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Utilization of Yoghurt and Sucralose to Produce Low-calorie Cakes

Hussein AMS*, **Hegazy NA, Kamil MM and Ola SSM**

Food Technology Department, National Research Centre, Dokki, PO box 12311, Giza, Egypt

***Corresponding author:** Hussein AMS, Food Technology Department, National Research Centre, Dokki, PO box 12311, Giza, Egypt, Tel: 01224642449, 01016426755; E-mail: a_said22220@yahoo.com

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Abstract

In this study we had replaced sucrose with sucralose in the manufacture of sponge cake and yoghurt cake. These cakes were chosen because their ingredients include little fat so they were of low calories. Such functional cakes were evaluated chemically, physically and sensorial. The results suggest that, sucrose substitution with sucralose in cakes increased the cake volume and softened the texture (as shown by lower values of hardness, chewiness and gumminess). Water activity of the yoghurt control cake prepared with 100% sucrose with a value of 0.91 was higher than the yogurt cake containing sucralose ($p<0.05$). The mean water activity of sponge cakes prepared with sucrose was significantly higher than the sponge cakes containing sucralose ($p<0.05$). The obtained low calorie yoghurt cake characterized with its low calorie and food energy (103.22 and 431.3 per100 g) than control yoghurt cake (268 and 1119 per 100 g). Also, low calorie sponge cake had low calorie and food energy (98.0 and 409.4 per100 g) compared to control sponge cake (276.9 and 1156.9, respectively). Sensory scores of studied cake samples indicated that, texture and flavor of all samples were not affected significantly in case of replacing sucrose with sucralose in yogurt or sponge cake. A significant difference in cells and crumb color was observed in all cake samples when compared with control cake samples.

Keywords: Functional cake; Sucralose; Low calorie cake; Sponge cake; Yoghurt cake; Texture profile; Calorie values

Introduction

Cake is one of baked products, which generally contains fat, sugar, wheat flour, egg and milk. It is composed of 20-50% fat and 10-30% sugar depending on types of cakes. Due to its high fat and high calorie content, overconsumption may contribute to high risk of health problems such as coronary diseases, high blood pressure and cholesterol, diabetes, obesity and some cancers [1,2].

Low calorie foods available to consumer shelves on the market are products prepared with low energy sweeteners. These products are very popular among weight and health conscious consumers [3]. Generally, fat reduction is the primary target prior to the replacement of sucrose in the production of low-calorie foods. The replacement of sucrose by using these sugar substitutes alone (xylitol, sorbitol, acesulfame-K, aspartame, saccharin) or their combinations at levels of above 25% resulted in a decrease in the quality and acceptability of cakes [4,5]. Consequently, it is important to find an alternative sugar substitute to traditional sugars in order to improve the quality of cakes.

Sucralose was discovered by British researchers in 1976. It is a chlorinated disaccharide [6]. Sucralose (1,6-dichloro-, 1,6-dideoxy-β-Ddructofuranosyl-4-chloro-deoxy-α-D-galactopyranoside) is synthesized from sucrose by selectively replacing 3 hydroxyl groups with chlorine atoms [7,8]. It is a zero-calorie sweetener that is 600 times sweeter than sucrose [9] but can range from 400-800 times sweeter, depending on desired sweetness and product formulation [10]. Sucralose tastes like sugar, has no unpleasant or bitter aftertaste [11], and is non-calorie, non-carcinogenic, and proven safe for human consumption [12]. Sucralose contains no calorie because it is not hydrolyzed in the intestinal lumen, not converted to energy in the body. It is poorly absorbed by experimental animals and is excreted largely unchanged in the feces [10]. Sucralose is highly soluble in water and alcohol [11], chemically compatible with all common food ingredients, and stable in a wide range of pH levels and thermal processes [11]. Thus, it could be a suitable sweetener for bakery products [13]. Although sucralose provides the sweetness and crystallization properties of sucrose, it cannot mimic the structural contribution of sucrose to baked products [9]. It cannot create bulk properties in the cake batter as sucrose does. As a result, sucralose must be combined with other substances to match sucrose's bulking properties. A few previous studies reported that replacing sucrose with sucralose up to 50% has produced acceptable products: chiffon cake formulated with a mixture of sucralose and a type of indigestible dextrin in chiffon cakes [7], reduced-fat chiffon cake containing 50% erythritol-sucralose [14], and muffins using sucralose and polydextrose [9]. Sweeteners were successful in making the texture of cakes softer and the quality of the texture of the cake did not change for a long time after baking [15]. Therefore, this study aimed to produce and evaluate low calorie yoghurt and sponge cakes free from shortening and sucrose that could be used as a functional cake for diabetes and obesity.

Materials and Methods

Materials

Soft wheat flour (Gemiza 9), 72% extraction was obtained from the Cairo south Company of milling (EL-Haram Milling). Yoghurt, sucralose, ground sugar, vanilla, eggs and baking powder were obtained from the local market, Cairo, Egypt.

Methods

Yoghurt Cake preparation: Yogurt, sugar, and eggs were whipped at medium speed using a kitchen mixer (Moulinex, Model HM1010, Beijing china) for 7 minutes then vanilla was added. In a medium bowl, whisk together flour, baking powder, and salt. In a separate bowl, whisk together yoghurt, Sugar, eggs, and vanilla were mixed well with wheat flour and passed through a stainless steel screen and then added to the mixture. Sample of cake was placed into rectangular metallic pans (80 mm width, 175 mm length and 50 mm depth) and baked at 180°C in an electric oven for 35 minutes. Cakes were removed from the pans and left at room temperature for one hour. The cakes were then sealed in polyethylene bags to be prevented from becoming dry. For the manufacture of cakes for diabetics follow the same steps in the normal cake with sugar replacement with sucralose.

Preparation and evaluation of sponge cakes: Sponge cakes were prepared according to Bennion and Pamford [16] with some modifications as follows: Flour (100 gm) and baking powder (3 gm) were mixed together; whole fresh eggs (125 gm), and sugar (100 gm) were whipped for 6 min. using a mixer at high speed, then vanilla was added. Flour mixture was added gradually on mixture and beaten for 3 min. using the mixer at low speed. Cake were poured in baking pan (80 mm width, 175 mm length and 50 mm depth), then placed in a preheated oven and baked at 180°C for 35 min. Cakes were allowed to cool for 30 min. in the pans at room temperature. Low calorie cakes were prepared using the same steps in the common cake (control) with replacing sucrose with sucralose.

Physico-chemical analysis: All cakes and wheat flour (72%) were homogenized to prepare the samples for analysis. Moisture, protein, lipid, ash and carbohydrate were determined according to AOAC [17]. Water activity of the cakes was determined by using an Aqua Lab device (Model CX2, Decagon Device, and Pullman, WA).

Specific volume was determined according to AACC [17], where rapeseed displacement was used to measure cake volume. The cake volume was divided by cake weight to express the specific volume of the cake.

Color parameters of all samples were determined using a spectro-colorimeter (Tristimulus Colour Machine) with the CIE lab colour scale (Hunter, Lab Scan XE-Reston VA, USA) in the reflection mode. The instrument was standardized with white tile of Hunter Lab Colour Standard (LX No.16379). The color parameters are based on the Hunter L^*, a^* and b^* coordinates. The L scale ranges from 0 black to 100 white; the a^* scale extends from a^* negative value (green hue) to a positive value (red hue) and the b^* scale ranges from negative blue to positive yellow.

Texture profile analysis of cakes Hardness and resilience analysis was conducted using Brookfield Texture Analyzer. The analyzer was set to perform single cycle measurements which are used for the determination of the first bite force of cakes. The measurement speed of 2 mm/s and a distance of 5 mm were applied. A force-time diagram was taken for each test. The force-time plots were analyzed for peak breaking force (g) and time (s) to reach the peak. Textural attributes were measured in three independent samples and the presented values are mean values.

Differential scanning calorimetry (DSC) measurements were performed with Shimadzu DSC-50 in the four blends and in the corresponding biscuits of the control and the TNF-containing biscuits. The samples were heated to 200°C at a 10°C/min heating rate. The onset temperature (T_o), peak temperature (T_p), end set temperature (T_e) and (ΔH) of the enthalpy was calculated from the DSC thermo grams. The enthalpy was expressed in J/g of baked cakes.

Determination of energy

Calculation from the following equation: Calculated Energy=(Protein + carbohydrate) × 4 + fat × 9.

Calorimeter device: Differential scanning calorimeters, isothermal micro calorimeters, titration calorimeters and accelerated rate calorimeters are among the most common types.

Sensory evaluation: Cake samples were evaluated for the following parameters according to the method described in AACC [17]: cells (30), grain (16), texture (34), crumb color (10) and flavor (10).

Freshness of Cakes: Cakes freshness was tested after wrapping with polyethylene bags and stored at room temperature for 0, 1 and 3 days. Alkaline Water Retention Capacity test (AWRC) was carried out according to the method of Yamazaki [18]; and modification by Kitterman & Rubenthaler [19].

Statistical analysis: The obtained results were evaluated statistically using analysis of variance as reported by McClave & Benson [20].

Results and Discussion

Chemical composition and nutritional evaluation

Data presented in Table 1 compared between gross chemical compositions and energy value of common yoghurt cake, sponge cake (control 1 and 2) and their low calorie cakes products (S1 and S2). The obtained results showed that moisture content of control samples in yoghurt (25.7%) or sponge cake (28%) was higher than low calorie cakes products of S1 (21%) or S2 (22%). Consequently, protein and ash of low calorie cakes products were increased. Also, replacing sucrose with sucralose in cakes led to decrease carbohydrates in cake of S1and S2 to 13.5 and 12%, while control samples of yoghurt and sponge cake reached to 54.3 and 56%, respectively.

Fat content of the cake was minimized in order to lower its calorie value, since it is well documented that obese and diabetic people have a tendency towards hypercholesterolemia. Therefore, yoghurt and sponge cakes samples were prepared without using shortening then sucrose was replaced with sucralose to offer cake suitable for diabetics. Table 2 showed the calculated (K. Cal/100 g) and determined energy (kJ/100 g) of studied cakes samples. The obtained results indicated that, replacing sucrose with sucralose in yoghurt cake (S1) decreased its food energy to 408.8 K.Cal/100 g, while control yoghurt cake reached to 1050 K.Cal/100 g. Also, replacing sucrose with sucralose in sponge cake (S2) decreased its food energy to 390.4 K.Cal/100 g compared to control sponge cake which reached to 1082.4 K.Cal/100 g. Consequently, low calorie sponge cakes and low calorie yoghurt cakes could be recommended to obese and diabetic people.

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Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbo-hydrate (%)	Energy	
						Calculated*K.Cal/100g	Determined**kJ/100g cake
Yoghurt cakes							
Control (1)	25.7 ± 0.15	6.8 ± 0.11	2.0 ± 0.05	1.4 ± 0.01	54.3 ± 0.32	262.4	1050 ± 0.59
S1	21.0 ± 0.19	7.2 ± 0.13	2.1 ± 0.02	1.8 ± 0.01	13.58 ± 0.12	102.02	408.8 ± 0.62
Sponge cakes							
Control (2)	28.0 ± 0.14	7.6 ± 0.05	1.8 ± 0.01	1.5 ± 0.02	56 ± 0.34	270.6	1082.4 ± 0.76
S2	22.0 ± 0.12	7.9 ± 0.08	2.0 ± 0.02	1.7 ± 0.01	12.0 ± 0.09	97.6	390.4 ± 0.52

Table 1: Chemical composition of yoghurt cake (control 1), sponge cake (control 2) and their cakes after replacing sucrose by sucralose, Mean values ± Standard Deviation, S1=Yoghurt cakes of replaced sucrose by sucralose, S2=Sponge cakes of replaced sucrose by sucralose, *Calculated Energy= (Protein + carbohydrate) x 4 + fat x 9, **Determined Energy=using calorimeter apparatus.

Ingredients	Yoghurt cake control (1)	Yoghurt cake (S1)	Sponge cake control (2)	Sponge cake (S2)
Wheat flour (gm)	100	100	100/ 29%	100 / 38.51%
Sucrose (gm)	75	- - -	100/ 29%	- - -
Succharalose (gm)	- - -	12.5	- - -	12.5
Yoghurt (gm)	225	225	- - -	- - -
skim milk (gm)	- - -	- - -	20	20
Whole Egg (gm)	56	56	125	125
Baking powder (gm)	3	3	0.5	0.5
Vanilla (gm)	0.65	0.65	0.65	0.65
Salt (gm)	1	1	1	1

Table 2: Formulations of yoghurt cake, sponge cake samples and their cakes after replacing sucrose by sucralose. S1=Yoghurt cakes of replaced sucrose by sucralose, S2=Sponge cakes of replaced sucrose by sucralose.

Color quality of cakes

Color is one of the most important sensory attribute that affect directly the consumer preference of any product. Special attention should be given to bakery products to attract the consumer attention. The color parameters of cake samples were evaluated using a Hunter laboratory colorimeter. Table 3 showed that low-calorie cake products (S1 & S2) were darker than control cakes (1 & 2), where lightness (L^*), redness (a^*) and yellowness (b^*) of low-calorie cakes (S1 & S2) decreased compared to the control cakes (1 & 2). Such findings are in-agreement with Kim et al. [21], Kordonowy &Young [22] and Ramy [23].

Samples	crust				Crumb			
	L	a	b	ΔE*	L	a	B	ΔE*
Yoghurt cakes								
Control (1)	55.29	16.94	42.16	71.56	67.27	5.56	37.14	77.04
S1	53.15	18.19	44.56	71.70	67.43	7.36	35.8	76.70
Sponge cakes								

Control (2)	70.13	5.31	40.87	81.34	73.04	1.72	40.35	83.46
S2	57.7	17.15	42.36	73.61	70.92	5.1	38.21	80.72

Table 3: Cake color parameters of yoghurt cake (control 1), sponge cake (control 2) and their cakes after replacing sucrose with sucralose, S1=Yoghurt cakes of replaced sucrose by sucralose, S2=Sponge cakes of replaced sucrose by sucralose, *$\Delta E=(L^2 + a^2 + b^2)^{1/2}$.

Textural properties of cakes

Texture profile analysis (TPA) is a very useful technique for investigating the physical properties of food products. In the present study, the TPA parameters of control samples in yoghurt, sponge cakes (1 & 2) and their cakes of replacing sucrose with sucralose (S1 & S2) were evaluated using texture analyzer by double compression tests, and presented in Table 4. Hardness was defined as the maximum force of the first compression of the product at the point of 50% compression (12.5 mm) of the original sample height. The hardness values of baked cakes increased significantly with the replacement of sucrose with sucralose. However, cohesiveness determined from the area of work during the second compression divided by the area of work during the first compression [24]. There was no significant difference between cohesiveness of cake samples with or without sucralose, where they ranged between 0.52-0.56. Springiness was defined as the distance to which the sample recovered in height during the time that elapsed between the end of the first compression cycle and the start of the second compression cycle.

Samples	Hardness(N)	Cohesiveness	Springiness(mm)	Gumminess(N)	Chewiness(Nm)
Yoghurt cakes:					
Control (1)	120	288	2.4	390	320
S1	130	285	2.28	400	380
Sponge cakes:					
Control (2)	125	330	2.64	450	410
S2	140	332	2.60	410	380

Table 4: Texture profile analysis parameters of yoghurt cake (control 1), sponge cake (control 2) and their cakes after replacing sucrose with sucralose (S1 & S2), S1=Yoghurt cakes of replaced sucrose by sucralose, S2=Sponge cakes of replaced sucrose by sucralose.

Springiness of testing cakes not affected significantly by replacing sucrose with sucralose in yoghurt cakes or sponge cakes. Gumminess was calculated by the product of (that is by multiplying) hardness and cohesiveness, whereas chewiness, defined as the energy required to masticate solid food to a state of readiness for swallowing [25] was obtained from the product of hardness, cohesiveness and springiness. Chewiness and gumminess values in cakes with and without sucralose exhibited a similar trend with the hardness values, as shown in Table 4. Significantly lower chewiness and gumminess were found in the cake samples containing sucralose. The obtained results suggest that partial sucralose in cakes increased the cake volume and softened the texture (as shown by lower values of hardness, chewiness and gumminess).

Differential scanning calorimetry

Differential scanning calorimetry of of yoghurt cake (control 1), sponge cake (control 2) and their cakes after replacing sucrose with sucralose (S1 & S2) are clearly shown in Table 5. Onset temperature (To), peak temperature (Tp) and enthalpy change ΔH (J/g) were automatically calculated using Universal Analysis software published by TA Instruments, New Castle, Delaware. As the amount of sucrose in formulation was decreased, both the onset and peak temperatures decreased. Control cakes had the highest onset and peak temperature; 72.64°C and 74.44°C, respectively. The treatment with 100% sucrose replacement showed the lowest onset (69.65°C) and peak (69.81°C) temperatures. The same results of onset and peak temperature in the sponge cake were noticed. These results correspond with differential scanning calorimetry testing conducted by Lim [26] on wheat starch, sucrose and water interactions. The researchers reported that the increase of onset temperature as sucrose concentrations were increased [26].

Samples	To (°C)	Tp (°C)	ΔH (J/g)
Yoghurt cakes			
Control (1)	72.64	74.44	0.887
S1	69.65	69.81	0.880
Sponge cakes			
Control (2)	70.88	72.66	0.877
S2	68.87	70.97	0.907

Table 5: Thermal properties of yoghurt and sponge cakes and their low-calories cakes (S1&S2), Mean values ± Standard Deviation, S1=Yoghurt cakes of replaced sucrose by sucralose, S2=Sponge cakes of replaced sucrose by sucralose, To=Onset temperature, Tp=Peak temperature, Te=End temperature, ΔH=The enthalpy of the transition.

Water activity

Water activity is an important consideration for food product design and food safety, where food designers use water activity to formulate shelf-stable food. Mean water activity of control cake samples (1 & 2) and their low calorie cakes products (S1 & S2) were determined and presented in Table 6. Water activity of yoghurt cake (control 1) and sponge cake (control 2) were 0.92 and 0.89, respectively. While low calorie products of yoghurt cake (1) and sponge cake (S2) decreased to 0.72 and 0.81, respectively. This result indicates that the use of sucralose instead of sucrose in yoghurt or sponge cakes able to reduce water activity of cake product. Consequently, using sucralose instead of sucrose able was to improve the shelf-life of yoghurt or sponge cakes. This result agreed with Zoulias [27] who reported that acesulfame-K as a replacement for sucrose able to decrease the water activity of cookies. Also, Wetzel [28] stated that, Truvia^{TM} as replacement for sucrose in doughnuts product reduced its water activity compared to those prepared with sucrose. Furthermore, Kim [29] reported that water activity was decreased as the concentration of polyols increased during replacing sucrose in formulation.

Sensory evaluation

The sensory properties (Cells, grain, Texture, Crumb color and flavor) of yoghurt cake (control 1) and sponge cake (control 2) was compared with their low calorie prepared cakes (S1 & S2). Table 7 indicated that, grain, Texture and flavor of cakes samples were not affected significantly in case of using sucralose in yoghurt cake (S1) or sponge cake (S2) compared to control cakes (1 & 2). But a significant difference in Cells and crumb color was observed in S1 and S2 cake samples if compared with control cake samples.

Samples	Water activity (aw)	Water content (%)
Yoghurt cakes		
Control (1)	0.92 ± 0.03	25.7 ± 0.15
S1	0.72 ± 0.05	21.0 ± 0.19
Sponge cakes		
Control (2)	0.89 ± 0.04	28.0 ± 0.14
S2	0.81 ± 0.0.2	22.0 ± 0.12

Table 6: Water activity and water content of yoghurt cake (control 1), sponge cake (control 2) and their low-calories cakes products, Mean values ± Standard Deviation, S1=Yoghurt cakes of replaced sucrose by sucralose, S2=Sponge cakes of replaced sucrose by sucralose.

Samples	Cells (30)	Grain (16)	Texture (34)	Crumb color (10)	Flavor (10)
Yoghurt cakes					
Control (1)	24.29b ± 2.82	14.13 ± 1.01	30.17 ± 2.17	8.71b ± 0.68	9.15 ± 0.6
S1	21.81c ± 3.77	13.11 ± 1.06	27.35 ± 2.38	7.82c ± 1.20	8.33 ± 1.09
Sponge cakes					
Control (2)	26.11a ± 2.20	13.25 ± 0.33	28.14 ± 2.26	9.65a ± 1.03	8.61 ± 1.19
S2	22.88c ± 1.13	13.02 ± 0.19	25.24 ± 3.15	7.35c ± 0.96	7.65 ± 0.95
LSD at 0.05	2.55	NS	NS	1.04	NS

Table 7: Sensory properties of yoghurt cakes (control 1), sponge cakes (control 2) and their low-calories cakes products, Mean values ± Standard Deviation, S1=Yoghurt cakes of replaced sucrose by sucralose, S2=Sponge cakes of replaced sucrose by sucralose, LSD=Lest Significance Difference, NS=Non Significant difference.

Baking quality and freshness

The effect of replacing sucralose instead of sucrose on baking quality and freshness of yoghurt and sponge cakes were studied. Table 8 indicated that, weight and cake volume of low calorie cakes of yoghurt cake (S1) or sponge cake (S2) was decreased significantly compared to control cakes (1 & 2), while, specific volume was increased. The specific volume of baked cake indicates the amount of air that can remain in the final product. The higher gas retention and higher expansion of the product leads to a higher specific volume [30] After baking at 180°C for 35 min, the specific volumes of yoghurt cake (S1) and sponge cake (S2) cake were significantly higher than cakes of control (1 & 2). This result indicated that using sucralose instead of sucrose to prepare yoghurt or sponge cakes was able to remain a higher amount of air in cake samples [31,32].

Samples	Baking quality			Water retention capacity (Freshness)		
	Weight (g)	Volume (cc)	Specific volume	Zero time	3 days	7 days
Yoghurt cakes						
Control	130 ± 1.10	242 ± 1.68	1.82 ± 0.11	400 ± 2.02	360 ± 1.65	320 ± 1.16
S1	120 ± 1.15	235 ± 1.72	2.4 ± 0.09	360 ± 2.09	310 ± 1.44	270 ± 1.22
Sponge cakes						

Control	135 ± 1.20	284 ± 1.79	2.18 ± 0.15	370 ± 2.16	320 ± 1.10	260 ± 1.30
S2	125 ± 1.30	250 ± 1.82	2.64 ± 0.08	320	270 ± 1.19	220 ± 1.40

Table 8: Freshness properties and baking quality of yoghurt cakes, sponge cakes and their low-calories cakes. Mean values ± Standard Deviation, S1=Yoghurt cakes of replaced sucrose by sucralose, S2=Sponge cakes of replaced sucrose by sucralose.

The effect of storage period for 7 days at room temperature on freshness of low calorie yoghurt and sponge cakes products was evaluated. Table 8 showed that, yoghurt cake control of sucrose had highest alkaline water retention capacity, where it was declined during 0,3 and 7 days of storage to 400, 360 and 320%, respectively. However, low calorie yoghurt or sponge cakes of sucralose caused a noticeable decrease in alkaline water retention capacity values at the same storage period. Such effect might be related to the replacement sucrose with sucralose.

Conclusion

From the obtained results it could be concluded that, sucralose is a suitable sweetener for low-calorie sponge or yoghurt cakes (sugar-free bakery products). Incorporating this formula should yield a high quality cake free from sucrose and shortening. Due to its low fat and low calorie content, consumption sponge or yoghurt cake of sucralose could prevent from risk of health problems such as coronary diseases, high blood pressure and cholesterol, diabetes and obesity.

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