and those prepared with 50% replacers level. Fat or sugar or fat-sugar replacers did not significantly affect the crust and crumb colour properties of prepared cakes. Cakes prepared with 25% replacers level had higher mean scores for appearance and similar mean scores for crust colour, crumb colour, flavour, texture and overall acceptability compared to control. Increasing the level of replacers from 25 to 75% resulted in significant decrease in all sensory properties rating scores compared to that of the control.

Key words: Cake, low calorie, commercial sweetener, physical and sensory properties

INTRODUCTION

The health-conscious public demands high-quality and low-calorie products that are low in fat and sugar. However, altering amounts of ingredients to reduce caloric content may compromise texture, mouthfeel, flavour and appearance (Pong *et al*., 1991; Khalil, 1998). Cake is a product that is high in calories, fat and sugar. Therefore, a reduced calorie alternative is needed for that kind of product in the marketplace.

Fat in cake is usually derived from shortening which functions in the incorporation of air during mixing and help to leaven the product (Pong *et al*., 1991; Khalil, 1998; Mahmoud *et al*., 2002). In addition, shortening tenderizes the crumb and enhances mouthfeel (Glicksman, 1991). The quality of cake mainly depends on ingredients used in the recipe, mixing conditions during batter preparation and baking conditions employed. Other than contributing to the appearance and aroma, shortening (fat) provides a tender and soft texture to cakes by assisting in the entrapment of air during creaming and in leavening action (Kalinga and Mishra, 2009). When shortening is completely removed from a cake formulation, volume decreases, the crumb becomes less tender and the cell structure becomes uneven (Kim *et al*., 2001).

One option is available for reducing fat in the cake by partial replacing of fat with fat replacers such as carbohydrate-based fat replacers. Artichoke (*Helianthus tuberoses*) has drawn much attention as a potential energy crop (Wenling *et al*., 1999).

Artichoke inulin has unusual high degree of polymerization (DP value = 46) compared to other inulin. The degree of polymerization can influence some properties of these products such as a digestibility, prebiotic activity, caloric value, sweetening power, water binding capacity (Van de Wiele *et al*., 2007). Also, the addition of inulin, oligofructose in cereal bar can cut sugar by 40% and reduce the caloric value by 18-20 while providing 200% of added fiber (Dutcosky *et al*., 2006).

High-intensity sweeteners are used in small quantities for a replacement of sucrose, thus reducing ingredients volume. The functional properties of sucrose are not replaced when high-intensity sweeteners are used as a substitution. Polydextrose, a bulking agent, may be used to compensate for the loss in volume (Pong *et al*., 1991; Mahmoud *et al*., 2002; Hicsasmaz *et al*., 2003). Since polydextrose is only partially metabolized, caloric utilization is only 1 kcal g^{-1}. Furthermore, polydextrose increase the onset and peak gelatinization temperatures of starch to values similar to those of sucrose (Kim *et al*., 1986). Aspartate has been used to sweeten cakes (Pong *et al*., 1991; Attia *et al*., 1993; Mahmoud *et al*., 2002). Also found that low levels of fructose enhanced sweetness and tenderness of cakes sweetened with aspartate.

In this study, fat or sugar or fat and sugar together (fat-sugar) in cake were partially replaced with different levels (0, 25, 50 and 75%) of artichoke (as fat replacer), Equal, a commercial sweetener (as a sugar replacer) and artichoke-Equal (as fat and sugar replacer). The objective of this study was to evaluate the effect of these replacements on the physical properties of batter and physical, chemical and sensory properties of cake.

MATERIALS AND METHODS

- Wheat flour (72% extract), powdered sugar and single baking powder were obtained from Shibin El-Kom Milling Company, Shibin El-Kom, Minufiya, Egypt
- Margarine (sunflower oil, stearin and palm oil) was obtained from Oil Refining Company, Alexandria, Egypt. Fresh whole egg was obtained from Poultry Farm, Minufiya University, Minufiya, Egypt
- Defatted milk was obtained from Dairy Science and Technology Department Minufiya University, Minufiya, Egypt
- Artichoke tubers (*Helianthus tuberosus* L.) were obtained from Horticulture Center, Agriculture Research Center, Cairo, Egypt. Artichoke tubers were hand-peeled cut into strips and washed with cold water. The strips were blanched by heating at 85°C for 3 min. These strips were then ground in a Hobart meat grinder (Model No. 4046, Hobart Manufacturing Co., Troy, OH, USA)

Equal: It is a commercial sweetener (registered trademark of Merisant Company, Distributed by Merisant US, Inc., Chicago, IL 60654), a balanced blend of dextrose, maltodextrin and aspartate. Polydextrose is used to compensate for the loss in volume.

Cake preparation: Cakes were prepared according to the formula of Khalil (1998) using the following recipe: 28 g wheat flour, 24 g margarine, 24 g sugar, 13.55 g whole egg, 0.45 g baking powder and 10 mL defatted milk. To prepare the control cake, the sugar and margarine were creamed for 3 min at speed 5 in an Oster kitchen aid mixture (Model 972-26H, Sunbeam Corporation, Milwaukee Wisconsin, USA). The whole eggs were added and mixed in at the same speed for 2 min. The flour, baking powder and defatted milk were added and the batter was mixed for 4 min at speed 6. After scraping down the bowl the batter was mixed for an additional 1 min at speed 6. To prepare the replacer cakes, (1) the margarine (fat weight basis) in the formula was replaced with artichoke (0, 25, 50 and 75%), (2) the sugar (sugar weight basis) in the formula was replaced with Equal (0, 25, 50 and 75%), (3) fat and sugar together (fat-sugar weight basis) in the formula were replaced with artichoke-Equal (0, 25, 50 and 75%). The same order of mixing as described for the control was followed. Cake batter (100 g) was weight into a greased and floured aluminum foil cake pan. Cake batters were baked at 180°C for 45 min. After 5 min, the cakes were removed from the pans and cooled for 60 min then wrapped in transparent film to avoid surface drying and stored at room temperature (~25°C) for 24 h.

Analytical methods: All analysis was carried out in triplicate. Moisture, crude protein (N×5.7), crude oil and ash were estimated according to AOAC (1990). Carbohydrate was calculated by difference.

Cake batter specific gravity and pH: Specific gravity of batter was determined as the ratio of the weight of a standard container filled with batter to that of the same container filled with water. The pH of the batter was determined by direct immersion of a pH electrode in the batter at room temperature (~25°C) using a Digital pH meter (Jenway, Model 3020, Dunmow, Essex, UK).

Cake height, volume and specific volume: The height (cm) was measured in the center of the cake. Cake volume was measured by rapeseed displacement after cooling the cake for 1 h at room temperature (~25°C). The cake was weighed after removal from the pan and the specific volume was also calculated (cake volume/cake weight).

Colour evaluation: The crust and crumb colour of cakes were determined using a Lovibond Tintometer (The Tintometer LTD., Salisburg, England). The readings were further converted into CIE units using visual density graphs and the instruction manual supplied with the apparatus.

Sensory evaluation: Twenty panelists who were graduate students and staff members in the Department of Nutrition and Food Science, Minufiya University performed sensory evaluation. Panelists were selected on the basis of their interest and availability. Two training sessions were conducted in which the panelists were trained to evaluate sensory attributes of cakes. Sensory quality attributes were evaluated using a 9-point hedonic rating scale with 1 for dislike extremely to 9 for like extremely for each attribute. Cakes were evaluated for appearance, crust and crumb colours, flavour, texture and over all acceptability. Cakes were evaluated 24 h after baking. After cooling, cakes were cut into 1.5 cm radial sections, placed in plastic bags, sealed and stored at room temperature (~25°C) until subjected to sensory analysis. Randomly coded samples were presented to the panelists on white plates and served one at a time. Samples were served to panelists in a room with partitions between each seat with overhead fluorescent light. Panelists were instructed to rinse their mouth with tap water before starting and between sample evaluations.

Statistical analysis: A completely randomized 4 (replacer leve×3) (replacer type× 3) (replication) factorial design was used. Data were analyzed by analysis of variance akewith the Student-Newman-Keuls test. Significant differences were determined at ($p \le 0.05$) (SAS, 1995).

RESULTS AND DISCUSSION

Physical properties of batter and cake: Data presented in Table 1 indicated that the specific gravity of the cake batters was significantly ($p \le 0.05$) influenced by fat, sugar and fat-sugar replacer levels but did not influenced ($p > 0.05$) by replacer types. Cake batters prepared with 25% replacers level had a lower ($p \le 0.05$) specific gravity than control cake and other treatments. However, cake batters prepared at the 50 and 75% replacement levels had higher ($p \le 0.05$) specific gravity than that of control. Low specific gravity is associated with good aeration of the batter. The results indicate that replacers with 25% level might aid in incorporation large numbers of air cells into the batter. Similar results were obtained by Khalil (1998) who reported that the specific gravity of the cake batter prepared at the 75% fat replacement level was higher than the control. Pong *et al.* (1991) reported that batters prepared without shortening had higher specific gravity than those prepared with shortening.

The pH values of cake batters were not affected ($p > 0.05$) by the replacement levels and types Table 1. Khalil (1998) reported that the pH value of cake batters decreased as the fat replacement level increased. The pH values of all cake batters were within the optimum levels (6.5-7.7) described by Ash and Colmey (1973).

Cakes prepared at 25% replacement level had higher ($p \le 0.05$) height (5.6 cm) than that of controls (5.1 cm). These findings are supported by the results on specific gravity of cake batter prepared with 25% replacers level Table 1. There were no significant ($p > 0.05$) difference in height between control cake and those prepared with 50% replacers levels. Cakes prepared at the 75% replacement levels had the lowest ($p \le 0.05$) height among treatments. Cake height was not significantly ($p > 0.05$) affected by replacer types.

Cake volume was significantly ($p \le 0.05$) affected by fat, sugar and fat-sugar replacer levels but did not affected ($p > 0.05$) by replacer types. Cakes prepared with 25% replacers' level had higher ($p \le 0.05$) volume (109.1 cm^3) than that of control cake (102.3 cm^3). There was no significant ($p > 0.05$) difference in cake volume between control cake and those prepared with 50% replacers levels. At 75% replacement level, cake volume was lower ($p \le 0.05$) than that of control cake and other treatments. The improvement in cake volume due to replacing 50% of fat by maltodextrin,

Table 1: Change on butter and cake properties of low calorie cakes prepared with different fat and sugar replacer levels

	Replacer level					Replacer type			
Property	Control	25%	50%	75%	LSD	Fat	Sugar	Fat-sugar	LSD
Butter									
Specific gravity	0.93^c	0.91^d	0.95^b	0.97^a	0.01	0.93^a	0.95^a	0.93^a	0.02
pH	6.9^a	6.6^a	6.7^a	6.6^a	0.30	6.8^a	6.8^a	6.5^a	0.30
Cake									
Height (cm)	5.1^b	5.6^a	4.9^b	4.6^c	0.21	5.1^a	5.0^a	5.0^a	0.22
Volume (cm^3)	102.3^b	109.1^a	104.8^b	98.4^c	3.90	104.7^a	103.6^a	103.9^a	3.96
Specific volume ($g\ cm^{-3}$)	1.35^b	1.45^a	1.38^b	1.30^c	0.04	1.39^a	1.37^a	1.38^a	0.04
Compressibility (mm)	4.1^b	4.6^a	4.1^b	3.8^c	0.21	4.1^a	4.2^a	4.1^b	0.20

Means in the same row with different letters are significantly different ($p \le 0.05$)

50% of sugar by aspartate + polydextrose and 5% of wheat flour by wheat bran has been reported by Mahmoud *et al.* (2002). An inverse relationship between batter specific gravity and cake volume was observed in this study. This might indicate that fat replacers had the ability to retain greater amount of air into the batter (less specific gravity) and maintained more air during the final stage of baking (large cake volume) Khalil (1998) and Raeker and Johnson (1995).

Cakes prepared at 25% replacement level had higher ($p \leq 0.05$) specific volume (1.45 g/cm^3) than that of control cake (1.35 g/cm^3). However, at 75% replacement level, specific volume was lower ($p \leq 0.05$) than control cake. There was no significant ($p>0.05$) difference in specific volume between control cake and those prepared with 50% replacers level. Specific volume was not significantly ($p>0.05$) affected by replacer types. Khalil (1998) reported that cakes prepared with fat replacers at 25 and 50% levels had higher volumes, specific volumes and heights than those of control.

Cakes prepared with 25% replacers level were more ($p \leq 0.05$) compressible (softer) than that of control cake. However, cakes prepared with replacers at 75% replacement level were firmer ($p \leq 0.05$) than control cake. On the other hand, cakes prepared with replacers at 50% replacement level had similar compressibility to control cake. Compressibility of prepared cakes was not significantly ($p>0.05$) affected by replacer types. These results are in good agreement with those obtained by Paraskevopoulou and Kiosseoglou (1997) and Khalil (1998) reported that cakes prepared with fat replacers at 25 and 50% levels were more compressible than control.

Chemical characteristics of cake: Table 2 indicated that the protein of cake was significantly ($p \leq 0.05$) influenced by fat, sugar and fat-sugar replacer levels as well as replacer types. The highest contents of protein (15.45 and 15.56%) shown at the highest level of replacer and at fat and sugar replacer type, respectively. However, fat content of cake significantly ($p \leq 0.05$) decreased as levels of replacement increased. There was no significant ($p>0.05$) difference between fat and fat-sugar types in fat content, however, both treatments were significantly lower ($p \leq 0.05$) than that of cake control. On the other hand, sugar type had the highest ($p \leq 0.05$) content of fat when compared with other treatments. The total carbohydrates of cake were not affected ($p>0.05$) by the replacement levels. Meanwhile, types of replacer were significantly ($p \leq 0.05$) affected in carbohydrate content. The lowest ($p \leq 0.05$) carbohydrate content was shown with sugar type (36.33%). Finally, control cake had the lowest ($p \leq 0.05$) moisture content among other treatments. The calorie of cakes was significantly ($p \leq 0.05$) decreased as the replacer levels increased. Sugar type had the highest ($p \leq 0.05$) calorie among other treatments.

Table 2: Change on chemical composition of low calorie cakes prepared with different fat and sugar replacer levels

	Replacer level					Replacer type			
Property	0	25%	50%	75%	LSD	Fat	Sugar	Fat-sugar	LSD
Crude protein	11.98^d	13.46^c	14.39^b	15.45^a	0.85	13.36^c	14.38^b	15.56^a	0.83
Total fat	25.64^a	22.37^b	17.80^c	14.21^d	1.26	13.81^b	25.60^a	14.63^b	1.47
Total ash	1.10^c	1.62^b	2.21^a	2.26^a	0.17	2.01^b	1.37^c	2.83^a	0.52
Total carbohydrate	41.92^a	41.35^a	42.35^a	44.17^a	3.17	48.51^a	36.33^c	43.03^b	4.10
Moisture	19.36^b	21.53^{ba}	23.33^a	23.80^a	1.85	20.95^c	22.41^b	23.95^a	1.50
Calorie	446.36^a	417.57^b	387.22^c	366.31^d	9.36	371.8^b	433.24^a	366.06^b	8.98

Means in the same row with different letters are significantly different ($p \leq 0.05$)

Table 3: Change on crust colour properties of low calorie cakes prepared with different fat and sugar replacer levels

Property	Replacer level					Replacer type			
	0	25%	50%	75%	LSD	Fat	Sugar	Fat-sugar	LSD
Red	5.0[a]	5.3[a]	5.1[a]	5.1[a]	0.34	5.1[a]	5.3[a]	5.2[a]	0.23
Yellow	8.7[a]	8.8[a]	8.4[a]	8.1[b]	0.72	8.6[a]	8.3[a]	8.5[a]	0.39
Blue	5.6[a]	5.7[a]	5.7[a]	5.6[a]	0.28	5.8[a]	5.5[a]	5.5[a]	0.31
Visual density	0.31[a]	0.33[a]	0.31[a]	0.30[a]	0.05	0.31[a]	0.32[a]	0.32[a]	0.02
Brightness (%)	48.3[a]	49.0[a]	48.7[a]	48.4[a]	0.75	48.9[a]	48.8[a]	48.4[a]	0.57
Hue wave length (nm)	580.1[a]	580.4[a]	579.5[a]	580.0[a]	2.78	579.7[a]	580.2[a]	580.1[a]	2.68
Saturation (%)	69.7[a]	70.3[a]	69.5[a]	69.1[a]	0.65	69.9[a]	69.6[a]	69.5[a]	0.53

Means in the same row with different letters are significantly different ($p \leq 0.05$)

Table 4: Change on crumb colour properties of low calorie cakes prepared with different fat and sugar replacer levels

Property	Replacer level					Replacer type			
	0	25%	50%	75%	LSD	Fat	Sugar	Fat-sugar	LSD
Red	7.3[a]	7.4[a]	7.4[a]	7.4[a]	0.33	7.4[a]	7.6[a]	7.2[a]	0.43
Yellow	9.7[a]	9.7[a]	9.6[a]	9.5[a]	0.26	9.6[a]	9.6[a]	9.6[a]	0.23
Blue	6.0[a]	6.5[a]	6.0[a]	6.5[a]	0.50	6.3[a]	6.1[a]	6.6[a]	0.52
Visual density	0.40[a]	0.42[a]	0.43[a]	0.42[a]	0.03	0.42[a]	0.43[a]	0.41[a]	0.03
Brightness (%)	37.1[a]	37.7[a]	37.3[a]	36.9[a]	0.81	37.5[a]	37.1[a]	37.3[a]	0.64
Hue wave length (nm)	582.1[a]	583.8[a]	583.2[a]	583.1[a]	2.73	583.2[a]	583.9[a]	583.1[a]	2.61
Saturation (%)	73.1[a]	73.1[a]	72.7[a]	72.5[a]	0.72	72.9[a]	72.7[a]	72.7[a]	0.73

Means in the same row with different letters are significantly different ($p \leq 0.05$)

Colour properties of cakes: Data in Table 3 and 4 show the crust and crumb colour properties of low calorie cakes prepared with different replacer levels and types. The results indicated that crust and crumb colour properties of prepared cakes were not significantly ($p>0.05$) affected by fat or sugar or fat-sugar replacers. There were no significant ($p>0.05$) differences in crust and crumb colour properties among fat replacer, sugar replacer and fat-sugar replacer treatments. Mansour *et al.* (2000) reported that neither fat replacer levels (25 and 50%) nor fat replacer type (N-Oil; N-Flate + Firm-Tex, 1:1) had any effect on crust and crumb colours of Betifore-type cookies. Mahmoud *et al.* (2002) reported that cakes prepared with 50% sugar replacer level (aspartate or stevioside) had lower mean scores for colour compared to control. Khalil (1998) found that cakes prepared with fat replacers (N-Flate, Paselli MD 10, Litesse) exhibited higher crust and crumb colour values compared to control. The dominant hue wavelength of cakes ranged from 579 to 584 nm indicating that the general colours of all cakes lay in the area bounded by the red and yellow lines on the spectrum locus of the chromaticity diagram.

Sensory properties of cakes: Sensory rating scores of low calorie cakes were significantly ($p \leq 0.05$) affected by fat sugar and fat-sugar replacer levels but did not significantly ($p>0.05$) affect by replacer types Table 5. Cakes prepared with 25% replacer level had higher ($p \leq 0.05$) mean scores for appearance and similar ($p>0.05$) mean scores for crust colour, crumb colour, flavour, texture and overall acceptability compared to control. Increasing the level of replacers from 25 to 75% resulted in significant ($p \leq 0.05$) decreases in all sensory properties rating scores compared to that of the control. Khalil (1998) reported that cakes prepared with 25 or 50% fat replacers had higher mean scores for flavour, softness and eating quality than control.

Table 5: Sensory properties of low calorie cakes prepared with different fat and sugar replacer levels

	Replacer level					Replacer type			
Property	0	25%	50%	75%	LSD	Fat	Sugar	Fat-sugar	LSD
Appearance	8.3^{b}	8.8^{a}	7.7^{c}	6.5^{d}	0.28	7.6^{a}	7.7^{a}	7.5^{a}	0.24
Crust colour	8.7^{a}	8.8^{a}	7.6^{b}	6.6^{c}	0.24	7.9^{a}	7.8^{a}	7.7^{a}	0.24
Crumb colour	8.6^{a}	8.8^{a}	7.5^{b}	6.9^{c}	0.25	7.6^{a}	7.5^{a}	7.4^{a}	0.22
Flavour	8.5^{a}	8.7^{a}	7.6^{b}	6.7^{c}	0.27	7.7^{a}	7.9^{a}	7.8^{a}	0.23
Texture	8.8^{a}	8.9^{a}	7.9^{b}	6.5^{c}	0.29	7.7^{a}	7.9^{a}	7.8^{a}	0.25
Overall acceptability	8.7^{a}	8.9^{a}	7.8^{b}	6.7^{c}	0.26	7.8^{a}	7.8^{a}	7.7^{a}	0.22

Means in the same row with different letters are significantly different ($p \le 0.05$)

CONCLUSION

Fat or sugar or fat-sugar in cake formula can be partially replaced with artichoke (as a fat replacer), Equal (as a sugar replacer) and artichoke-Equal (as a fat-sugar replacer) up to a 25% to produce high quality low calorie cake. The caloric values of prepared cakes were reduced by increasing levels of replacement.

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