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Full Length Research Paper

Effect of konjac flour incorporated with soy protein isolate on quality characteristics of reduced-fat chiffon cakes

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Effect of konjac flour (0.5 and 1%) incorporated with soy protein isolate (SPI) (5 and 10%) against wheat flour on physical, chemical and sensory properties of reduced-fat chiffon cakes prepared with 50% vegetable oil replacement with water were investigated. The addition of konjac flour and SPI produced reduced-fat cakes with significantly lower ($p < 0.05$) in specific volume, but higher ($p < 0.05$) in weight loss and water activity. All reduced-fat formulations were significantly darker ($p < 0.05$) than the control. The high concentration of SPI produced the cakes with higher L*(lightness) but lower a*(red) and b*(yellow). The addition of konjac flour incorporated with SPI significantly decreased ($p < 0.05$) hardness, cohesiveness and springiness of reduced-fat cakes. Sensory results indicated that the cakes with konjac flour and SPI tended to be darker, juicy, sweet and flavour, but less hard than the control; nevertheless, the cake with 0.5% konjac flour and 10% SPI was rated as tender as the control. Also, the reduction of fat and total caloric value of this cake were about 37.9 and 14.6%, respectively, whereas the increment of protein was 24.5% in relation to 100 g of the control cake.

Key words: Chiffon cake, bakery products, konjac flour, soy protein isolate.

INTRODUCTION

Health food products have been extensively manufactured with reduced or no added fat, sugar and salt in combination with the addition of functional ingredients. These products may be used to prevent or decrease the risk of coronary disease, obesity, some cancers and other chronic diseases, as well as to provide health-promoting substances and nutrients (Newsome, 1993). Gums or hydrocolloids have been used as fat replacement in many foods based on their ability to provide viscosity and body and in some cases form gels, which control rheological characteristics of aqueous and emulsion systems, reduce or control crystallization and inhibit syneresis (Lucca and Tepper, 1994). Also, in contrast to starches and proteins, gums have high fibre composed of content, which help to relieve constipation (Ward, 1997). Konjac flour, an non-ionic polysaccharide which of mannose and glucose (3: 2) units with β-(1, 4)–linkages has been carried out to retain sensory and textural attributes through fat reduction by replacing fat with konjac gel in some bakery products (Thomas, 1997) such as reduced-fat butter cakes made with konjac gel and less sugar by using sorbitol and polydextrose (Akesowan, 2003) and reduced-fat, less sugar chiffon cakes prepared with konjac flour and erythritol-sucralose (Akesowan, 2009).

Soy protein isolate (SPI) has considerable potential for use as protein supplement in a variety of foods, because of its high protein content (≥ 90% protein) and a good balance of amino acid patterns (Conforti and Davis, 2006). It is highly recommended for solving protein-malnutrition in developing countries, as an inexpensive high protein resource. Besides its functional properties such as emulsification and foaming capacity, SPI is also naturally composed of phytochemicals such as isoflavones, which have been shown to possess natural antioxidant activity to combat oxidative degradation that could lead to disease

Abbreviations: SPI, Soy protein isolate; **SEM,** scanning electron microscopy.

inside the body (Corforti and Davis, 2006). Richardson et al. (2002) showed that SPI is beneficial to incorporate and stabilize air cells or bubbles, resulting in a finer dispersion and higher cake quality. Similar result was confirmed by Subagio and Morita (2008) who studied of cake characteristics with addition of protein isolates from hyacinth beans.

Cake, one of high fat and calorie food products, has been extensively studied for fat reduction (Berglund and Hertsgaard, 1986; Zambrano et al., 2004). Essentially, cake products are leavened mainly by baking powder or leavening agent, which air cells occurred are emulsified by fat and to produce for the cake structure during baking. Reduction in fat content affects cake characteristics, as a result of decreased air cells and also unstabilized air cells. Chiffon cakes often refer to foam-type cakes; rely mostly on air cells produced by mixing or leavening agent for volume and texture. Sung et al. (2006) studied for the supplement with soy protein concentrate in sponge cakes in which it improved their functional and nutritional characteristics. Although gums or soy proteins have been investigated for use in reduced or low-fat bakery products, the combination of these substances as fat replacement is limited. Therefore, the aim of this study was to investigate the effect of konjac flour incorporated with SPI on physical, chemical, sensory and microstructure properties of chiffon cakes with 50% vegetable oil replacement with water.

MATERIALS AND METHODS

Materials

Konjac flour was purchased from the Thai Food and Chemical Co., Ltd., Thailand while SPI was obtained from the Vichi Consolidate Co., Ltd., Thailand. The cake ingredient including wheat flour, sugar, salt, fresh eggs, soybean oil, evaporated milk, baking powder, cream of tartar and orange juice were purchased from a local supermarket.

Cake preparation

Four reduced-fat chiffon cakes were prepared by using 50% soybean oil replacement with water in combination with varying levels of konjac flour (0.5 and 1%) incorporated with SPI (5 and 10%) against wheat flour as followed: CC1 (0.5: 5: 94.5), CC2 (0.5: 10: 89.5), CC3 (1: 5: 94) and CC4 (1: 10: 89). For cake processing, dry ingredients on flour weight basis (100 g of a mixture of wheat flour/konjac flour/SPI), 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 1 h 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 homogenised to make the samples for analysis. Moisture, protein, lipid, ash and carbohydrate were determined according to AOAC (1995) 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 cm × 3 cm cake pieces. The colour was determined by using a Hunterlab colourimeter (Model ColourFlex, Hunter Associates Laboratory, Reston, VA). Values for L^* (lightness), a^* (red) and b^* (yellow) were recorded for 3 samples per batch using a 25 mm aperture. Hue and chroma values were determined using the formula, ($\tan^{-1}$ b/a) and $(a^2+b^2)^{1/2}$, respectively.

Texture profile analysis

The Lloyd texture analyser (Model LRX, Lloyd Instruments, Hampshire, UK) with 25 N load cell and crosshead 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

Sensory evaluation was conducted by a semi trained panel (ten judges) drawn from the University of the Thai Chamber of Commerce (UTCC). Each panelist was trained in four 30-min sessions for basic aspects and the differences concern all the attributes of the samples. Definitions were developed for each of these terms chosen (tenderness, hardness, crumb colour, crust colour, juiciness, sweetness and flavour). A 13-cm unstructured line scale test (1 = extremely low, 10 = extremely strong) was used to rate intensity of

Table 1. Physical analysis of reduced-fat chiffon cakes with konjac flour and SPI.

Physical properties	Proportion of konjac flour/SPI/wheat flour				
	Control (0: 0: 100)	CC1 (0.5: 5: 94.5)	CC2 (0.5: 10: 89.5)	CC3 (1: 5: 94)	CC4 (1: 10: 89)
Specific volume (cm^3/g)	3.72 ± 0.06 [a]	3.34 ± 0.02 [b]	3.32 ± 0.09 [b]	3.25 ± 0.49 [b]	3.04 ± 0.52 [c]
Batter weight loss (%)	14.85 ± 0.28 [b]	18.75 ± 0.32 [a]	18.14 ± 0.48 [a]	17.65 ± 0.29 [a]	19.03 ± 0.39 [a]
Water activity	0.86 ± 0.04 [b]	0.92 ± 0.05 [a]	0.93 ± 0.22 [a]	0.93 ± 0.19 [a]	0.92 ± 0.15 [a]
CIE colour scales					
L*	53.85 ± 0.58 [a]	44.45 ± 0.28 [c]	48.14 ± 0.83 [b]	45.75 ± 0.06 [c]	49.17 ± 0.67 [b]
a*	8.65 ± 0.17 [c]	9.34 ± 0.48 [a]	8.85 ± 0.33 [b]	9.45 ± 0.71 [a]	9.19 ± 1.02 [b]
b*	27.13 ± 0.28 [a]	27.15 ± 0.28 [a]	26.54 ±1.11 [ab]	27.00 ± 0.90 [a]	25.85 ± 0.31 [b]
Chroma	28.48 ± 0.13 [a]	28.71 ± 0.20 [a]	27.98 ± 0.16 [b]	28.61 ± 0.09 [a]	27.35 ± 0.17 [b]
Hue	72.32 ± 0.22 [a]	71.02 ± 0.28 [b]	71.56 ± 0.09 [b]	70.71 ± 0.25 [b]	70.43 ± 0.15 [b]
Texture profile analysis					
Hardness	1.10 ± 0.02 [a]	0.88 ± 0.04 [b]	0.72 ± 0.05 [b]	0.44 ± 0.01 [c]	0.41 ± 0.06 [c]
Cohesiveness	0.56 ± 0.03 [a]	0.26 ± 0.00 [b]	0.49 ± 0.01 [a]	0.21 ± 0.01 [b]	0.06 ± 0.00 [c]
Springiness	11.63 ± 0.19 [a]	9.27 ± 0.09 [b]	8.12 ± 1.01 [b]	8.09 ± 0.88 [b]	8.22 ± 0.72 [b]
Chewiness	6.56 ± 1.11 [a]	2.22 ± 0.01 [b]	2.65 ± 0.64 [b]	1.15 ± 0.29 [c]	0.47 ± 0.02 [c]
Adhesiveness	-0.33 ± 0.01 [b]	-0.76 ± 0.00 [a]	-0.57 ± 0.01 [b]	-0.45 ± 0.02 [b]	-0.42 ± 0.05 [b]

All values are means of three determinations ± standard deviation. 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).

the attributes. All testing sessions were held in a sensory evaluation laboratory with partitioned booth at UTCC. Distilled water was provided to rinse their palates between samples (Lawless and Heymann, 1998).

Electron microscopy

Small pieces of samples (0.5 cm in diameter x 0.3 cm thick) were used for scanning electron microscopy (SEM) analysis. Samples were frozen by using liquid nitrogen (N_2) before mounting on a stub, allowing surface and cross-section visualization. Micrographs of samples were obtained with scanning electron microscope (JSM-5410LV, JEOL, Japan).

Statistical analysis

The production of redcued-fat chiffon cakes with different SPI levels was in triplicate. Data were analysed statistically by analysis of variance (ANOVA) using SPSS for Window version 16.0. Means with a significant difference ($p < 0.05$) were compared by Duncan's new multiple range test (Cochran and Cox, 1992).

RESULTS AND DISCUSSION

Physical analysis

Effects of addition of konjac flour and SPI on characteristics of reduced-fat chiffon cakes prepared with 50% oil replacement with water are presented in Table 1. The cakes with konjac flour incorporated with SPI were observed for significantly lower ($p < 0.05$) in specific volume in relation to that of the control, indicating higher compact texture; consequently, the reduced-fat cake with 1% konjac flour incorporated with 10% SPI showed the least specific volume ($p < 0.05$). Significantly high ($p < 0.05$) weight loss and water activity were observed in reduced-fat cakes than the control, probably due to their water-holding capacity and stabilization of emulsion, as a result of konjac flour and SPI, respectively, and also the 50% oil replacement with water in the formulation (Arrese et al., 1991; Lucca and Tepper, 1994). The volume of cake is affected by the gas expansion that occurs during mixing. The SPI could decrease the surface tension of gas/liquid system thereby increasing the foam formulation whereas konjac flour made the water phase in batter more viscous, resulting in trapped air bubbles in batter, which expanded by heat during baking to provide both framework and structure of the cake (Barndt and Antenucci, 1993). This finding revealed that the suitable proportion of konjac flour and SPI was feasible for use as fat replacement in chiffon cakes.

When considering colour evaluation, it was evident that addition of konjac flour and SPI significantly decreased ($p < 0.05$) L*-values (lightness) whereas increased ($p < 0.05$) a*-values (red) of reduced-fat chiffon cakes in relation to the control cake. This finding revealed that cake colour would become more brownish red, as Effects of addition of konjac flour and SPI on expressed by Hue values.

The Maillard reaction involves the reaction between

Table 2. Sensory evaluation of reduced-fat chiffon cakes with konjac flour and SPI.

Sensory attributes	Proportion of konjac flour/SPI/wheat flour				
	Control (0: 0: 100)	CC1 (0.5: 5: 94.5)	CC2 (0.5: 10: 89.5)	CC3 (1: 5: 94)	CC4 (1: 10: 89)
Tenderness	6.5 ± 0.6^{a}	5.6 ± 0.2^{b}	6.8 ± 0.7^{a}	5.5 ± 0.9^{b}	4.0 ± 0.2^{c}
Hardness	6.1 ± 0.8^{a}	5.3 ± 0.3^{b}	5.4 ± 0.8^{b}	4.5 ± 1.2^{c}	4.4 ± 0.3^{c}
Crumb colour	2.8 ± 0.5^{c}	6.6 ± 0.9^{ab}	5.9 ± 0.2^{b}	5.9 ± 0.7^{b}	8.0 ± 0.9^{a}
Crust colour	3.0 ± 0.8^{c}	5.1 ± 0.2^{b}	5.3 ± 0.9^{b}	5.7 ± 0.1^{b}	6.7 ± 0.7^{b}
Juiciness	4.1 ± 0.8^{b}	6.2 ± 1.3^{a}	5.6 ± 0.6^{a}	6.1 ± 0.9^{a}	6.5 ± 0.3^{a}
Sweetness	4.2 ± 1.1^{b}	5.3 ± 0.4^{a}	5.9 ± 0.9^{a}	5.7 ± 0.6^{a}	5.9 ± 1.46^{a}
Flavour	7.3 ± 0.3^{a}	6.5 ± 0.9^{ab}	5.9 ± 0.8^{b}	5.2 ± 0.8^{b}	5.6 ± 0.5^{b}

All values are means of three determinations ± standard deviation. Means in the same row with different superscripts are different ($p < 0.05$). Based on a 13-cm unstructured line scale test (1 = extremely low, 10 = extremely strong).

aldehydes and amines, resulting in the formation of dark pigments (melanoidins), which affects the cake colour (Alais and Linden, 1991). In addition, konjac flour is light brown colour that would influence on products colour. As a result, the addition of SPI would increase the amine compounds, resulting in more melanoidins and more intense brownish red colour. On the other hand, when the addition of konjac flour was increased from 0.5 to 1% level, the cakes displayed darker colour. Also, the decrease in chroma values of reduced-fat cakes with 10% SPI could be attributed to the decrease in red colour (a*-values).

Texture profile analysis of 50% oil replacement chiffon cakes with konjac flour and SPI presented in Table 1 shows a significant decrease ($p < 0.05$) in most textural parameters with respect to those of the control. Overall, the cakes with 1% konjac flour incorporated with either 5 or 10% SPI were significantly less hard and chewy than those with 0.5% konjac flour, demonstrating highly unleavened structures of cakes with gummy texture. The reduced-fat chiffon cake with 0.5% konjac flour and 10% SPI showed no significant differences ($p > 0.05$) in cohesiveness and adhesiveness with respect to those of the control. This result implied that some textural characteristics such as hardness and springiness could be less in quality in reduced-fat cakes, by way of fat replacement using water incorporated with konjac flour and SPI.

Sensory evaluation

The results of sensory evaluation in Table 2 presents that there were significant differences ($p < 0.05$) for all attributes, except for tenderness observed in the cake with 0.5% konjac flour incorporated with 10% SPI, between control and reduced-fat formulations. The addition of konjac flour and SPI at different levels altered sensory properties among all reduced-fat cakes, except for crust colour, juiciness, sweetness and flavour attributes. With respect to the control cake, reduced-fat cakes tended to be more dark, juicy, sweet and flavour whereas less hard. Generally, the cake texture is influenced by the three-dimensional structure and the size and distribution of gas (air) cells in the cake (Subagio and Morita, 2008). Konjac flour is capable of providing viscosity to retain air cells in cake batter during mixing, resulting in the cake structure (Waring, 1998). Also, the SPI might decrease the surface tension of the colloidal system, resulting in a decrease in the globule size of the foam during cake mixing (Subagio and Morita, 2008). This can explain as why konjac flour and SPI can be used as fat replacement in reduced-fat, added water chiffon cakes; however, some imitation for functional properties of soybean oil is limited, resulting in some diminish sensory attributes of the products.

As the 1% konjac flour and 5 or 10% SPI were used, reduced-fat cakes were significantly the least tender and hard as compared with other formulations, which may be explained as a large amount of konjac flour (1%) causes the batter is more viscous, producing the cake with gummy texture that is moist and soft after baking. When konjac flour was added at 0.5% level with any SPI levels, the cakes showed better sensory characteristics in relation to those with 1% konjac flour. The statistical analysis showed that only the 50% oil replacement with water incorporated with 0.5% konjac flour and 10% SPI produced cakes equal to the control cake with respect to the tenderness.

Crumb colour of reduced-fat chiffon cakes were darker than the control, probably because of Maillard reaction in which the amine portions was increased, by the way of SPI addition. This sensory colour was in agreement with colour results obtained by the instrumental determination where lower L* and b* but higher a* were observed in reduced-fat cakes compared with the control. Results also indicated that reduced-fat cakes were significantly higher ($p < 0.05$) in juiciness, which was attributed to the water-holding capacity of both konjac flour and SPI, as confirmed by increased moisture content shown in Table 3. It was interesting to note that panelists rated the reduced-fat cakes sweeter than the control; nevertheless, the cause of increase in sweetness with added konjac flour

Table 3. Chemical composition of reduced-fat chiffon cakes with konjac flour and SPI.

Chemical composition (%)	Proportion of konjac flour/SPI/wheat flour				
	Control (0: 0: 100)	CC1 (0.5: 5: 94.5)	CC2 (0.5: 10: 89.5)	CC3 (1: 5: 94)	CC4 (1: 10: 89)
Moisture	21.90 ± 0.07^{a}	29.16 ± 0.75^{b}	27.40 ± 0.85^{b}	28.11 ± 0.08^{b}	27.93 ± 0.55^{b}
Protein	6.83 ± 0.94^{c}	7.59 ± 0.16^{b}	8.50 ± 0.44^{a}	7.61 ± 0.43^{b}	8.52 ± 0.95^{a}
Fat	18.70 ± 0.56^{a}	11.50 ± 0.02^{b}	11.61 ± 0.09^{b}	11.99 ± 0.18^{b}	11.66 ± 1.02^{b}
Ash	1.95 ± 0.22^{b}	2.15 ± 0.76^{a}	2.14 ± 0.11^{a}	2.11 ± 0.16^{a}	2.23 ± 0.92^{a}
Carbohydrate	50.62 ± 0.77	49.60 ± 0.55	50.36 ± 0.89	50.18 ± 1.49	49.66 ± 0.75
Total energy (kcal/100 g)	398.10	332.26	339.84	339.07	337.66

All values are means of three determinations ± standard deviation. Means in the same row with different superscripts are different ($p < 0.05$).

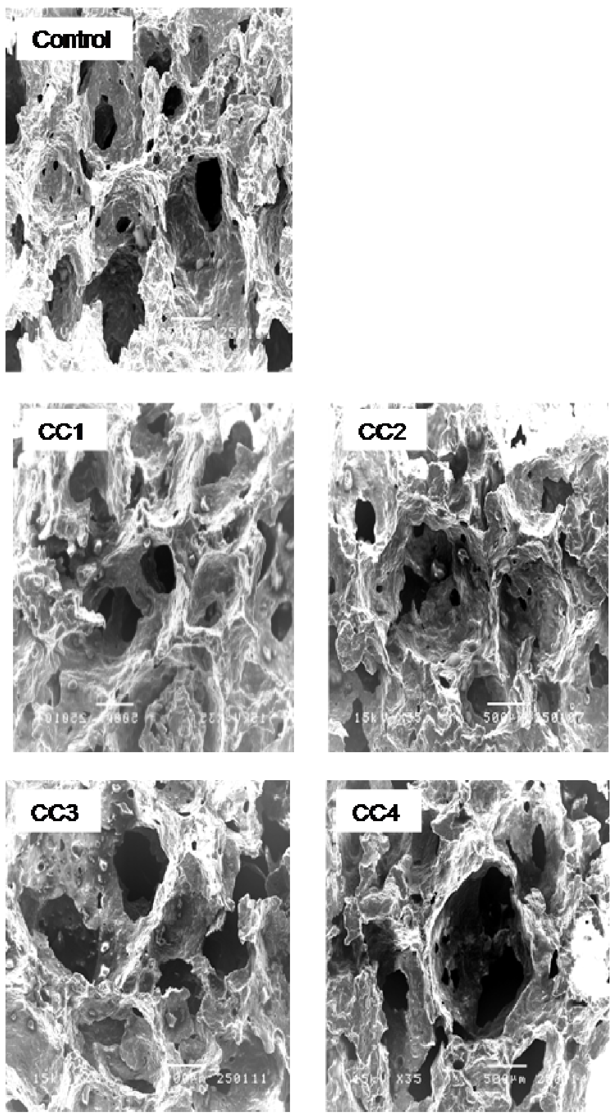

Figure 1. Scanning electron micrographs of reduced-fat chiffon cakes with konjac flour and SPI. Based on different proportion of konjac flour/SPI/wheat flour on each formulation. Control (0: 0: 100), CC1 (0.5: 5: 94.5), CC2 (0.5: 10: 89.5), CC3 (1: 5: 94) and CC4 (1: 10: 89) (Bar = 500 µm).

and SPI is not known. However, the beany flavour of SPI significantly affected ($p < 0.05$) the cake flavour, showing lower scores in all reduced-fat cakes in relation to the control. This was confirmed by the study of Mashayekh et al. (2008) who report that the flavour of 12% soy flour-blended bread might be affected by the flavour of soy bean flour.

Scanning electron microscope

Micrographs of control and reduced-fat chiffon cakes prepared with a mixture of konjac/SPI/wheat flour as followed: CC1 (0.5: 5: 94.5), CC2 (0.5: 10: 89.5), CC3 (1: 5: 94) and CC4 (1: 10: 89) samples are shown in Figure 1. Overall, the control micrograph showed consistent sizes of air cells throughout the cake whereas greater sizes of inconsistent air cells were observed by SEM following each increasing of konjac flour and SPI in the cakes. The structure of reduced-fat cakes (CC1 to CC4) was more cohesive and coarse, showing gel-type structures. Larger porous texture was evident in the cake with 1% konjac flour incorporated with 5 or 10% SPI (CC3 and CC4) whereas low concentration of konjac flour (0.5%) would promote the distribution of air cells (CC1 and CC2).

Chemical composition and nutritional evaluation

Results of chemical composition as presented in Table 3 shows that reduced-fat chiffon cakes were more moist than the control cake as expected. This could be due to the water-binding properties of konjac flour and SPI, which seemed to positively affect the moisture retention of the cakes during storage. When 50% vegetable oil content was replaced with water incorporated with konjac flour and SPI, the fat and energy content declined whereas the protein content increased. It might be the SPI used, which is composed of $\geq$ 90% protein content. This incorporation of SPI into wheat flour increased the protein content in proportion to the level of replacement. In this study, the reduced-fat cake with 0.5% konjac flour and 10% SPI was considered nutritious because the consumption of about 100 g would provide more than 24.5% of protein and less than 37.9% of fat as compared to the control cake. These values can be calculated as total caloric values of the reduced-fat cake indicating that total caloric value reduction was about 14.6% in relation to 100 g of the control cake.

Conclusion

Konjac flour incorporated with SPI could be used as a functional and nutritional ingredient to partially substitute for fat in a chiffon cake. The level of 0.5% konjac flour and 10% SPI against wheat flour (0.5: 10: 89.5) was the optimum proportion to produce the acceptable cake with 37.9% less fat and 24.5% more protein and the total caloric reduction is of 14.6%.

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REFERENCES

AACC (1983). Approved method of the American Association of Cereal Chemists, 8th ed., American Association Cereal Chemists. St. Paul, MN, USA.
Akesowan A (2003). Effect of polydextrose or sorbitol on quality characteristics of reduced-calorie cakes containing konjac flour. UTCC J. 23: 139-152.
Akesowan A (2009). Quality of reduced-fat chiffon cakes prepared with erythritol-sucralose as replacement for sugar. Pak. J. Nutr. 8: 1383-1386.
Alais C, Linden G (1991). Food Biochemistry. Ellis Horwood, London.
AOAC (1995). Official method of analysis, 16th ed., Association of Official Chemists. Washington D.C., USA.
Arrese EL, Sorgentini DA, Wagner JR, Anon MC (1991). Electrophoretic, solubility and functional properties of commercial soy protein isolates. J. Agric. Food Chem. 39: 1029-1032.
Barndt RT, Antenucci RN (1993). Fat and calorie-mogified bakery products. In: Khan R. (ed.) Low-calorie Foods and Food Ingredients, Blackie Academic & Professional, London. pp. 106-137.
Berglund PT, Hertsgaard DM (1986). Use of vegetables oils at reduced levels in cake, pie crust, cookie, and muffins. J. Food Sci. 51: 640-644.
Cochran WG, Cox GM (1992). Experimental Design. 2nd ed. John Wiley and Sons,New York.
Conforti FD, Davis SF (2006). The effect of soya flour and flaxseed as a partial replacement for bread in yeast bread. Int. J. Food Sci.Technol. 41: 95-101.
Lawless HT, Heymann H (1998). Sensory Evaluation of Food.Chapman and Hall, New York.
Lucca PA, Tepper BJ (1994). Fat replacers and the functionality of fat foods. Trends Food Sci. Technol. 5 : 12-19.
Mashayekh M, Mahmoodi MR, Entezari MH (2008). Effect of fortification of defatted soy flour on sensory and rheological properties of wheat bread. Int. J. Food Sci. Technol. 43: 1693-1698.
Newsome R (1993). Sugar substitutes. In: Altschull AM (Ed.), Low-calorie Food Handbook. Marcel Dekker, New York. pp. 139-170.
Richardson G, Langton M, Faldt P, Hermanson AM (2002). Microstructure of a crystalline emulsifier and their influence on air incorporation on cake batter. Cereal Chem. 79: 546-552.
Subagio A, Morita N (2008). Effects of protein isolate from hyacinth beans (*Lablab purpureus* [L.] Sweet) seeds on cake characteristics. Food Sci. Technol. Res. 14: 12-17.
Sung MJ, Park YS, Chang HG (2006). Quality characteristics of sponge cake supplemented with soy protein concentrate. Food Sci. Biotechnol. 15: 860-865.
Thomas WR (1997). Konjac gum. In: Imeson A. (ed.) Thickening and gelling agents for food, 2nd ed., Chapman & Hall, London. pp. 169-179.
Ward FM (1997). Hydrocolloid systems as fat mimetics in bakery products: Icings, glazes and fillings. Cereal Foods World, 42: 386-390.
Waring S (1988). Shortening replacement in cakes. Food Technol. 42: 114-117.
Zambrano F, Despinoy P, Ormenese RCSC, Faria EV (2004). The use of guar and xanthan gums in the production of 'light' low fat cakes. Int. J. Food Sci. Technol. 39: 959-966.