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Full Length Research Paper

Partial fat and sugar replacement with soy milk, inulin and sucralose on quality of Thai *Pandanus* custard

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Thai *Pandanus* custard samples replaced with coconut milk, and sugar with soy milk, inulin and sucralose, were compared with quality characteristics of the regular formulation (control). With increasing levels of coconut milk replacement, the product pH and redness increased, whereas there was no significant difference in water activity. As 1/3 or 2/3 coconut milk replacement with soy milk were applied with no significant effect of inulin levels used (2.5 and 5%), custard samples with complete reduction of sugar with sucralose were rated in lower scores of all sensory attributes, with lack of a product-typical taste and texture. The *Pandanus* custard was replaced with 1/3 coconut milk and soy milk, 5% added inulin and 50% sugar replacement with sucralose presented desirable sensory characteristics in relation to the regular formulation; however, as frequency distribution of sensory scores was considered, some attributes such as taste, flavor and texture need to be improved in order to meet a high acceptable level. The product had about 20.7% reduction in energy and was pale in color throughout the storage time at 4 ± 2°C for 3 weeks, whereas the microbiological safe was about a week of storage.

Key words: Soy milk, *Pandanus,* sucralose, inulin, custard samples.

INTRODUCTION

Consumers' concern regarding healthy diet and convenience of foods has significantly increased in the last decade. With a common knowledge, nutrition-related diseases such as coronary disease, diabetes, high blood pressure and some cancers are increasing because of high energy and low dietary fiber intake and no time for exercise. In dairy product category, fat and sugar are the major constituents providing the energy value of 9 and 4 kcal/g, respectively. They are responsible for not only sensory perception including texture, flavor, mouthfeel and palatability of the diet (Grigelmo-Miguel et al., 2001), but also many other functional properties in foods that make them useful as aeration, bulking agent, texture modifier and preservative (Knetch, 1990; Lucca and Tepper, 1994). Generally, an approach for energy reduction in food products is to use low-calorie ingredients that can mimic sufficiently the techno-functional properties of fat and/or sugar. However, low-calorie products with desirable quality and nutritive values available to consumer demand are being challenged.In Thailand, *Pandanus* custard is one of the most popular indigenous food products where fat (coconut milk) and sugar are important ingredients in its preparation; consequently, this product has a creamy consistency and sweetish-rich aroma. It is a common dipping sauce for fresh breads and waffles. Parallel to the consumer preference for food products that offer some nutritional value, there is an increasing trend for consumption of low-calorie food products. Soy milk is considered as a good source for health ingredients such as isoflavones which have been shown to possess antioxidant activity that may combat oxidative degradation that could lead to disease inside the body in addition to a low fat content and free of milk sugar (lactose) (Conforti and Davis, 2006). Inulin is a fructosyl-fructose-linked oligomeric carbohydrate with a polymerization degree ≥ 10, which moderately dissolves in water and at higher concentration forms a spreadable gel network that has the potential of

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Table 1. Formulations of *Pandanus* custard samples with energy reduction.

Formulation	Fat replacement		Sugar replacement with sucralose
	Soy milk : coconut milk ratio	Inulin (g/100 g coconut milk)	
T1	1 : 2	2.5	50% sugar replacement
T2	1 : 2	5	50% sugar replacement
T3	1 : 2	5	100% sugar replacement
T4	2 : 1	2.5	50% sugar replacement
T5	2 : 1	5	50% sugar replacement
T6	2 : 1	5	100% sugar replacement

Control (C): Regular formulation included: 40% coconut milk, 22% sugar, 4% corn flour, 14% whole egg and 20% *Pandanus* juice.

being used as fat replacer (Franck, 2002; Zahn et al., 2010). Also, it is resistant to human digestion but highly fermentable by large intestine microbial and associated with a pronounced bifidogenic effect which promotes the growth of (beneficial) bifidobacteria in the intestinal tract (Meyer and Stasse-Wolthuis, 2009). In addition to fat replacement, high-intensity low-calorie sweeteners provide consumers with many benefits, both psychologic and physiologic.

Sucralose, a non-caloric sweetener with no bulking property, has shown advantages in relation to other low-calorie sweeteners used in nutritive products, because it provides about 600 times of sucrose sweetness with no aftertaste and tooth decay, good storage stability and low pH and high temperature stability.

It has also been proved as safe for human consumption (Wallis, 1993; Mendoca et al., 2001; Martínez-Cervera et al., 2012). However, it is essential to have a clear understanding of which concentration of sucralose best match the sweetness intensity and characteristics of the equivalent products sweetened with sucrose.

To the best of our knowledge, no study has compared the quality characteristics of coconut *Pandanus* custard simultaneously replaced with soy milk, inulin and sucralose for coconut milk and sugar which is the regular formulation. Therefore, the aim of this study was to evaluate physical, sensory and microbiological properties of reduced calorie of *Pandanus* custard made with various levels of soy milk, inulin and sucralose. The storage stability of the optimal product was also investigated.

MATERIALS AND METHODS

Materials

Commercial food grade inulin (Fibruline®Instant, Cosucra Groupe Warcoing, Belgium) and sucralose (Xi'an Hao Tian Bio-engineering Technology Co.,Ltd, China) were used. Low-fat, no added sugar soy milk [V-soy®, Greenspot (Thailand), Bangkok, Thailand] and other *Pandanus* custard ingredients including coconut milk, sugar, corn flour, whole egg and *Pandanus* leaf were purchased from a local supermarket.

Preparation of Thai *Pandanus* custard

Six Thai *Pandanus* custard formulated by replacing part of coconut milk with soy milk and inulin and part of sugar with sucralose were identified as C (control) and T1–T6, which are shown in Table 1. Initially, *Pandanus* juice was prepared by blending 200 g *Pandanus* leaf (small pieces) with 500 g distilled water for 2 min, filtered through cheesecloth and the filtrate was mixed with water (1:4 w/w). Dry ingredients(what is the make-up) were added into the mixture of *Pandanus* juice and coconut milk in the bowl, followed by egg yolk and was thoroughly mixed by hand. The mixture was filtered through cheesecloth into a pot and heated at 90-95°C with continuous stirring for 10 min. *Pandanus* custard was allowed to cool down at room temperature (30 ± 2°C) and filled into plastic cups before it was stored at 4 ± 2°C.

Physical analysis

Proximate analysis and caloric value

All samples were homogenized prior to analysis. Moisture, protein, lipid, ash and carbohydrate were determined according to AOAC (1995) procedures. The total caloric value was calculated from the results obtained in the proximate analysis of the energy component.

Water activity

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

pH

The pH was measured by using a pH-meter (Model 320, Mettler-Toledo Ltd., Essex, UK) according to AOAC (1995) standard method.

Color

The color of sample was measured in the term of L*(lightness), a*(red/green) and b*(yellow/blue) values using a HunterLab digital colorimeter (Model Color Flex, Hunter Associates Laboratory, Reston, VA). Hue and chroma values were calculated with the following equations: Hue = $\tan^{-1} b^*/a^*$ and chroma = $[a^{*2} + b^{*2}]^{1/2}$.

Sensory evaluation

Sensory evaluation was conducted by twenty four panelists who

Table 2. pH and water activity of *Pandanus* custard samples with energy reduction.

Formulation	pH	Water activity[ns]
Control	6.85 ± 0.12^{b}	0.79 ± 0.01
T1	7.27 ± 0.06^{ab}	0.80 ± 0.05
T2	7.28 ± 0.01^{ab}	0.80 ± 0.01
T3	7.28 ± 0.04^{ab}	0.81 ± 0.03
T4	7.44 ± 1.74^{a}	0.81 ± 0.00
T5	7.46 ± 0.04^{a}	0.81 ± 0.01
T6	7.43 ± 0.03^{a}	0.81 ± 0.01

The means in the same column with different superscripts are different ($p < 0.05$); ns = Non-significant; C and T1–T6 refer to formulation codes on Table 1.

were experienced in sensory evaluation of foods, but received no specific training relevant to these products. Sensory appearance, color, taste, flavor, texture and overall acceptability were evaluated by using a 9-point hedonic scale test (1 = extremely dislike, 9 = extremely like). All testing sessions were held in sensory evaluation laboratory with partitioned booth. Unsalted cracker, apple juice and distilled water were provided to rinse the palate between samples (Lawless and Heymann, 1998).

Microbiological analysis

Samples of 10 g (week 0, 1, 2, and 3) were aseptically weighed and placed in a stomacher bag containing 90 ml of sterile 0.1% peptone (Difco) diluent and pummeled for 1 min with a Stomacher-400 (Tekmar Company, Cincinnati, OH). Aerobic plate count, yeast and mold were determined in this work. The serial (1:10) dilution of sample homogenates were spread plated onto Plate Count Agar, Dichoran Rose Bengal Chloramphenicol employing an incubation condition at 37°C for 24 to 48 h and 25°C for 5 to 7 days, respectively. Number of colony-forming units (CFU) were counted and reported as log CFU/g.

Statistical analysis

The production of *Pandanus* custard with partial coconut milk and sugar replacement was done in triplicate. Data were analyzed statistically by analysis of variance (ANOVA) using SPSS for Window version 17.0. The 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 properties

Influences of coconut milk replacement with soy milk and added inulin incorporated with sugar replacement with sucralose on the physical properties of *Pandanus* custard samples are presented in Table 2. There were no significant differences in water activity observed for all formulations, whereas significantly higher ($p < 0.05$) pH values were evident with increasing soy milk proportion in formulation. This was attributed to the difference in pH value between coconut milk and soy milk, which is within the range of 6.0 to 6.3 and 6.6 to 6.8, respectively (Seow and Gwee, 1997; Pathomrungsiyounggul et al., 2010). Nevertheless, pH values determined in custard samples with 2/3 coconut milk replacement were significantly increased ($p < 0.05$), whereas there were no significant differences in pH values obtained for custard samples with 1/3 coconut milk replacement and the control. The inulin addition also showed no significant effect on pH of the samples. In addition, based on the same level of coconut milk replacement, pH value was not affected by sugar replacement with sucralose.

The color values of T1-T6 formulations differed significantly depending on level variations of ingredients used for fat and sugar replacement, as shown in Figure 1. Clearly, the control formulation had higher negative a* (green) than any of the formulation with 1/3 and 2/3 coconut milk replacement, possibly due to it high sugar content. Sucrose (sugar) is one of active ingredients which participate in the Maillard reaction, a reaction between aldehydes (reducing sugars) and amines (amino acids) resulting in the formation of dark pigments (melanoidin) (Alais and Linden, 1991). The intense brown color is proportional to the concentration of reactants, thus sucrose is thermally degraded to glucose and fructose, which are reducing sugars involving in the Maillard reaction. As a result, formulations with 100% sugar replacement (T3 and T6) showed higher L* (lightness) than the control and other formulations, because there were insufficient sugars to participate in Maiillard reaction in addition to the fact that sucralose does not relate in non-enzymatic browning reaction (Newsome, 1993).

It was evident that all formulations with 2/3 coconut milk replacement (T4–T6) showed lower L* and negative a* than those with 1/3 replacement (T1–T3), suggesting that the differences in chemical composition and color of coconut milk (white) and soy milk (pale cream) are responsible for product color. Coconut milk is mainly composed of fats and fatty acids whereas soy milk is an excellent source of high quality proteins and amino acids. The more coconut milk replacement results in the more proportion of soy milk exists in formulation, allowing the increase in amine compounds which are subjected to

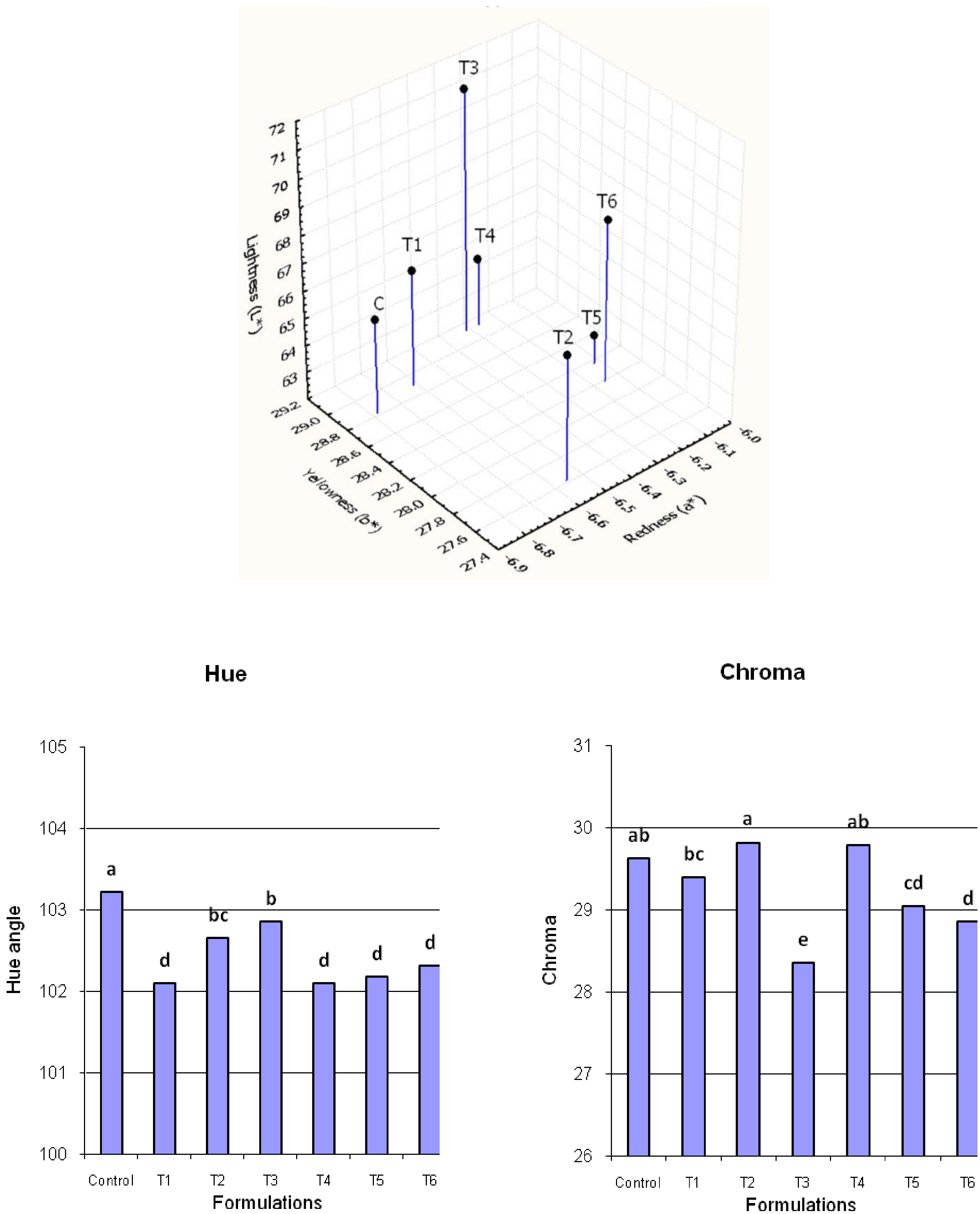

Figure 1. CIE L*a*b* color values, hue and chroma of *Pandanus* custard samples with energy reduction: C and T1–T6 refer to formulation codes on Table 1.

Table 3. Sensory scores of *Pandanus* custard samples with energy reduction.

Formulation	Sensory score*					
	Appearance	Color	Taste	Flavor	Texture	Overall acceptability
Control	7.46 ± 1.18^{a}	7.67 ± 0.96^{a}	7.46 ± 0.78^{a}	7.17 ± 0.87^{a}	7.29 ± 0.69^{a}	7.54 ± 0.51^{a}
T1	6.96 ± 1.19^{a}	7.00 ± 1.14^{bc}	7.12 ± 1.26^{ab}	6.95 ± 1.12^{ab}	7.16 ± 1.20^{a}	7.29 ± 0.85^{ab}
T2	7.50 ± 1.02^{a}	7.50 ± 1.06^{ab}	7.00 ± 1.14^{ab}	6.70 ± 1.45^{abc}	7.29 ± 1.16^{a}	7.45 ± 1.10^{ab}
T3	5.63 ± 1.93^{b}	5.46 ± 1.74^{d}	5.00 ± 1.76^{d}	5.33 ± 1.45^{d}	5.70 ± 1.68^{b}	5.20 ± 1.69^{d}
T4	7.08 ± 1.28^{a}	6.83 ± 1.34^{c}	6.04 ± 1.82^{c}	6.08 ± 1.44^{c}	6.08 ± 1.30^{a}	6.66 ± 1.23^{c}
T5	7.21 ± 1.14^{a}	7.37 ± 1.05^{abc}	6.67 ± 1.37^{bc}	6.45 ± 0.93^{bc}	7.08 ± 1.12^{a}	6.87 ± 1.39^{bc}
T6	6.25 ± 1.92^{b}	5.95 ± 1.54^{d}	4.58 ± 1.88^{d}	4.79 ± 1.61^{d}	5.66 ± 1.85^{b}	4.91 ± 1.66^{d}

The means in the same column with different superscripts are different ($p < 0.05$); ns = non-significant; C and T1–T6 refer to formulation codes on Table 1. *Based on a 9-point hedonic scale test (1 = extremely dislike, 9 = extremely like).

having more melanoidins and intense brownish red color. This may be the reason why formulations with 2/3 coconut milk replacement seem to be darker than those with 1/3 replacement.

When considering hue and chroma in Figure 1, hue angle of all formulations (T1-T6) were significantly lower ($p < 0.05$) than the control, indicating that the samples would become less green or more yellowish. Chroma, which measures the saturation of color, largely decreased in the formulation with 100% sugar replacement, which was attributed to the increase in red color.

Sensory evaluation

Sensory results of *Pandanus* custard samples that were replaced with coconut milk and sugar with soy milk, inulin and sucralose are shown in Table 3 and they indicate that there were significant differences ($p < 0.05$) for all sensory attributes with respect to those of the control formulation. Regarding of 100% sugar replacement with sucralose, custard formulations prepared either with 1/3 or 2/3 coconut milk replacement (T3 and T6) were rated in the lowest scores ($p < 0.05$) for all sensory attributes, indicating the impossibility of replacing the total sugar with sucralose in the preparation of sugar-free custard samples. Furthermore, most panelists comment that these two samples were not considered as desirable in relation to the acceptable criteria which include smooth and creamy consistency and sweetish-rich aroma. In general, viscosity increases in many food products such as mayonnaise, ice cream, yogurt and cake batter in parallel with sugar concentration; as a result, decreasing of sugar content causes a reduction of viscosity and texture of the products (Akesowan, 2009; Choonhahirun and Akesowan, 2011). This result implies that sucrose helps to form a viscous and binding effect in the product; on the contrary, sucralose had insufficient water-binding capacity, resulting in a product with lower creamy texture. At the same time, these products seemed to be pale in color, not a common practice commercially, thus it could have driven the lower panelist rating.

In general, when 50% sugar replacement was applied, all formulations with 1/3 or 2/3 coconut replacement (T1–T2 and T4–T5) were well accepted because the panelists' scores were quite similar and higher than 6.0 (like slightly). Although, scores for all sensory attributes of the formulations with 2/3 coconut milk replacement appeared to decreased in a comparison with that of 1/3 replacement, no statistical differences were observed for each condition (T1 vs T4 and T2 vs T5); except for taste, flavor and overall acceptability (Table 3). The lower scores for taste and flavor were attributed to decreasing proportion of coconut milk that pronounces in custardy characteristic. Also, the result indicate that overall acceptability of these custard samples was mostly influenced by their taste and flavor properties; consequently, the maximum level of 1/3 coconut milk replacement with soy milk incorporated with 50% sugar replacement with sucralose and any levels of inulin can be used in lower calorie custard production to obtain acceptable and better textural quality products in relation to the control. Because the level of inulin addition had no significant effect on sensory attributes of the products, the formulation with 5% inulin (based on coconut milk weight) or 'T2-formulation' was selected and considered as 'healthy image' product of its low energetic value and high prebiotic effect.The ratings given to the sensory properties were investigated for frequency distribution, as suggested by Temelli et al. (2004). Figure 2 shows the frequency distribution of all sensory attributes for control and T2-formulation. It was found that at a score of 7 or higher, percentages of panelists rated for appearance, color, taste, flavor, texture and overall acceptability of the T2-formulation were 79.2, 87.5, 70.8, 62.5, 75 and 87.5%, respectively; while for the control, they were 70.8, 87.5, 87.5, 79.2, 87.5 and 100%, respectively. This finding implies that though these two products did not significantly differ ($p > 0.05$) in all sensory attributes (Table 2), but some sensory attributes, namely taste, flavor and texture, need to be improved in order to meet the high

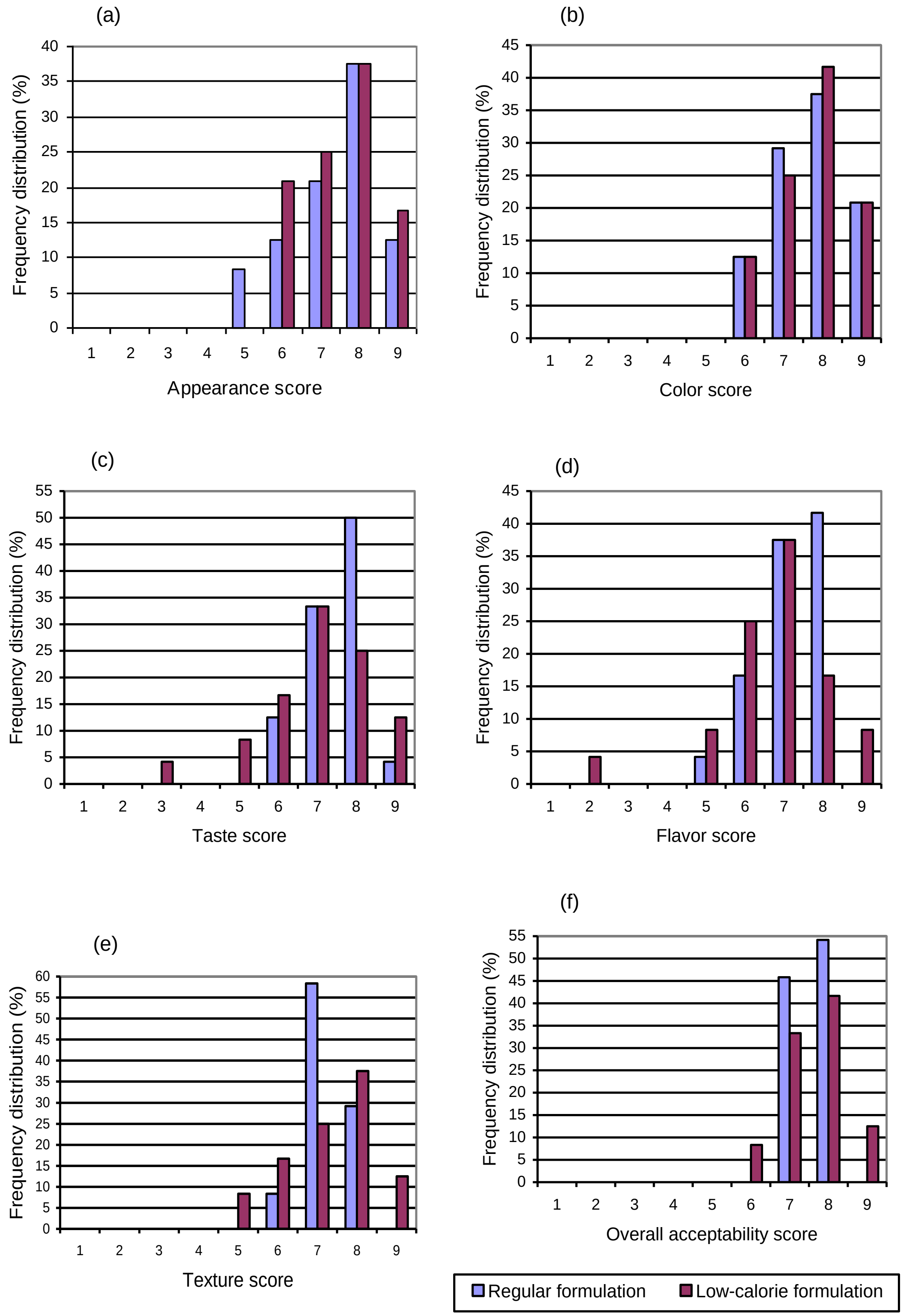

Figure 2. Frequency distribution of sensory scores of *Pandanus* custard samples with energy reduction: (a) appearance; (b) color; (c) taste; (d) flavor; (e) texture; (f) overall acceptability.

acceptable level. Nevertheless, it is interesting to note that panelists prefer the product appearance of T2-formulation, possibly because it is lighter in texture which eases dipping or spreading.

Table 4. Chemical composition and caloric values of *Pandanus* custard products.

Chemical composition	Regular formulation	T2-formulation
Moisture	57.44[b]	66.70[a]
Protein (N x 6.75)	2.18[b]	2.88[a]
Fat	8.87[a]	7.56[b]
Ash	0.28[b]	0.41[a]
Total carbohydrate	31.23[a]	22.45[b]
Energy (Kcal/g)	213.47	169.36

The means in the same row with different superscripts are different ($p < 0.05$); C and T2 refer to formulation codes on Table 1.

Chemical composition and nutritional evaluation

Chemical composition of regular (control) and T2-formulation shown in Table 4 reveals that moisture content in the T2-formulation was significantly higher ($p < 0.05$) than that of the control. In addition, significant increase in protein and ash and decreasing fat and carbohydrate content were observed in the T2-formulation as compared with the control. Generally, the change in fat, protein, ash, fiber and carbohydrate percents in food products is usually attributed to the change in concentration due to water evaporation and fat loss. Thus, increment of water content would cause other chemical components to decrease; however, type and properties of fat or sugar substitutes are also considered. Increases in protein and ash are possibly due to higher protein content in soy milk than coconut milk and dietary fiber property of inulin (Salazar et al., 2009). Whilst, a lower fat content in soy milk and a few amount of sucralose used, provides 600 times the sweetness of sucrose, may be possibly the reason for this case. According to energy content, this T2-formulation was considered preferable because the intake of 100 g would provide less than 14.8% of fat and 28.1% of carbohydrate content and the total calorie value reduction was about 20.7% in relation to the control. Based on food label claims, if at least the T2-formulation has 25% less sugar than the original item, it can be claimed as ‘reduced sugar’. Therefore, T2-formulation meets this definition, but not for a declaration of reduced calorie because the 20.7% energy reduction is lower than the 25% requirement (Anon, 2006). In addition, this product could be considered as ‘healthier’ because it contains inulin, which enhances health benefits to human digestive system as compared with the regular product.

Storage stability of *Pandanus* custard products

The results obtained for control and T2-formulation in Figure 3 reveal a similar trend for increasing Aw and L* values but decreasing pH with progress in storage duration. The T2-formulation was significantly higher ($p < 0.05$) in Aw than the control over storage time, while higher pH was observed for only the first week; afterwards, it was lowered than the control. This may be possibly due to carbohydrate breakdown as a result of microbial growth to produce acids, causing a decrease in pH of the sample (Jariyawaranugoon and Akesowan, 2010). Also, the higher Aw in T2-formulation promotes microbial growth resulting in a rapid decrease in pH with respect to the control. This result is in accordance with the microbiological analysis showing a considerable increase of total bacteria count determined in the control and T2-formulation after keeping for 2 weeks; nevertheless, there was no yeast and mold growth detected over storage time (data not shown). For color determination, the control showed significantly lower ($p < 0.05$) L* (lightness) on each time of storage, probably because of its high sugar content which participate in brown formation via Maillard reaction. Besides, significant increase in lightness of both samples was observed throughout 3 weeks, which was attributed to chlorophyll components in *Pandanus* juice been oxidized by light, oxygen and other factors, resulting in more pale color, as confirmed by the study of Vongsawasdi et al. (2010).

Conclusion

There is a potential for partial replacement of coconut milk and sugar with soy milk, inulin and sucralose in the preparation of Thai *Pandanus* custard with lower energy. Total sugar replacement produces a product with higher lightness and no satisfactory sensory requirements. The *Pandanus* custard with 1/3 coconut milk replacement with soy milk, 50% sugar replacement with sucralose and 5% inulin is rated in good sensory acceptability. The product, fairly enough meet the criterion for ‘reduced sugar’ with fat and calorie reduction and can be considered as ‘healthy image’. More energy reduction by nutritional ingredients and shelf life extension of this product needs to be investigated in further studies.

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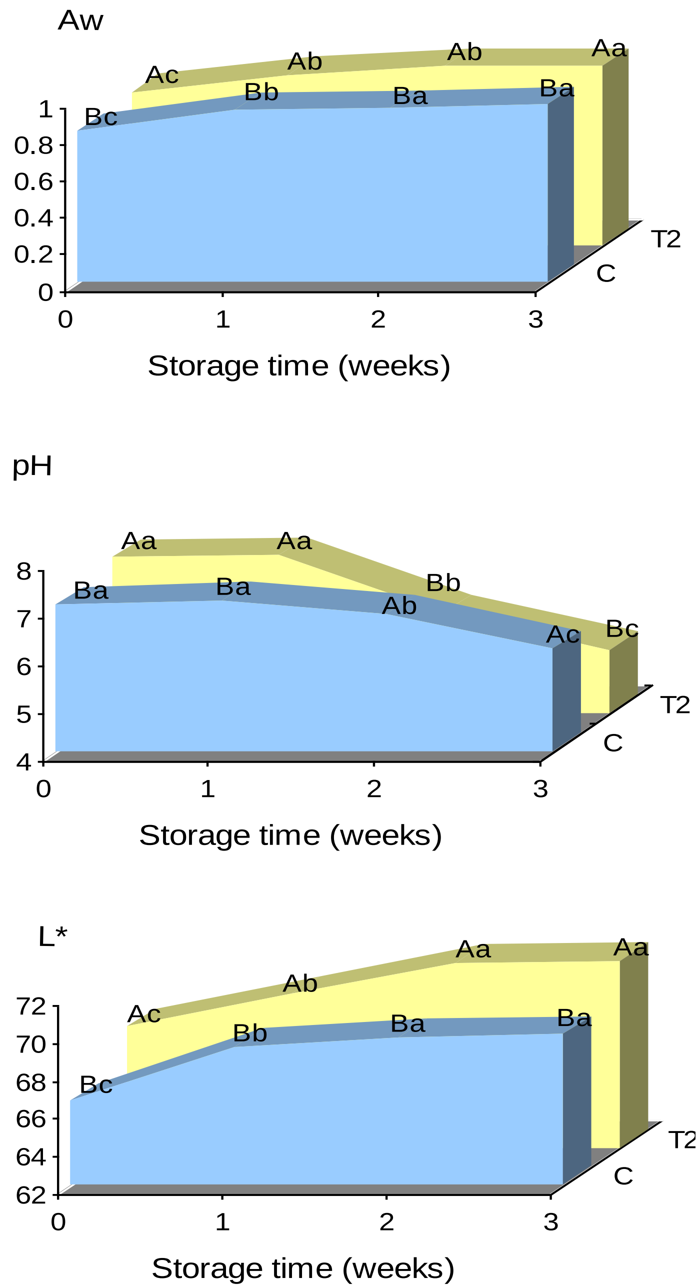

Figure 3. Aw, pH and L* values of regular and T2-formulation custard samples after storage at chilled temperature for 3 weeks. Equal capital letters are not significantly different regarding formulation ($p<0.05$); Equal lowercase letters are not significantly different regarding storage time ($p<0.05$); C and T2 refer to formulation codes on Table 1.

conduct this study and the panelists for their time.

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