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Quality of Reduced-Fat Chiffon Cakes Prepared with Erythritol-Sucralose as Replacement for Sugar

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Abstract: Quality characteristics of reduced-fat chiffon cakes containing 0, 25, 50, 75 and 100% erytthritol-sucralose as sugar replacement were carried out. Specific volume decreased ($p<0.05$) with increased sugar replacement, but weight loss and water activity increased ($p<0.05$). The 100% erytthritol-sucralose cake produced darker colour crumb, more cohesive and adhesive and less springy in relation to those of the control cake. Results from sensory evaluation also showed significant differences in all attributes for any cakes. The cakes with higher levels of erytthritol-sucralose content became darker crumb, more moist and less tender and sweet than those with sugar. Total caloric value reduction in 50% erytthritol-sucralose cake was about 21.3% in relation to 100 g of the standard cake.

Key words: Low-calorie food, bakery product, sugar substitutes, nutrition

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, over-consumption may contribute to high risk of health problems such as coronary diseases, high blood pressure and cholesterol, diabetes, obesity and some cancers (Knecht, 1990; Newsome, 1993). Generally, fat reduction is the primary target prior to the replacement of sucrose in the production of low-calorie foods. The previous study in my laboratory showed the potential use of a konjac Flour-Soy Protein Isolate (SPI) blend as replacement for partial fat in chiffon cakes in which 50% soybean oil was replaced with water (Akesowan, 2007). 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 (Hess and Setser, 1983; Attia *et al*., 1993). Consequently, it is important to find an alternative sugar substitute to traditional sugars in order to improve the quality of cakes. Erythritol, a 4-carbon sugar alcohol with about 60-80% of the sucrose sweetness, can be used in low-calorie foods because it provides less than 0.5 Kcal/g with no increase in blood glucose and insulin, non-cariogenic and non-toxic substance (Goossens and Röper, 1994; Munro *et al*., 1998). Another is 'sucralose' which provides about 600 times of sucrose sweetness with no unpleasant residual flavour, non-caloric, non-cariogenic and proven as safe for human consumption (Wallis, 1993). The tendency for combination of low-calorie sweeteners has been increased, this means that combined sweeteners between intense sweeteners and sugar alcohols can produce both of intense sweetness and bulk property, which promote a better quality of low-calorie bakery products.

An erythritol-sucralose or D-et®, which combines a sugar alcohol (erythritol) with an intense sweetener (sucralose), is recently introduced to the food market. It provides virtually 8 times of sucrose sweetness with less than 0.18 Kcal/g (U-Sing Co., Ltd., 2007). The sugar substitute was selected in my study for the reason that: suitable for people with diabetes, currently available in a market, a combination of a sugar alcohol and an intense sweetener and increase data base for application in food. Therefore, my present research was aimed to study on physical, chemical, sensory and nutritional characteristics of reduced-fat chiffon cakes prepared with different levels of erythritol-sucralose as sugar replacement.

MATERIALS AND METHODS

Konjac flour was purchased from the Thai Food and Chemical Co., Ltd., Thailand while SPI was obtained from the Vichi Consolidate Co., Ltd., Thailand. Erythritol-sucralose (D-et®) was purchased from U-Sing Co., Ltd., Thailand. The cake ingredients, including wheat flour, sugar, salt, fresh eggs, soybean oil, evaporated milk, baking powder, cream of tartar, oranges and coffee powder were purchased from a local supermarket.

Cake preparation: The reduced-fat chiffon cake, as a control formulation, was prepared according to the research of Akesowan (2007), using a mixture of konjac flour-SPI together with 50% soybean oil replacement with water. Reduced-fat cakes were prepared containing 0, 25, 50, 75 and 100% erythritol - sucralose as replacement for sugar. The equivalent sweetness of erythritol-sucralose (8 times of sucrose sweetness) was calculated at 125 g/kg of sucrose. For the control cake processing, the dry ingredients on flour weight basis (100 g of a mixture of wheat flour-konjac flour-SPI (89.5:0.5:10), 112.4 g of sugar, 3 g of salt and 3 g of baking powder) were thoroughly mixed in a bowl by hand. The 55.5 g of egg yolk, 30 g of soybean oil, 30 g of water, 120 g of orange juice and 3 g of vanilla flavour were poured into the dry ingredients bowl and then well mixed with an eggbeater until smooth (about 2 min). The 100 g of egg white, 0.7 g of salt and 0.5 g of cream of tartar were whipped until they formed soft peaks. The 24 g of sugar was added and whipped to form firm, moist peaks. The whipped egg white was folded into the flour-liquid mixture, gently mixed and immediately deposited into cake pans and then baked at 170-180°C for 25-30 min. The cakes were allowed to cool for 1h before packing in low density polyethylene bags and stored at room temperature (27-28°C) for 24 h prior to further analysis.

Physical and chemical analysis

Proximate analysis: All cakes were homogenized to make the samples for analysis. Moisture, protein, lipid, ash and carbohydrate were determined according to AOAC (1990) procedures.

Specific volume: Rapeseed displacement method (AACC, 1983) was used to measure cake volume. The cake volume divided by cake weight was used to express the specific volume of the cake.

Weight loss: The batter was weighed before baking and the cake was weighed after baking. The percent weight loss was calculated as: A-B/A×100, where A and B were the weights of the batter and the baked cake, respectively.

Crumb colour: Interior crumb cakes were cut off to obtain 3×3 cm cake pieces. The colour was determined by using a Hunterlab colourimeter (Model ColorFlex, Hunter Associates Laboratory, Reston, VA). Values for L* (lightness), a* (redness/greenness) and b* (yellowness/ blueness) were recorded for 3 samples per batch using a 25 mm aperture.

Texture profile analysis: The Lloyd texture analyzer (Model LRX, Lloyd Instruments, Hampshire, UK) with 25 N load cell and cross head speed 1 mm/min was used for texture determination.

Water activity: The water activity of the cakes was determined by using an Aqua Lab device (Model CX2, Decagon Device, Pullman, WA).

Caloric value: The total caloric value was calculated from the results obtained in the proximate analysis of the energy component.

Sensory evaluation: A total of ten judges drawn from the University of the Thai Chamber of Commerce (UTCC) based on participant's interest and discriminative ability was used for the evaluation. Panelists were semitrained before initiation in the experiment. Sensory attributes tested included for crumb colour, tenderness, moistness and sweetness were evaluated by using a 13 cm unstructured line scale test (Lawless and Heymann, 1998).

Statistical analysis: Data were subjected to Analysis of Variance (ANOVA) using Statistical SPSS for Window version 14.0. When ANOVA showed a significant effect at a level of 5%, treatment means were compared using the Duncan's New Multiple Range Test (Cochran and Cox, 1992).

RESULTS AND DISCUSSION

Physical analysis: The results of physical analysis as presented in Table 1, showed that significant differences were observed in specific volume, weight loss and water activity of reduced-fat chiffon cakes with different levels of erythritol-sucralose. Cakes produced with higher levels of erythritol-sucralose exhibited decreased specific volume, but increased weight loss and water activity. These results suggest that cake batter containing higher erythritol-sucralose content tend to lower ability to retain air, resulting in the formation of tunnels with unequal cells, rough grains and a moist crumb. The 100% erythritol-sucralose cake presented not much tunnels and fairly closed cells, producing a compacted cake. Reduction of sugar significantly increased the water activity of these formulations, probably due to erythritol-sucralose do not provide water binding property as that of sugar.

The lightness (L* value) of cake crumb was affected ($p<0.05$) by the erythritol-sucralose replacement, while redness (a* value) and yellowness (b* value) did not change obviously (Table 1). The colour of 75 and 100% erythritol-sucralose cakes became darker. However, there was no significant decrease in crumb colour with 25 and 50% erythritol-sucralose cakes compared with the control. This finding was not similar to the study of Lin *et al*. (2003) who found that the L values of chiffon cakes gradually increased with higher levels of erythritol. This was probably due to coffee powder used in this study, which no use in Lin's work, influencing on color of the cakes. Because of their thermal stability, both erythritol and sucralose do not degrade and react with amino acids by Maillard reaction (Berlitz and Grosch, 1986; Hoch, 1999); therefore, the change of L* value occurred with increasing erythritol-sucralose levels.

Table 1: Physical properties of reduced fat chiffon cakes with different levels of sugar replacement

Physical parameters	Erythritol-sucralose replacement (%) 0	25	50	75	100
Specific volume (cm^3/g)	5.59[a]	5.47[a]	5.08[a]	3.74[b]	3.18[b]
Weight loss (%)	15.05[d]	19.02[b]	17.30[c]	18.86[b]	20.56[a]
Water activity	0.889[d]	0.925[c]	0.956[b]	0.964[a]	0.965[a]
CIE colour scales					
L*	53.45[a]	51.39[abc]	51.72[ab]	49.82[bc]	48.74[c]
a*	7.69[b]	8.38[a]	7.84[ab]	7.84[ab]	7.94[ab]
b* [ns]	25.46	26.27	25.18	24.66	24.75
Texture profile analysis					
Hardness (kgf)[ns]	0.52	0.49	0.67	0.68	0.36
Cohesiveness	0.55[ab]	1.47[a]	0.31[b]	0.77[ab]	-3.86[c]
Springiness (mm)	12.74[a]	10.79[a]	12.49[a]	6.93[b]	3.67[b]
Adhesiveness (kgf.mm)	-0.23[a]	-0.21[a]	-0.25[a]	-0.11[b]	-0.09[b]

Means in the same row with different superscripts are different (p<0.05); CIE colour scales : L* = lightness (0 = black, 100 = white); a* = redness/greenness (+ = red, – = green); b*= yellowness/ blueness (+ = yellow , – = blue); ns = non–significant

As shown in Table 1, there were significant differences for all textural attributes, except for hardness among all formulations. The cakes were more cohesive and adhesive, but less springy with increase in the level of sugar replacement. The result implied that structural failure occurred in the cakes when 75% and more of sugar content was replaced. This result could be related to the property of sugar to retard the gelatinization of starch which has a tenderizing effect on cake texture (Barndt and Antenucci, 1993). However, no significant differences were found in all textural attributes between 50% erythritol-sucralose and control cakes.

Sensory evaluation

Crumb colour: Mean scores from crumb colour evaluation decreased (p<0.05) as the level of erythritol-sucralose was increased (Table 2). The control cake had yellowish brown crumb while 100% erythritol-sucralose cake had brown crumb. This result was agreed with L* value which indicated that the crumb of cake became darker as the erythritol-sucralose content increased.

Tenderness: There was significant difference (p<0.05) in tenderness scores for all formulations indicated that erythritol-sucralose replacement did affect the texture of chiffon cakes (Table 2). This was confirmed by instrumental texture profile analysis, the more the erythritol-sucralose used, the less the texture quality of the cake occurred. The 100% erythritol-sucralose cake presented a fairly compacted characteristic.

Moistness: Mean scores from moistness evaluation decreased (p<0.05) with increasing of levels of sugar replacement (Table 2), showing that the moist texture of the cakes related to higher levels of erythritol-sucralose replacement. The lowest score of moistness was observed for 100% erythritol-sucralose.

Table 2: Sensory scores of reduced fat chiffon cakes with different levels of sugar replacement

Sensory scores	Erythritol-sucralose replacement (%) 0	25	50	75	100
Crumb colour	3.85[c]	6.00[b]	6.27[b]	6.28[b]	8.55[a]
Tenderness	7.87[a]	6.64[ab]	5.93[b]	3.99[c]	2.15[d]
Moistness	6.30[a]	4.92[a]	5.15[a]	4.30[ab]	2.61[b]
Sweetness	7.05[a]	5.43[b]	4.48[b]	2.28[c]	0.91[d]

Means in the same row with different superscripts are different (p<0.05); Based on a 13 cm unstructured line scale test: Crumb colour (1 = yellowish brown, 10 = brown); Tenderness (1 = slightly tender, 10 = strongly tender); Moistness (1 = moist, 10 = dry); Sweetness (1 = slightly sweet , 10 = strongly sweet)

Table 3: Chemical composition and calorie content of chiffon cakes

Composition (g/100 g sample)	Chiffon cakes: Standard formulation	Reduced fat formulation	Reduced-fat, less sugar formulation
Moisture	21.90[c]	27.40[b]	33.65[a]
Protein	6.83[c]	8.50[ab]	10.34[a]
Fat	18.70[a]	11.60[b]	12.08[b]
Ash	1.95[b]	2.14[ab]	3.09[a]
Carbohydrate	50.62[a]	50.36[a]	40.84[b]
Caloric value (Kcal/100g)	398.10	339.84	313.44

Means in the same row with different superscripts are different (p<0.05). Standard formulation = a full fat chiffon cake. Reduced-fat formulation = a chiffon cake with 50% soybean oil replacement with water incorporated with a konjac flour-SPI blend. Reduced-fat, less sugar formulation = a reduced-fat chiffon cake with 50% erythritol-sucralose as sugar replacement

Sweetness: The control chiffon cake had the highest sweetness scores (Table 2). The scores were subsequently reduced when the level of erythritol-sucralose replacement was increased. The sweetness of 100% erythritol-sucralose cakes was significantly less than (p<0.05) those made with 0, 25, 50 and 75% erythritol-sucralose. The effect of erythritol-sucralose replacement on sweetness could be the reason for the sweetness of erythritol being about 60-80% compared to that of sucrose and different sweetness profile of both erythritol and sucralose in relation to that of sucrose (Newsome, 1993; Goossens and Röper, 1994).

Nutritional evaluation: The results of proximate analysis as presented in Table 3, showed that the erythritol-sucralose replacement was significantly affected (p<0.05) chemical compositions and caloric values of the cakes with respect to those of standard and reduced-fat formulations. The 50% erythritol-sucralose cake demonstrated the most moisture and the least carbohydrate content. Both reduced-fat and reduced-fat, less sugar formulations exhibited higher protein than that of the standard cake, probably due to SPI, which is composed of $90% protein content. In this study, the reduced-fat, less sugar cake was considered nutritious because the consumption of about 100g would provide approximately >51.4% of protein and <35.4% of fat as compared to the standard cake. These values can be calculated as total caloric values of the reduced-fat, less sugar formulation indicating that total caloric value reduction was about 21.3% in relation to 100 g of the standard cake.

Conclusion: The reduced-fat chiffon cake containing 50% erythritol-sucralose had an acceptable sensory quality and contained less caloric value, which may be as an alternative for health-care consumers. Further work is needed to study on storage stability of the cake.

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