Quality Assessment of Reduced-calorie Thai Mung Bean Marzipan Made with Erythritol-Sucralose Blend and Soy Milk

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Abstract: This study aimed to investigate the effects of sugar and coconut milk substitution by erythritol-sucralose blend and soy milk, respectively on physical properties and sensory acceptance of Thai mung bean marzipan. Four reduced-calorie marzipans coded as T1 (50% erythritol-sucralose and 25% soy milk), T2 (50% erythritol-sucralose and 50% soy milk), T3 (75% erythritol-sucralose and 25% soy milk) and T4 (75% erythritol-sucralose and 50% soy milk) were studied. They had significantly higher ($p < 0.05$) pH and L^*, lower ($p < 0.05$) consistency, but no difference ($p > 0.05$) in titratable acidity as compared with the control. While, a yield value, which may be either high or low, was dependent on a soy milk level used. An acceptance test revealed decreasing scores of taste, flavor and texture in reduced-calorie marzipans; in addition, their higher percentages of frequency distribution were obtained in "ideal level" for sweet and flavor attributes. The most preferable reduced-calorie formulation was the T3 marzipan and it also achieved the highest score for consumer purchasing decision among the others. With regard to the control, it presented a reduction of fat, carbohydrate and total caloric values about 16.1, 20.4 and 16.4%, respectively.

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1. Introduction

The trend for consumption of food products with lower in sugar and/or saturated fat has still increased since the high intake of these biomolecules promotes the risk of diseases such as coronary disease, high blood pressure/cholesterol, diabetes, obesity, overweight and some cancers (Newsome, 1993). Desserts, generally possess a high amount of sugar and/or fat content, are preferably consumed by all aged people after meal, especially older. It is therefore recommended for refuse or reduction in consumption these desserts to lower the incidence of food-related diseases or to gain over-calorie intake. This behavior is well documental for human health promotion. Conversely, it inevitably affects consumer purchasing decision of these products, resulting in the failure of product survival. In general, unpopular or unhealthy desserts usually lower their purchasing opportunity, and finally disappear from the market. This would be a long serious problem reflecting a traditional culture for dessert making in long history countries. Food caloric reduction may be an alternative to response consumer demand and to sustain culture-related foods.

Total caloric reduction was successfully obtained by reducing either sugar or fat or simultaneously both. Sugar and fat substitutes like aspartame, sucralose, sorbitol, hydrocolloids and whey and soy proteins are introduced to make low-calorie food products. Nevertheless, the success of energy reduction in food products is dependent on not only how much calorie values can be decreased, but also consumers' sensorial satisfaction on the products. Consequently, the selection of proper sugar and/or fat substitutes would be a crucial requirement influenced by many factors such as a kind of food categories like meat, bakery or beverage products, properties and functions of these substances, health impact and benefits, competitive prices, market availability, culture and legal regulation.

An erythritol-sucralose (98.6:1.4) blend has been applied in several low-calorie food products since it has a pleasant taste and provides approximately 8 times of sucrose sweetness with calorie value of 0.18 Kcal/g (Akesowan, 2009; U-sing, Co., 2012). It is also considered as a bulking sweetener that can be used to compensate for viscosity and consistency properties of sucrose. Another ingredient, soy milk was selected as a fat replacer for coconut milk according to many reasons including lower fat but higher protein content, convenient availability and health promotion like isoflavones which functions as an antioxidant (Conforti and Davis, 2006; Ikya et al., 2013). Both substitutes were chosen to use in one of most popular desserts, a Thai mung bean marzipan coated with agar or locally called "Look Choup". The product is preferable in terms of sweet, aromatic and creamy characteristics as well as considered as a good source of vegetable proteins.

This present study was aimed to develop reduced-calorie Thai mung bean marzipan by partial substitution of sugar and coconut milk with various levels of erythritol-sucralose blend and soy milk, respectively. Physicochemical determination and sensory evaluation were performed to evaluate the quality of the product.

2. Material and Methods

Materials

Ingredients used for Thai mung bean marzipan included dry dehusked and halved mung beans (Raithip®, Rai Thanee, Thailand), erythritol-sucralose (D–et®, U-Sing Co., Ltd., Thailand), soy milk (Silk® (unsweet), White Wave Foods, USA), coconut milk (Aroidee®, Thai Agri Foods, Thailand), sugar and agar powder.

Preparation of Thai bean marzipan

The control formulation of Thai mung bean marzipan (% by total weight) included: 40% mung bean, 40% coconut milk and 20% sugar. Whilst, the reduced calorie formulations were prepared by substituting sugar and coconut milk with different levels of erythritol-sucralose blend and soy milk, respectively and identified as T1-T4 in Table 1. Dry mung beans were cleaned and soaked in water overnight, and then steamed for about 30 min or until the beans were soft. The beans were ground with sugar and coconut milk for 1 min before pouring into a brass wok. The mixture was heated to low temperature for 20-30 min and continuously stirred with a wooden paddle until the paste was smooth and thickened. After the bean paste cooled down, kneaded once, and rolled up a ball (2 cm diameter), then painted with a food or natural color. Each marzipan was dipped in a hot 10-12% (w/v) agar/sugar (2:3) solution), allowed agar to set and repeated the dipping process again. All marzipans coated with agar were kept in a plastic box before analysis.

Physical analysis

pH and titratable acidity: A pH meter (Model 320, Metler–Toledo Ltd, Essex, UK) was used to measure pH of samples. The titratable acidity was determined by sodium hydroxide titration/phenolphthalein indicator as described by AOAC (1995).

Yield: Samples were weighed before (initial weight) and after (final weight) heat processing. The percentage yield was determined from final weight divided by initial weight, and then multiply with 100.

Table 1. Reduced-calorie Thai mung bean marzipan formulations.

Formulation*	Sugar substitution* (sugar :erythritol-sucralose)	Fat substitution** (coconut milk : soy milk)
C	Regular formulation (100% sugar and 100% coconut milk)	
T1	50:50	75:25
T2	50:50	50:50
T3	25:75	75:25
T4	25:75	50:50

*The sugar substitution by erythritol-sucralose blend was calculated based on equivalent sugar sweetness at 125 g/kg of sugar.
**The coconut milk substitution by soy milk was done based on weight basis.

Texture: Firmness was determined by a texture analyser (LRX, Lloyd Instruments, Hampshire, UK). The sample was prepared to reach 4-cm height of a cylinder cup (4 cm diameter x 6 cm height). The puncture probe (1.25 cm in diameter) working with a crosshead speed at 200 mm/min was performed to measure the peak force (N) after 50% compression.

Color: Color scales; lightness (100 = white, 0 = black), red/green (+ = red, – = green) and yellow/blue (+ = yellow, – = blue), were measured using a HunterLab colorimeter (Color Flex, Hunter Associates Laboratory, Reston, VA).

Proximate analysis and calorie value: Chemical compositions (moisture, protein, fat, ash and total carbohydrate) of regular and optimal reduced-calorie bean marzipans were determined according to AOAC (1995) methods. The energy value was calculated based on the content of fat (9 Kcal/g), protein (4 Kcal/g) and carbohydrate (4 Kcal/g).

Sensory evaluation: A regular and four reduced-calorie bean marzipans were evaluated for appearance, color, taste, flavor, texture and overall acceptance using a 9-point hedonic scale test (1 = extremely dislike, 9 = extremely like). A just-about-right scale test (-3 = strongly less than, 0 = ideal and +3 = strongly more than) was also used for evaluating sweet and flavor of the samples. In addition, the question for product purchase was tested using a 5-point scale test (1 = certainly would not buy, 5 = certainly would buy). All sensory tests were conducted by 100 untrained panelists from the University of the Thai Chamber of Commerce, Thailand. Panelists were invited to rinse their palates before testing each sample (Lawless and Heymann, 1998).

Statistical analysis: The production of reduced-calorie mung bean marzipans was done in triplicate. Data were analyzed statistically by analysis of variance (ANOVA) using SPSS for Window version 17.0. Means with a significant difference ($p < 0.05$) were compared by Duncan's new multiple range test (Cochran and Cox, 1992).

3. Results and Discussion

Physicochemical analysis

Table 2 shows physical changes of mung bean marzipans subjected to 50 to 75% sugar substitution by erythritol-sucralose blend and 25 to 50% coconut milk substitution by soy milk. There were significant differences ($p < 0.05$) in yield, pH and consistency among all marzipans, while no change ($p > 0.05$) in titratable acidity was found. Yield values determined in bean marzipans with 50% soy milk incorporated with 50 or 75% erythritol-sucralose (T2 and T4) were greatly lower ($p < 0.05$) than those with 25% soy milk (T1 and T3). At the same time, the higher sugar substitution also slightly decreased ($p < 0.05$) yield values of the marzipans (T1 vs. T3 and T2 vs. T4), relatively indicating that a yield reduction was mostly influenced by increasing soy milk. This was possibly attributed to a lower proportion of coconut milk in formulation that related to a decreasing oil portion needed to lubricate and facilitate a bean paste mixing during low hot processing, resulting in the difficulty of mixing and some bean paste stuck to the bottom of the wok. Likewise, the marzipans with 25% soy milk had higher yield with respect to the control, possibly because of higher water content found in soy milk than coconut milk. This resulted in a higher moisture content of the final reduced-calorie product against the control (Table 4) when the same processing method was applied.

The increment of soy milk increased pH values of the marzipans, as evidence in Table 2. This was in consonance with our previous study showing an increasing pH of a reduced-calorie pandanus custard was paralleled with increasing soy milk, as the pH of soy milk (pH 6.6-6.8) is higher than that of coconut milk (pH 6.0-6.3) (Seow and Gwee, 1997; Pathomrungsiyounggul et al., 2010; Choonhahirun and Akesowan, 2012). However, the pH was not affected by the level of sugar substitution.

It was apparent in Table 2 that the highest consistency was observed ($p < 0.05$) for the control marzipan. At the same sugar substitution, the consistency of the marzipans with 50% soy milk were lower, but not significantly ($p > 0.05$) in relation to that with 25% soy milk (Table 2). Although, the increased percentage of erythritol-sucralose blend caused a decrease of marzipan consistency; however, no significant difference ($p < 0.05$) was found with respect to the control. When the 75% erythritol-sucralose was applied, the decreased consistency of marzipans with any levels of soy milk were evident ($p < 0.05$), probably due to erythritol-sucralose blend could not provide water holding capacity and viscosity to the marzipan paste as does the sugar (Newsome, 1993). The reduction in marzipan consistency was corresponded to the acceptance test in Table 3, in which a significant decreasing sensory texture was pronounced for all reduced-calorie marzipans in relation to the control.

Table 2. Physical properties of reduced-calorie mung bean marzipans.

Formu-lation	Yield (%)	pH	Titratable acidity (%)	Consistency (N)
C	60.92 ± 1.45^{c}	7.06 ± 0.02^{c}	0.02 ± 0.00^{a}	9.28 ± 1.10^{a}
T1	64.42 ± 1.91^{a}	7.22 ± 0.00^{b}	0.02 ± 0.00^{a}	9.14 ± 1.85^{a}
T2	56.75 ± 2.06^{d}	7.41 ± 0.01^{a}	0.02 ± 0.00^{a}	8.82 ± 0.82^{a}
T3	62.86 ± 1.22^{b}	7.18 ± 0.03^{b}	0.02 ± 0.00^{a}	7.56 ± 0.90^{b}
T4	54.40 ± 2.28^{e}	7.42 ± 0.02^{a}	0.02 ± 0.00^{a}	7.47 ± 1.22^{b}

Means in the same column with different superscripts are different ($p < 0.05$). C and T1-T4 refer to formulation codes on Table 1.

Figure 1 shows the three dimensional graph of internal color $L^*a^*b^*$ of all marzipans. The substitution of sugar and coconut milk affected internal marzipan color in different directions depending on the level of reduction. All reduced-calorie marzipans were relatively higher in L^* or lighter than the control, probably due to their lower sugar content in recipe. In general, reducing sugars and amino acids are participated in the Maillard reaction resulting in the formation of brown or dark pigment (melanoidin) (Knetch, 1990; Alais and Linden, 1991). The high level at 75% erythritol-sucralose produced the marzipan darker than that with 50% level. Moreover, the erythritol-sucralose blend, a sugar substitute used in this study, is not associated with the non-enzymatic browning reaction (Newsome, 1993). Apart from the effect of the sugar substitution, the increment of soy milk proportion, a good source of proteins and amino acids, may allow increasing amine compounds, which are subjected to participate in the Maillard browning reaction. These were the reasons responsible for darker color of the reduced-calorie marzipan (Belitz et al., 2009). As seen in the Figure 1, the bean marzipan with 75% erythritol-sucralose and 25% soy milk (T3) revealed its color as close to the control marzipan.

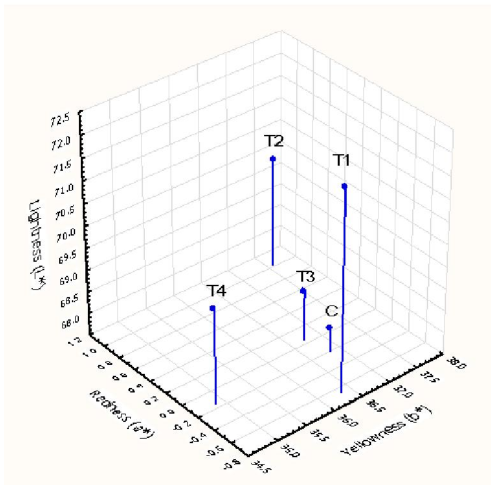

Figure1. CIE $L^*a^*b^*$ color values of reduced-calorie mung bean marzipans. C and T1-T4 refer to formulation codes on Table 1.

Sensory evaluation

In case of this study, the sensory evaluation was firstly tested for panelists' acceptance as presented by 9-point hedonic results in Table 3. The reduction of sugar and fat significantly affected ($p < 0.05$) all sensory attributes among control and reduced-calorie bean marzipans, in exception of appearance. Comparatively, it clearly lowered ($p < 0.05$) panelists' acceptance in terms of taste, flavor and texture, and as such attributes influenced on overall acceptance of the product. This was attributed to the different sweet taste and potency provided by erythritol-sucralose against the sugar, and the substitution by soy milk may not entirely compensate for the creaminess of coconut milk. In addition, all reduced-calorie marzipans were less cohesive than the control. Most panelists suggested that both T2 and T4 marzipans (50% soy milk) lacked of specific flavor of coconut milk. Here, the least preferable product was observed for the T4 marzipan (75% erythritol-sucralose and 50% soy milk) with a comment that it tasted unpleasant sweet and less creamy and flavor. Some panelists suggested that this product was under the acceptable criteria. Among reduced-calorie marzipans, the T3 marzipan (75% erythritol-sucralose and 25% soy milk) was achieved ($p > 0.05$) scores of appearance, color, taste and overall acceptance similar to the control. Also, these scores ranged from 6.56 to 7.05, indicating a well accepted in a moderate preference level.

Table 3. Sensory scores of reduced-calorie mung bean marzipans.

Formulation	Appearance	Color	Taste
C	6.96 ± 1.41^{ab}	7.18 ± 1.31^{a}	6.78 ± 1.61^{a}
T1	6.84 ± 1.48^{ab}	6.75 ± 1.64^{bc}	6.35 ± 1.73^{bc}
T2	6.72 ± 1.50^{b}	6.64 ± 1.76^{c}	6.01 ± 1.96^{cd}
T3	7.02 ± 1.46^{a}	7.05 ± 1.44^{a}	6.56 ± 1.82^{ab}
T4	7.02 ± 1.38^{a}	6.97 ± 1.50^{ab}	5.95 ± 1.93^{d}

Formulation	Flavor	Texture	Overall acceptance
C	6.94 ± 1.61^{a}	7.04 ± 1.65^{a}	7.12 ± 1.60^{a}
T1	6.42 ± 1.64^{b}	6.11 ± 1.94^{b}	6.55 ± 1.62^{b}
T2	6.40 ± 1.85^{b}	6.43 ± 1.98^{b}	6.57 ± 1.94^{b}
T3	6.58 ± 1.71^{b}	6.53 ± 1.87^{b}	6.89 ± 1.43^{a}
T4	6.39 ± 1.95^{b}	6.17 ± 2.04^{b}	6.56 ± 1.83^{b}

Means in the same column with different superscripts are different ($p < 0.05$). C and T1-T4 refer to formulation codes on Table 1.

The just-about-right scale analysis results were illustrated in Figure 2, showing that higher frequency percentage for both sweetness and flavor of control and all reduced-calorie marzipans were presented at 0 score, considering as "ideal" sweet and flavor attributes. However, for sweetness analysis, the T4 marzipan was clearly rated for the least frequency of score 0 (Figure 2a), probably due to most of its frequency obtained in the score between -1 to -3 indicating the sweetness was less than the ideal. This result was in line of the acceptance test (Table 3) where the lowest taste score was significantly pronounced ($p < 0.05$) in the T4 marzipan (25% erythritol-sucralose and 50% soy milk). At the same time, all reduced-calorie marzipans had lower frequency distribution of score 0 than the control, corresponding to lower flavor acceptance in Table 3.

The results of product purchasing decision shown in Figure 3 present that the chances for panelists would certainly or possibly buy the control, T3, T1, T2 and T4 marzipans were approximately 56, 48, 44, 43 and 40%, respectively. Consequently, the T3 marzipan (75% erythritol-sucralose and 25% soy milk) would be the better choice for this development.

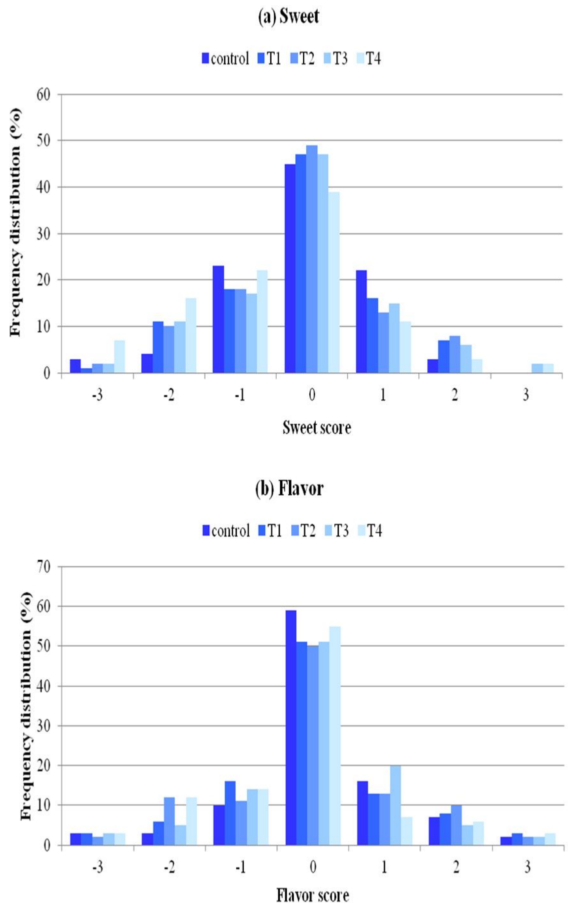

Figure 2. Frequency distribution of sensory scores of reduced-calorie mung bean marzipans: (a) sweet and (b) flavor. Based on a just-about-right scale test (-3 = much less sweet or flavor than the ideal, 0 = as same as the ideal, +3 = much more sweet or flavor than the ideal. C and T1-T4 refer to formulation codes on Table 1.

Chemical composition and nutritional evaluation

It can be seen that both control and optimal T3 marzipans were rich in protein content because of a main component of mung beans (Table 4). As expected, the T3 marzipan was significantly lower ($p < 0.05$) in fat and carbohydrate content, but higher in moisture ($p < 0.05$) with respect to the control (Table 4). This was the difference in fat composition contained in coconut milk (10-15% fat) as compared with soy milk (2-3% fat) (Ikya et al., 2013). In general, the high moisture can shorten the shelf life of food products, particular on fat-based desserts (Jariyawaranugoon and Akesowan, 2010); therefore, the storage stability of this product needed to be further investigated. Here, the T3 marzipan (75% erythritol-sucralose and 25% soy milk) provided less than 16.1% of fat, 20.4% of carbohydrate and 16.4% of total caloric value as compared with the control.

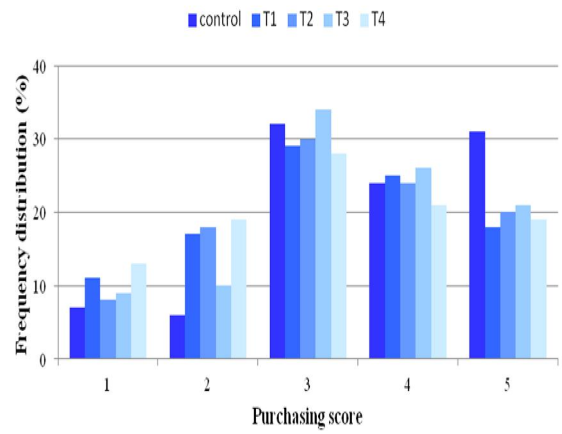

Figure 3. Frequency distribution of purchasing decision of reduced-calorie mung bean marzipans. Based on a 5-point structured scale test (1 = certainly would not buy, 5 = certainly would buy). C and T1-T4 refer to formulation codes on Table 1.

Table 4. Chemical composition and caloric values of mung bean marzipans.

Chemical composition	Regular formulation	T3 - formulation
Moisture	53.28^{b}	60.84^{a}
Protein (N x 6.75)	6.92^{a}	7.09^{a}
Fat	5.10^{a}	4.28^{b}
Ash	0.66^{a}	0.69^{a}
Total Carbohydrate	34.04^{a}	27.10^{b}
Energy (Kcal/g)	209.74	175.28

Means in the same row with different superscripts are different ($p < 0.05$). C and T3 refer to formulation codes on Table 1.

Conclusion

The changes of physicochemical of Thai mung bean marzipans were dependent on how much of which sugar and coconut milk were substituted by erythritol-sucralose and soy milk, respectively. The higher level of erythriltol-sucralose caused a darker product, while a lower thickened bean paste was mostly affected by soy milk. All reduced-calorie marzipans had evidently lower scores of taste, flavor and texture with respect to the control. The reduced-calorie mung bean marzipan achieved by 75% erythritol-sucralose and 25% soy milk was relatively more acceptable and provided a 16.4% total caloric reduction.

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