FABJ

Food and Applied Bioscience Journal

ISSN : 2286-8615
VOLUME 10 ISSUE 1
(JANUARY - APRIL 2022)

FABJ

Food and Applied Bioscience Journal

TABLE OF CONTENTS

PAGE

ISSN : 2286-8615
VOLUME 10 ISSUE 1
(JANUARY - APRIL 2022)

FABJ
Food and Applied Bioscience Journal

Formulation of Reduced-Sugar, Fiber-Enriched Thai Traditional Sweet Egg Yolk Cake '*Thong Ake*'

Nitjaree Maneerat[1], Phimphida Sitkongden[2], Radchaneekorn Saiyart[2], Nattapol Tangsuphoom[3], and Chitraporn Ngampeerapong[2,*]

[1]*School of Food Industry, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520, Thailand*
[2]*Division of Food Science and Technology, Faculty of Engineering and Agro-Industry, Maejo University, Chiang Mai, 50290, Thailand*
[3]*Food and Nutrition Academic and Research Cluster, Institute of Nutrition, Mahidol University, Nakhon Pathom, 73170, Thailand*
**Corresponding author. E-mail: chitraporn_n@mju.ac.th*
Received: 22 February 2022, Revised: 19 April 2022, Accepted: 22 April 2022, Publish: 25 April 2022

Abstract

An excessive consumption of Thong Ake, a Thai traditional auspicious dessert made of sugar, flour, coconut milk, and egg yolk, could be a potential risk factor for non-communicable diseases. This study, thus, aimed to formulate reduced-sugar and fiber-enriched Thong Ake containing stevioside-sorbitol mixture and resistant starch type 2 (RS). A mixture of stevioside and sorbitol (1 : 500) was used to replace 50, 75, and 100% of sugar in the control recipe to maintain the sweetness intensity. Fiber enrichment was performed by substituting RS for 25, 50, 75, and 100% of rice flour. The findings revealed that Thong Ake with 50% sugar and 50% flour substitutions received the highest sensory acceptability scores, rated by 50 untrained panelists on a 9-point hedonic scale, among other modified formulas, but not different from the control formula. Therefore, such formula was selected to evaluate its chemical and physical properties. The results indicated that the modified product contained 13 g of sugar and 7 g of dietary fiber in an 80-g serving, which is 50% less and 92% more than the control recipe, respectively. All color values (L^*, a^*, b^*) were higher than the control sample. Texture profile analysis indicated that its hardness value was lower than the control formula, while the springiness and cohesiveness values were higher. Therefore, sugar reduction and fiber enrichment in Thong Ake could be achieved by partial substitution of sugar and flour with stevioside-sorbitol mixture and RS, respectively. The developed Thong Ake could be an alternative to Thai dessert for people who want to limit their carbohydrate intake.

Keywords: Thai dessert; Thong Ake; Sugar reduction; Fiber enrichment; Healthy diet

1. Introduction

Non-communicable diseases (NCDs) are important public health issues as they are the prominent threats to health, well-being, and economic burden worldwide, including in Thailand (World Health Organization and United Nations, 2021). Inappropriate dietary pattern, especially excessive daily consumption of sugar and energy-dense food with a lack of physical activity may increase the risk of obesity and consequently increase the risk of NCDs such as diabetes, stroke, and ischemic heart disease (Peters *et al.*, 2019; Tappy *et al.*, 2010; Te *et al.*, 2013). In Thailand, the morbidity and mortality rate of NCDs have increased at a high rate annually (Division of Non-Communicable Diseases, 2019; Srivanichakorn, 2017). Division of Non-Communicable Diseases (2019) reported that the amount of sugar consumed by the Thai population each year was as high as 2.6 million tons in 2019. In addition, 75% of the Thai population consumed fruits and vegetables less than the daily recommendation which leads to the inadequacy of vitamins, minerals, and fiber.

Thai desserts, particularly traditionally auspicious ones such as Thong Ake (sweet egg yolk cake), Thong Yip (sweet egg yolk cup), Thong Yod (sweet egg yolk drops), Foy Thong (sweet egg yolk floss), and Med Kanoon (sweet egg yolk-coated mungbean paste balls), may be considered as imbalanced diets. These desserts contain rice flour, sugar, and egg yolk; and hence provide sugar, cholesterol, and energy as high as 65% of total carbohydrate, 269.5 mg and 516 kcal per a 100 g serving, respectively, while contain only 0.4-5.8 g of dietary fiber (Visasa, 2005). Regardless of its importance in representing Thai cultural heritage, the popularity of this type of desserts has waned since it is perceived as an unhealthy diet. Therefore, the development of such dessert to improve its nutrients' proportion, for example, the reduction of sugar and energy contents per serving and the enrichment of dietary fiber, could be an alternative way to achieve the healthier Thai dessert.

Sugar substitution by sugar alcohols and intense sweeteners could be one of the widely used procedures to reduce the sugar content. Sugar alcohols or polyols such as mannitol, xylitol, maltitol, and sorbitol are the sweeteners that are lower in caloric value, less sweet, and more slowly digested than sucrose. These bulk sweeteners are commonly used in combination with other sweeteners to achieve a desirable sweetness intensity and profile (Ding and Yang, 2021; Selvasekaran and Chidambaram, 2021). Apart from sugar alcohols, intense sweeteners, such as sucralose, acesulfame-K, stevia, and stevioside, are not metabolized in the human body, and accordingly provide a negligible amount of energy (Chattopadhyay *et al.*, 2014; Selvasekaran and Chidambaram, 2021). Regarding their high intensity of sweetness (approximately 200-600 times sweeter than sucrose), the usage level in a food product is usually low (Chattopadhyay *et al.*, 2014). Nevertheless, undesirable aftertaste may be detectable. To mitigate the off-taste, the combinations or blends of sweeteners have been successfully applied in various reduced-sugar food products (Mattes *et al.*, 2021). Results from previous studies indicated that mixtures of sorbitol and sucralose could substitute up to 75% of sugar in A-Lua, a Thai traditional dessert made of wheat flour, coconut milk and sugar, while minimally affected physical properties and sensory acceptability. Moreover, the modified product had a hard surface that covered the liquid gel, similar to those of original product (Srisangwan, 2012).

Dietary fiber enrichment in food products is an intervention to reduce the risk of obesity, cardiovascular disease, stroke, hypertension, diabetes and gastrointestinal distresses (Anderson *et al.*, 2009; Li and Komarek, 2017). Dietary fiber extracted from various sources has been used for enhancing the fiber content in several foods such as pomelo peel fiber powder in cracker (Siwnguan *et al.*, 2017), triticale insoluble fiber in yogurt (Tomic *et al.*, 2017), cereal fiber in gluten-free bread (Sabanis *et al.*, 2009), prebiotic dietary fiber in rice cracker (Kaewjun, 2015). At present, resistant starch (RS), which refers to a starch that is resistant to being digested and absorbed into a human body, has been commercially produced and used as a fiber source in the food industry. RS is categorized by its digestibility into 5 types, including physically indigestible or physically trapped starch (type 1), raw starch granule or ungelatinized granule (type 2), retrograded starch (type 3), chemically modified or cross-linked starch (type 4), and amylose-lipid complexes (type 5) (Ahuja *et al.*, 2013; Birt *et al.*, 2013). Different types of RS have been successfully used to replace the starch ingredient in several starch-based foods, such as pasta, bread, cookies, muffin, baked goods, and gluten-free products, with a less drastic effect on the sensory aspects than conventional dietary fibers (Arp *et al.*, 2021; Kaewjun, 2015). It has been reported that the substitution of type 2 RS for up to 50% of wheat flour had no significant effect on the physical characteristics and consumer acceptability of muffins (Sanz *et al.*, 2009). In addition, owing to its physico-chemical properties, most food products substituted or enriched with RS marked a decrease in the starch digestibility and *in vitro* glycemic index (Arp *et al.*, 2021). The consumption of the products with less sugar and carbohydrate, accordingly, may help to reduce the metabolic risk factors contributing to the diet-related NCDs. Therefore, to develop an alternative of Thai dessert, specifically Thai traditional sweet egg yolk cake or Thong Ake, for people with health concerns or who want to limit their carbohydrate intake, this study aims to formulate the reduced-sugar, fiber-enriched Thong Ake by substituting the stevioside-sorbitol mixture for sugar and replacing rice flour with type 2 RS.

2. Materials and Methods

2.1 Material

Type 2 RS (HI-MAIZE™ 260) was donated by National Starch and Chemical Ltd. (Thailand). Stevioside (Rebaudioside A97%) was provided by Hong Huat Co., Ltd. (Thailand). Sorbitol was purchased from Union Science Co., Ltd. (Thailand). Rice flour, eggs, sugar, and coconut milk were purchased from local supermarkets in Chiang Mai, Thailand.

2.2 Thong Ake formulation

2.2.1 Substitution of sugar with the stevioside-sorbitol mixture

The control formula of Thong Ake consisted of 20% (w/w) rice flour, 24% (w/w) sugar, 24% (w/w) coconut milk, 17% (w/w) egg yolk and 15% (w/w) water. For the modified formula, sugar was replaced by the stevioside-sorbitol mixture at 50%, 75%, and 100% (w/w), respectively. Following the study conducted by Srisangwan (2012), the weight of added stevioside was calculated to match the sweetness of sucrose being substituted, while sorbital was used to preserve the total weight. The relative sweetness of stevioside (rebaudioside A) used in this study was 500 (500 times sweeter than sucrose). So, the amount of stevioside in each modified recipe was calculated by dividing the amount of sugar to be replaced with 500, and

filled up the remaining weight with sorbitol. Approximately, the ratio of stevioside and sorbitol in all modified formulas was about 1 : 500.

The amount of ingredients for each formulation are shown in Table 1. The reduced-sugar samples were evaluated for the sensory characteristics including general appearance, color, odor, taste, texture, and overall acceptability by 50 untrained panelists on a 9-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. The modified formula receiving the highest sensory score was selected for the substitution of rice flour with RS in the next step.

Table 1 Ingredients of reduced-sugar Thong Ake at different levels of sugar substitution

Ingredients (%w/w)	Percentage (%)			
	s0[1]	s50[1]	s75[1]	s100[1]
Rice flour	20	20	20	20
Egg yolk	17	17	17	17
Coconut milk	24	24	24	24
Water	15	15	15	15
Sugar	24	12	6	0
Sorbitol	0	11.976	17.964	23.952
Stevioside	0	0.024	0.036	0.048

[1] s0, control (100% of sugar); s50, 50% substitution level of stevioside+sorbitol; s75, 75% substitution level of stevioside+sorbitol; s100, 100% substitution level of stevioside+sorbitol.

2.2.2 Substitution of rice flour with type 2 RS

Fiber enrichment was performed by substituting the amount of rice flour of the selected formula in 2.2.1 by RS at 0%, 25%, 50%, 75%, and 100% (w/w), respectively (Table 2). After the formulation, the samples from the modified formulas were then evaluated the sensory characteristics including general appearance, color, odor, taste, texture, and overall acceptability by 50 untrained panelists on a 9-point hedonic scale. The sample from the modified formula with the highest acceptability scores was selected to evaluate its nutritional compositions and physical properties and compare it with the control.

Table 2 Ingredients of reduced-sugar, fiber-enriched Thong Ake at different levels of RS substitution

Ingredients (%w/w)	Percentage (%)				
	s50-rs0[1]	s50-rs25[1]	s50-rs50[1]	s50-rs75[1]	s50-rs100[1]
Rice flour	20	15	10	5	0
Egg yolk	17	17	17	17	17
Coconut milk	24	24	24	24	24
Water	15	15	15	15	15
Sugar	12	12	12	12	12
Sorbitol	12	12	12	12	12
Stevioside	0.02	0.02	0.02	0.02	0.02
RS	0	5	10	15	20

[1] s50, 50% substitution level of stevioside+sorbitol; rs0, no substitution of RS; rs25, 25% substitution level of RS; rs50, 50% substitution level of RS; rs75, 75% substitution level of RS; rs100, 100% substitution level of RS; RS, resistant starch.

2.3 Determination of nutritional compositions and physical properties of the reduced-sugar, fiber-enriched Thong Ake

2.3.1 Nutritional compositions

Moisture and fat content were analyzed by the hot-air oven method and Soxtec system, respectively (AOAC, 2002). Protein and ash content were analyzed by Kjeldahl methods and gravity technique, respectively (AOAC, 2016). Fiber content was quantified by a dietary fiber analysis kit (AOAC, 2010). Sugar, total carbohydrate, and total energy were analyzed according to the compendium of a method for food analysis (2003).

2.3.2 Physical properties

The diameter and thickness of the samples were measured by a vernier caliper. The weights of the samples were recorded by using an electric balance scale. The color values (L^*, a^*, b^*) were measured using a colorimeter (Hunter Lab® Miniscan XE, Hunter Associates Laboratory, Inc. Reston, VA, USA). The L^*, a^* and b^* values represent the lightness, redness, and yellowness, respectively. Water activity (Aw) was measured using Aqualab (Serisen3, Decagon Device Inc., Pullman, WA, USA). A texture analyzer (Stable Microsystems, Godalming, UK) with cylinder probe P/50 was used to measure the hardness, springiness, and cohesiveness of the samples at a speed of 1 mm/sec (Noosing and Leelawa, 2016).

2.4 Statistical analysis

The Randomized Complete Block Design (RCBD) was applied in the sensory evaluation experiment (sensory panelists as a block). The nutritional composition and physical properties of the samples were determined in triplicate and were arranged in a Completely Randomized Design (CRD) was applied for. All data were reported as means with standard deviations (SD). An analysis of variance (ANOVA) and Duncan's multiple range test were conducted to compare the mean differences between groups at a 95% significance level. All statistical analysis was performed using SPSS® Statistics software (IBM, version 20; Chicago, IL, USA).

3. Results and Discussion

3.1 Formulation of reduced-sugar, fiber-enriched Thong Ake

3.1.1 Substitution of sugar with the stevioside-sorbitol mixture

A control sample (s0) and three reduced-sugar formulas (s50, s75, and s100) were not different in terms of diameter (3.2 cm), thickness (1.5 cm), and weight (10 g/piece) (Fig 1). The data from sensory evaluation is presented in Table 3. General appearance, odor, taste, and texture were not significantly different among the samples ($P>0.05$). However, their color and overall acceptability scores were significantly different ($P\leq0.05$). The sample with 50% sugar substitution (s50) was rated the highest liking score on color by the panelists. Also, the sample of such formula had the highest overall acceptability score than other reduced-sugar samples, but not significantly different from that of the control formula ($P>0.05$). Therefore, the modified Thong Ake formula with 50% of sugar substitution was selected for a further experiment on the substitution of rice flour with RS.

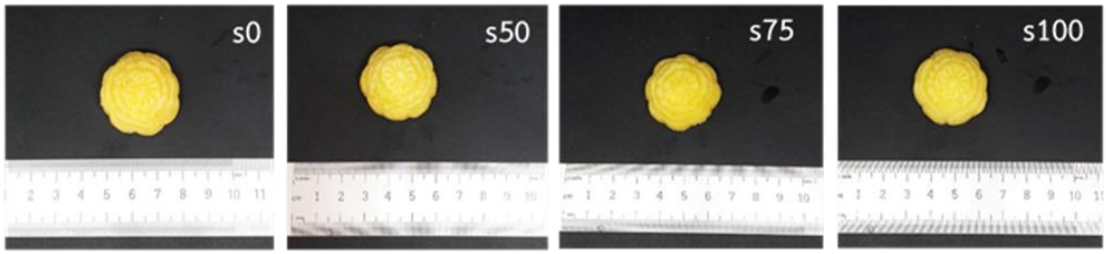

Fig 1 Appearance of Thong Ake samples with 0%, 50%, 75%, and 100% levels of substitution with the stevioside-sorbitol mixture

Table 3 Sensory evaluation of Thong Ake at different levels of sugar substitution

Formula[1]	Sensory acceptability scores[2,3]					
	General Appearance	Color	Odor	Taste	Texture	Overall Acceptability
s0	6.98±0.18^{a}	7.36±0.20^{b}	6.74±0.17^{a}	6.80±0.18^{a}	6.38±0.22^{a}	6.90±0.17^{a}
s50	6.78±0.19^{a}	8.06±0.18^{a}	6.74±0.18^{a}	6.54±0.18^{a}	5.94±0.22^{a}	6.70±0.19^{ab}
s75	7.02±0.19^{a}	7.32±0.17^{c}	6.73±0.17^{a}	6.51±0.17^{a}	6.06±0.21^{a}	6.61±0.16^{ab}
s100	6.88±0.20^{a}	7.36±0.20^{b}	6.76±0.19^{a}	6.30±0.21^{a}	5.72±0.25^{a}	6.63±0.09^{b}

[1] s0, control (100% of sugar); s50, 50% substitution level of stevioside+sorbitol; s75, 75% substitution level of stevioside+sorbitol; s100, 100% substitution level of stevioside+sorbitol.

[2] Means ± standard deviations from 50 panelists.

[3] Rated on a 9-point hedonic scale: 1=dislike extremely, 5=neither like nor dislike, 9=like extremely.

[a,b,c] Means with different superscripts within the same column are significantly different ($P\leq0.05$).

3.1.2 Substitution of rice flour with type 2 RS

Five reduced-sugar, fiber-enriched samples were developed with different levels of RS substitution (s50-rs0, s50-rs25, s50-rs50, s50-rs75, s50-rs100). Their diameter, thickness, and weight were not different from the control and the reduced-sugar samples (Fig 2). The results of the sensory evaluation indicated that the liking scores for general appearance, color, odor, taste, texture, and overall acceptability were not significantly different among the control and the samples with 25%, 50%, and 75% flour replacement levels (Table 2). However, the sample without rice flour (s50-rs100) received the lowest scores in all sensory attributes, and it was statistically different from other samples in the scores of all sensory attributes ($P \leq 0.05$), except color.

According to a previous report, approximately 20 g of RS is recommended for daily intake to obtain the bowel-related benefit (Sharma *et al.*, 2008). Such amount of RS has been proven for several health benefits, such as modulating blood glucose level, minimizing the risk of colon cancer, inhibiting fat accumulation, enhancing mineral absorption at the small intestine, and playing a prebiotic role (Sharma *et al.*, 2008; Birt *et al.*, 2013). Thong Ake with 50% sugar reduction and 50% flour substitution (s50-rs50) contained 8 g of RS in one serving (80 g), which is 40% of the recommended amount. When considering the amount and cost of RS, the sample of the s50-rs50 formula was selected for further analysis in chemical composition and physical properties.

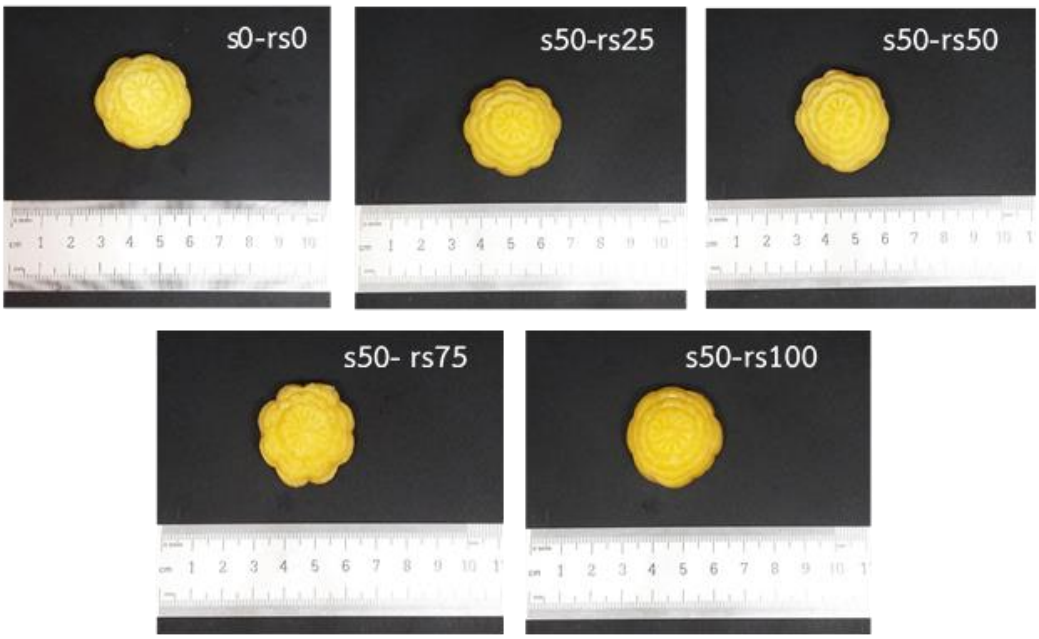

Fig 2 Appearance of reduced-sugar Thong Ake (50% substitution level of stevioside-sorbitol mixture) with 0%, 25, 50%, 75%, and 100% level of substitution with type 2 RS

Table 4 Sensory evaluation of reduced-sugar Thong Ake at different levels of RS substitution

Formula[1]	Sensory acceptability scores[2,3]					
	General Appearance	Color	Odor	Taste	Texture	Overall Acceptability
s50-rs0	6.98±0.18[a]	7.36±0.20[a]	6.74±0.17[a]	6.80±0.18[a]	6.38±0.22[a]	6.90±0.17[a]
s50-rs25	6.90±0.15[a]	7.00±0.17[a]	6.90±0.14[a]	6.64±0.17[a]	6.65±0.19[a]	6.76±0.15[a]
s50-rs50	6.88±0.16[a]	7.24±0.14[a]	6.48±0.19[a]	6.50±0.22[a]	6.48±0.21[a]	6.72±0.19[a]
s50-rs75	6.90±0.17[a]	8.36±1.62[a]	6.64±0.17[a]	6.54±0.20[a]	6.52±0.22[a]	6.84±0.18[a]
s50-rs100	6.04±0.26[b]	7.10±0.21[a]	5.84±0.24[b]	4.92±0.31[b]	4.54±0.28[b]	5.18±0.28[b]

[1] s50, 50% substitution level of stevioside+sorbitol; rs0, no substitution of RS; rs25, 25% substitution level of RS; rs50, 50% substitution level of RS; rs75, 75% substitution level of RS; rs100, 100% substitution level of RS; RS, resistant starch.

[2] Means ± standard deviations from 50 panelists.

[3] Rated on a 9-point hedonic scale: 1=dislike extremely, 5=neither like nor dislike, 9=like extremely.

[a,b,c] Means with different superscripts within the same column are significantly different ($P \leq 0.05$).

3.2 Nutritional compositions and physical properties of the reduced-sugar, fiber-enriched Thong Ake

3.2.1 Nutritional compositions

Table 5 compares the nutritional compositions of the control Thong Ake and modified Thong Ake (s50-rs50). There was no significant difference in the total carbohydrate, protein, fat, and ash contents between these two samples. However, the sugar contents of the modified Thong Aek (13 g in 80 g serving) were significantly lower than the control sample by approximately 50% ($P \leq 0.05$). As stated by the Notification of Ministry of Public Health No. 182 (1998) on nutrition labeling, the sugar content in a food product can be claimed as 'reduced, reduced in, lower, lower in, less' when it has been decreased by 25% of the reference product. The modified Thong Ake with 50% sugar reduction and 50% fiber substitution (s50-rs50), thus, can be claimed as a 'reduced sugar or lower in sugar' product. However, the sugar content in the modified Thong Ake still exceeded the recommended consumption amount for sugar (less than 6 teaspoons per day or 4.8 g per meal including snacks) (WHO, 2015). Further studies thus may consider to further decrease the amount of sugar in Thong Ake aiming to meet the recommendation.

Table 5 Nutritional compositions of control Thong Ake and Thong Ake with 50% sugar reduction and 50% RS substitution (s50-rs50)

Composition	Content per 100 g[1]	
	Control	s50-rs50[2]
Moisture (g)	26.39 ± 1.26[b]	30.81 ± 1.02[a]
Protein (g)	6.39 ± 0.35[a]	5.28 ± 0.52[a]
Fat (g)	13.71 ± 1.40[a]	14.35 ± 0.65[a]
Ash (g)	0.61 ± 0.05[a]	0.59 ± 0.06[a]
Carbohydrate (g)	52.96 ± 1.23[a]	48.70 ± 0.89[a]
Dietary fiber (g)	0.73 ± 0.37[b]	8.80 ± 0.52[a]
Sugar (g)	34.61 ± 0.46[a]	17.02 ± 1.70[b]

[1] Means ± standard deviations from triplicate samples.

[2] s50-rs50, 50% substitution level of stevioside+sorbitol and 50% substitution level of RS

[a,b] Means of each content per 100g with different superscripts within the same row are significantly different ($P \leq 0.05$).

One serving (80 g) of modified Thong Ake (s50-rs50) contained 9.6 g (12% w/w) of sorbitol and 0.016 g (0.02% w/w) of stevioside. Such amount of sorbitol was less than the dosage (50 g) that is known to cause potential health distress from laxation symptoms (Srisangwan, 2012). Moreover, the amount of stevioside in modified Thong Ake (63.8 mg/kg) did not exceed the recommendation and the usage limit of 165 mg/kg, as regulated by the Notification of the Ministry of Public Health No. 389 (2017). The content of dietary fiber of the modified Thong Ake (s50-rs50) were 7 g per 80 g serving, and it was significantly higher than in the control formula ($P \leq 0.05$). Dietary fiber content markedly increased by approximately 92% from the control recipe. This developed food product, thus, can be claimed 'good source, contains, provides' fiber according to the Notification of Ministry of Public Health No. 182 (1998) because its dietary fiber content reached 10-19% of Thai Recommended Daily Intakes (2.5-5 g).

Lowering consumption of sugar and heightening consumption of fiber could reduce the risk of NCDs such as diabetes, cardiovascular disease, and hypertension (Chaikate *et al.*, 2017). Further research to investigate the *in vitro* gastrointestinal digestion of the modified Thong Ake and the changes in blood glucose level after consuming the product would be beneficial to determine the actual starch digestibility and glycemic index of the developed product.

3.2.2 Physical properties

The results on physical properties determination indicated that the hardness, springiness, and cohesiveness of the control sample and modified Thong Ake (s50-sr50) were significantly different ($P \leq 0.05$) (Table 6). Comparing with the control formula, the hardness of the modified Thong Ake was lower, while its springiness and cohesiveness were higher. It was probably because of the partial replacement of sucrose by sorbitol. Sorbitol is widely used as a bulking agent and humectant in food products. It has more hygroscopic nature than sucrose. This might cause the modified Thong Ake to become softer than the control due to the greater water adsorption properties of the added sorbitol (Kanpairo, 2018). The modified Thong Ake could hold more water than the control, and thus its moisture content was higher, as shown in Table 5. A comparable result was also found in A-Lua dessert using sorbitol as a sugar substitute. The more sorbitol added, the lower the hardness value was reported

(Srisangwan, 2012). Moreover, Zhou *et al.,* (2005) indicated that the addition of sorbitol could decrease the storage modulus and loss modulus which implied that sorbitol may have a plasticizing effect on the product.

Besides, the addition of RS may also influence the changes of the modified Thong Ake, as the hardness of the muffin was reported to decrease with the addition of type 2 RS (Sanz, 2009). Type 2 RS has been demonstrated for their resistance to swelling in water and to gelatinization (Hern´andez *et al.,* 2008). Petchoo *et al.,* (2021) revealed that the addition of type 2 RS could interfere the microstructure of breadstick. The discontinuous and irregular matrix could reflect the lower hardness of the product.

Table 6 Physical properties of control Thong Ake and Thong Ake with 50% sugar reduction and 50% RS substitution (s50-s50)

Properties[1]	Control	s50-rs50[2]
Texture analysis profile		
Hardness (N)	2753.30 ± 335.61[a]	2101.76 ± 263.60[b]
Springiness	0.30 ± 0.03[b]	0.41 ± 0.04[a]
Cohesiveness	0.36 ± 0.02[b]	0.43 ± 0.03[a]
Chewiness	303.78 ± 43.55[a]	316.14 ± 11.77[a]
Color		
L*	53.13 ± 0.62[b]	55.18 ± 1.85[a]
a*	5.11 ± 0.13[b]	5.28 ± 0.18[a]
b*	25.28 ± 0.30[b]	26.03 ± 0.67[a]
Aw	0.89 ± 0.01[a]	0.90 ± 0.01[a]

[1] Means ± standard deviations from triplicate samples.

[2] s50-rs50, 50% substitution level of stevioside+sorbitol and 50% substitution level of RS

[a,b] Means of each property with different superscripts within the same row are significantly different ($P \leq 0.05$)

The color values *(L*, a*, b*)* of the modified Thong Ake (s50-sr50) were statistically higher than the control ($P \leq 0.05$). Potentially, the occurrence of Maillard reaction was limited due to the substitution and replacement of sweetener and RS in the sample; therefore, the development of brown color was reduced (Gao *et al.,* 2017). For water activity, there was no difference between the control and modified formulas ($P > 0.05$). Sorbitol is a humectant that binds strongly with water. So it helped to retain the water without the increase in free water content (Ghosh and Sudha, 2012). Therefore, the modified Thong Ake contained higher moisture content than the control, but its water activity did not increase. The water activity of the modified Thong Ake ranged from 0.89 to 0.90, which is sensitive to deterioration by microorganisms. It has been reported that the replacement of sugar with sorbitol in chiffon cake was feasible to suppress microbial growth and reduce microbial deterioration (Song and Han, 2015). Determination of shelf life of the product is recommended to investigate the changes in quality and safety of the modified Thong Ake during storage.

Furthermore, the cost per 80 g serving portion of the developed Thong Ake (s50-sr50) was approximately 9.70 baht higher than the control formula, owing to the cost of sweeteners and type 2 RS. Hence, future studies should be carried out

regarding consumer price acceptance and willingness to pay for the modified, healthier Thong Ake product.

4. Conclusion

The findings of this study reveal that the reduced-sugar, fiber-enriched Thong Ake was successfully developed. According to the sensory evaluation, the developed Thong Ake with 50% replacement of sugar by stevioside-sorbitol mixture and 50% substitution of rice flour by type 2 RS received the highest sensory preferences scores, rated by 50 untrained panelists on a 9-point hedonic scale, and did not significantly differ from the control formula. Regarding the nutritional compositions, it contained 50% less sugar and 92% more dietary fiber per serving than the control sample. This partial substitution changed the physical properties of the developed Thong Ake, i.e., color, hardness, springiness, and cohesiveness values; however, it did not affect the consumer acceptability. Therefore, the developed Thong Ake could be an alternative to Thai dessert for people who are concerned about their health and those who want to limit their carbohydrate intake.

Acknowledgements

We gratefully acknowledge to Maejo University for the financial support, National Starch and Chemical (Thailand) for supply of RS type 2 (HI-MAIZE® 260) and Hong Huat Co., Ltd for stevioside.

References

Ahuja, G., Jaiswal, S., and Chibbar, R. N. 2013. Starch Biosynthesis in Relation to Resistant Starch. In Y. C. Shi and C. C. Maningat (Eds). Resistant Starch: Sources, Applications and Health Benefits (pp. 1-22). John Wiley & Sons, New Jersey.

Anderson, J. W., Baird, P., Davis, R. H., Ferreri, S., Knudtson, M., Koraym, A., Waters, V.,and Williams, C.L. 2009. Health benefits of dietary fiber. Nutrition Reviews. 67(4): 188-205.

Arp, C. G., Correa, M. J., and Ferrero, C. 2021. Resistant starches: A smart alternative for the development of functional bread and other starch-based foods. Food Hydrocolloids. 121: 106949.

Association of Official Analytical Chemist (AOAC). 2002. 17th Ed. Official methods of analysis of AOAC international. Gaithersburg, MD: AOAC International.

Association of Official Analytical Chemist (AOAC). 2010. 18th Ed. Official methods of analysis of AOAC international. Gaithersburg, MD: AOAC International.

Association of Official Analytical Chemist (AOAC). 2016. Official methods of analysis of AOAC international. 20th Ed. Gaithersburg, MD: AOAC International.

Birt, D.F., Boylston, T., Hendrich, S., Jane, J.L., Hollis, J., Li, L., McClelland, J., Moore, S., Phillips, G.J., Rowling, M. and Schalinske, K. 2013. Resistant starch: promise for improving human health. Advances in Nutrition. 4(6): 587–601.

Chaikate, S., Morakotjinda, P. and Thongrod W. 2017. The Development of Healthy Thai Dessert: A Case Study of Thong Ake. Journal of Research Unit on Science, Technology and Environment for Learning. 8(2): 261-270.

Chattopadhyay, S., Raychaudhuri, U. and Chakraborty, R. 2014. Artificial sweeteners - a review. Journal of Food Science and Technology. 51(4): 611–621.

Compendium of Methods for Food Analysis. 2003. Compendium of methods for food analysis, Thailand. 1st Ed. Bangkok, Thailand.

Ding, S. and Yang, J. 2021. The effects of sugar alcohols on rheological properties, functionalities, and texture in baked products – A review. Trends in Food Science and Technology. 111: 670-679.

Division of Non-Communicable Diseases. 2019. Report on the situation of non-communicable diseases in Thailand: diabetes, hypertension and other risk factors – 2019. Bangkok: Department of Disease Control, Ministry of Public Health. (https://ddc.moph.go.th/uploads/publish/1035820201005073556.pdf).

Gao, J., Brennan, M.A., Mason, S.L. and Brennan, C.S. 2017. Effects of sugar substitution with "Stevianna" on the sensory characteristics of muffins. Journal of Food Quality. 2017: 8636043.

Ghosh, S., and Sudha, M.L. 2012. A review on polyols: new frontiers for health-based bakery products. International Journal of Food Sciences and Nutrition. 63(3): 372-379.

Hernández, O., Emaldi, U., and Tovar, J. 2008. In vitro digestibility of edible films from various starch sources. Carbohydrate Polymers. 71(4): 648-655.

Kaewjun, D. 2015. Supplementation of prebiotic dietary fibers in rice cracker. Master thesis. Silpakorn University.

Kanpairo, K. 2018. Effect of different sweeteners on the quality of Torch Ginger (*Etlingeraelatior* (Jack) R.M. Smith) gummy jelly. Burapha Science Journal. 23(2): 944-958.

Li, Y. O. and Komarek, A. R. 2017. Dietary fibre basics: Health, nutrition, analysis, and applications. Food Quality and Safety. 1(1): 47-59.

Mattes, R. D., Tan, S. Y. and Tucker, R. M. 2021. Sweeteners: sensory properties, digestion, consumption trends, and health effects. Reference Module in Food Science. Elsevier. pp. 1-15

Ministry of Public Health. 1998. Notification of the Ministry of Public Health No. 182. 1998. Nutrition labelling. Ministry of Public Health: Bangkok, Thailand.

Ministry of Public Health. 2013. Notification of the Ministry of Public Health No. 355. 2013. Title: Food in a Hermetically Sealed Container. Ministry of Public Health: Bangkok, Thailand.

Ministry of Public Health. 2017. Notification of the Ministry of Public Health No. 389. 2017. Re Steviol glycosides. Ministry of Public Health: Bangkok, Thailand.

Noosing, S. and Leelawa, B. 2016. Rheological properties and sensory qualities of mung bean (*Vigna radiate* L.) paste. Thai Science and Technology Journal (TSTJ). 24(2): 277-287.

Petchoo, J., Jittinandana, S., Tuntipopipat, S., Ngampeerapong, C. and Tangsuphoom, N. 2021. Effect of partial substitution of wheat flour with resistant starch on physicochemical, sensorial and nutritional properties of breadsticks. International Journal of Food Science and Technology. 56(4): 1750-1758.

Peters, R., Ee, N., Peters, J., Beckett, N., Booth, A., Rockwood, K. and Anstey, K.J. 2019. Common risk factors for major non-communicable disease, a systematic overview of reviews and commentary: the implied potential for targeted risk reduction. Therapeutic Advances in Chronic Disease. 10: 1-14.

Sabanis, D., Lebesi, D., and Tzia, C. 2009. Effect of dietary fibre enrichment on selected properties of gluten-free bread. LWT - Food Science and Technology. 42(8): 1380-1389.

Sanz, T., Salvador, A., Baixauli, R. and Fiszman, S. M. 2009. Evaluation of four types of resistant starch in muffins. II. Effects in texture, colour and consumer response. European Food Research and Technology. 229(2): 197-204.

Selvasekaran, P. and Chidambaram, R. 2021. Advances in formulation for the production of low-fat, fat-free, low-sugar, and sugar-free chocolates: An overview of the past decade. Trends in Food Science & Technology 113: 315-334.

Sharma, A., Yadav, B.S., and Ritika. 2008. Resistant starch: Physiological roles and food applications. Food Reviews International. 24(2): 193–234.

Siwnguan, K., Phugan, P., Compen, A. and Inpatom, P. 2017. Using of pomelo albedo powder as dietary fiber in cracker products. PSRU Journal of Science and Technology. 2(1): 14-23.

Song, Y. N. and Han, J. A. 2015. Effect of Sorbitol on the Physicochemical and Microbial Characteristics of Chiffon Cake. Korean Journal of Food Science and Technology. 47: 645-651.

Srisangwan, N., 2012. Nutritional improvement of A-Lua and Foi-Thong by using nonsugar sweeteners. Master thesis. Silpakorn University.

Srivanichakorn, S. 2017. Morbidity and mortality situation of non-communicable diseases (diabetes type 2 and cardiovascular diseases) in Thailand during 2010-2014. Disease Control Journal. 43(4): 379-390.

Tappy, L., Lê, K. A., Tran, C., and Paquot, N. 2010. Fructose and metabolic diseases: new findings, new questions. Nutrition. 26(11-12): 1044–1049.

Te, M.L., Mallard, S. and Mann, J. 2013. Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. BMJ. 2013(346): e7492.

Tomic, N., Dojnov, B., Miocinovic, J., Tomasevic, I., Smigic, N., Djekic, I. and Vujcic, Z. 2017. Enrichment of yoghurt with insoluble dietary fiber from triticale – A sensory perspective. LWT. 80: 59-66.

Visasa, K. 2005. Nutrient composition in selected Thai desserts. Master thesis, Mahidol University.

World Health Organization and United Nations. 2021. United Nations Thematic Working Group on Noncommunicable Disease Prevention and Control: case study – Thailand. Geneva: World Health Organization and United Nations Development Program. (https://www.who.int/publications/i/item/united-nations-thematic-working-group-on-noncommunicable-disease-prevention-and-control-case-study-thailand).

Zhou, C. F., Qian, P., Meng, J., Gao, S. M. and Lu, R. R. 2016. Effect of glycerol and sorbitol on the properties of dough and white bread. Cereal Chemistry. 93(2): 196-200.