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Effect of Malva Nut Gel as Fat Replacer on Sponge Cake

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Abstract

Malva nut originated in Southeast Asia and is cultivated in the Eastern part of Thailand. Gel prepared from its mature seed coat containing high water-soluble dietary fiber was used as a fat replacer in this research. Part of the butter (25-50%) and milk (10-20%) for the sponge cake were replaced with malva nut gel. Physical, chemical and organoleptic analyses were conducted to evaluate the effects of malva nut gel on the properties of the sponge cake. For specific volume, all samples were not significantly different ($p>0.05$); moreover, the roughness, lightness (L*) and yellowness (b*) of the crust increased while the values of the crumb decreased. In the final product obtained from this research 10% of the milk and 25% of the butter were replaced with malva nut gel, which was the highest replacement content of butter and milk with a high customer acceptance. Its chemical composition consisted of 22.72% moisture, 6.28% protein, 16.20% fat, 0.90% ash, 53.90% carbohydrate and 3.76% dietary fiber. Cholesterol and total calories were 114.22 mg and 386.52 Kcal, respectively. The content of fat, carbohydrate, cholesterol, and total calories of this product were lower than the basic formula ($p \leq 0.05$). In addition, 120 consumers accepted this cake in terms of appearance, color, aroma, taste, softness and rated it overall, as 'very much liking' and the aftertaste as 'moderate liking'.

Introduction

Malva nut is a seed of Scaphium scaphigerum (Wall. ex G. Don). G. Planch. It is originated in Southeast Asia and its seed is used as traditional medicine. In Thailand, it is cultivated in the East, especially in Chantaburi province. Its mature seed can form gel when it is soaked. The seed containing water soluble dietary fiber can absorb about 40-45 ml/g water and swell (Piyatrakul, 2013; Sukhasem & Kinkajorn, 2017) to produce brown jelly.

The nutrition composition of dry malva nut

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contains 12.0% moisture, 5.40% protein, 2.40% fat, 75.30% carbohydrate and 67.10% fiber (Disthai, 2019). Due to the high amount of dietary fiber, its swollen and fragmented structure can hold moisture, fat, sugar and other substances (Pramualkijja et al., 2016). Malva nut gel is able to remove fat and toxin in the intestine. Also, the gel can reduce suffering from constipation and control the body weight. Additionally, consuming two grams of fiber extract of malva nut twice a day results in increasing fiber intake and decreasing energy, and waist circumference (Chaitokkia & Panomai, 2018). When this gel was studied regarding a possible use as a fat replacer in food and bakery products (Health Benefits Times, 2019; Pramualkijja et al., 2016; Chaosomboon, 2018). Chajeamjen et al. (2017) found that added malva nut gel increases the moisture and crude fiber in cookie bars.

Nowadays, cake is a popular dessert. There are two types of cake: butter and foam. In a foam type cake, fat provides softness and flavor (Godefroidt et al., 2019). The aim of this research was to test malva nut gel as a partial substitute for butter and milk in a sponge cake, which is a foam type cake. The physical quality and sensory evaluation of the cake were examined. Also, nutrition and consumer acceptance were a focus. The product of the research could not only reduce the fat in the cake, but also show the benefits of using malva nuts.

Materials and methods

1. Materials

Dried malva nuts were from Chantaburi province, Eastern part of Thailand. Cake flour (Royal Fan, 7.0-8.3% protein, UFM Food Center Co. Ltd., Thailand), Double acting baking powder (Best Food, Unilever Thai Holdings Ltd., Thailand), fresh eggs, evaporated milk (Carnation, F&N Dairies (Thailand) Co. Ltd., Thailand), sugar (Mitr Phol, Mitr Phol Sugar Corporation, Ltd., Thailand), salt (Prung Thip, Thai Refined Salt Industrial Co. Ltd., Thailand), cake emulsifier (SP, American Baker Co. Ltd., U.S.A.) including Sorbitol, Ester of Fatty Acid, Monoglyceride, Sucrose Ester of Fatty Acid, Glycerine and Propylene Glycol, vanilla essence (Winner, Greathill Co. Ltd., Thailand) and unsweetened butter (Orchid. The Thai Dairy Industry Co. Ltd., Thailand) were used to make sponge cake.

2. Determination of color and chemical composition of prepared malva nut gel

2.1 Malva nut gel preparation

Dried malva nuts (Fig. 1) were washed in tap water. The top and bottom were cut and soaked in filtered water for 90 minutes at room temperature (30±2°C). The ratio of malva nuts to water was 1:20 (w/w). The swollen gel was drained and squeezed on a 40-mesh sieve. This gel was cleaned until the water was clear. The gel was drained and sealed in a plastic bag. It was kept at 4±2°C to be analyzed later (applied from Paseephol et al., 2016).

Fig. 1 Dried malva nuts

2.2 Color measurement

The color was investigated using a handy colorimeter (Nippon Denshoku NR-3000, Japan) which had been calibrated using a standardized black and white standard plate. The sample of 100 g prepared gel was put into a clear plastic tray for color measurement. Ten recordings were noted on average for the sample.

2.3 Determination of chemical composition

The chemical composition of malva nut gel was determined through proximate analysis, namely moisture, protein, fat, ash, dietary fiber and calculated carbohydrate including crude fiber with the standard methods (Association of Official Analytical Chemists, 2016). The experiment was done in duplicate with triplicate measurement.

3. Replacement of butter and milk in sponge cake with malva nut gel

The basic formula of sponge cake used in this study is shown in Table 1 (Suan Dusit International Culinary Center, 2017). Cake flour was mixed with baking powder (part 1). Eggs, evaporated milk, sugar, salt, cake emulsifier and vanilla essence were mixed together and defined as part 2. The cake batter was prepared by mixing part 1 with part 2, and then adding melted butter (or butter with malva nut gel). The batter was poured into a 5 cm. diameter paper cup with a case (25-26 g/cup).

These cupcakes were baked at 180-190°C for 18-20 minutes. They were left to cool completely on a wire rack.

Table 1 Ingredients of sponge cake (basic formula)

Ingredient (%)	Concentration (%)						
	Basic formula (control)	RM0/ RB25	RM0/ RB50	RM10/ RB25	RM10/ RB50	RM20/ RB25	RM20/ RB50
Cake flour	24.04	24.04	24.04	24.04	24.04	24.04	24.04
Baking powder	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Egg	24.03	24.03	24.03	24.03	24.03	24.03	24.03
Evaporated milk	7.21	7.21	7.21	6.49	6.49	5.77	5.77
Sugar	24.03	24.03	24.03	24.03	24.03	24.03	24.03
Salt	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Cake emulsifier	1.81	1.81	1.81	1.81	1.81	1.81	1.81
Vanilla essence	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Melted butter	18.03	13.52	9.02	13.52	9.02	13.52	9.02
Malva nut gel	0.00	4.51	9.01	5.23	9.73	5.95	10.45
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

The content of malva nut was varied using a factorial in completely randomized design (Factorial in CRD). A cake made by basic formula (RM0/RB0) was used as the control. This gel was used to replace the three levels of evaporated milk weight (RM) at 0, 10 and 20% and two levels of butter weight (RB) at 25% and 50%. There were seven formulas for this experiment as shown in Table 2. These levels were determined based on the appearances of mixture and cake (fluffy, spongy, and moist characteristics) which were compared to the control by visual observation. The treatments which provided a suitable product were selected for measurement of their physical qualities and sensory evaluation. The cake samples were analyzed on day 1 post-baking.

3.1 Physical quality

Diameter and height of the product sample was measured by Vernier calipers. The specific volume was determined by sesame seed displacement (Lee et al., 1982). The cake was weighed (W0). The empty container was filled with sesame seeds and the volume of the seeds was determined by a graduated cylinder (V1). The cake was placed in the container. The sesame seeds were poured over the sample in the box and leveled with a spatula. The seed volume was determined using a graduated cylinder (V2). The difference between V1 and V2 was defined as the sample volume (V0). The specific volume was calculated as the ratio of the volume to weight (V0/W0) or cubic centimeters per gram (cm^3/g). These measurements were done in triplicate.

The color of the crust and the crumb of samples were measured separately. The samples were analyzed on day 1 post-baking. The L*, a* and b* values of the crust and crumb of the cake were determined using a handy colorimeter (Nippon Denshoku NR-3000, Japan), which had been calibrated using a standardized black and white standard plate. Ten readings were recorded on the top part of the cake, Then the top of the cake was cut horizontally, and ten readings were recorded on the crumb color of the cake.

Texture profiles of products were analyzed by a texture analyzer (Stable Micro System TA-XT2i, England). A 3x3x3 cm^3 sample was pressed using a cylinder probe (100 mm. diameter, P/100), 3.0 mm./sec pre-test, 0.5 mm/sec test speed, 10.0 mm./sec of post-test speed, 20% strain, 60 sec and 20 g of trigger type. Hardness, adhesiveness, and springiness of the cake samples were reported. Five measurements were taken to obtain an average value of all texture parameters of each sample.

3.2 Sensory evaluation

Sensory evaluation of the cake with a randomized complete block design (RCBD) was carried out by 55 untrained panelists. Each panelist was presented with individual cupcakes (5 cm diameter) which were placed on a tray in a plastic bag coded with a three-digit random number and served in a randomized order. Drinking water was provided as a palate cleanser before tasting the next sample. The degree of liking was used on a 9-hedonic scale (1=extremely dislike and 9=extremely like) to rate different parameters such as appearance, color, flavor, taste, softness, aftertaste, and overall liking. The formula which provided a soft, good flavor and received the highest scores was accepted for this study.

4. Analysis of chemical composition of malva nut gel sponge cake

The chemical composition of the selected product was determined and compared with the control product by proximate analysis with the standard methods described in Association of Official Analytical Chemists (2016). The contents of moisture, protein, fat, ash, and dietary fiber were determined. Carbohydrate content (including crude fiber) was obtained by calculation. Additionally, cholesterol in both products was determined according to the Compendium of Methods for Food Analysis Thailand (Thailand National Bureau of Agriculture Commodity and Food Standards, 2003).

5. Evaluation of consumer acceptance of malva nut gel sponge cake

Consumer acceptability of the selected malva nut gel sponge cake was performed using central location test (CLT) by 120 consumers at Suan Dusit University,

Bangkok, Thailand. Each consumer received a cupcake (5 cm diameter) which was placed on a tray in a plastic bag with a glass of drinking water at room temperature and a questionnaire. The questionnaire consisted of general information, attitude, sensory evaluation with 9-point hedonic scale (1 = extremely dislike and 9 = extremely like) to evaluate 7 types of attribution: appearance, color, flavor, taste, softness, aftertaste, and overall and channel of distribution.

6. Statistical analysis

All formula developments were arranged in treatments and experiments with factorial in completely randomized design (Factorial in CRD). The experiment of sensory evaluation was performed applying the randomized complete block design (RCBD). The data obtained from this study were analyzed statistically using a t-test for 2 samples and analysis of variance (ANOVA) and the differences between average values were compared by Duncan's new Multiple Range Test (DMRT) for more than 2 samples at the level of significance ($p \leq 0.05$). This statistical analysis was performed using SPSS (Statistical Package for the Social Science).

Results and discussion

1. Color and chemical properties of malva nut gel

The color of the gel, which was from the mucilage in the outer of malva nut seed coat, was dark brown as shown in Fig. 2. Its chemical compositions were shown in Table 2. The water holding capacity of the gel was also measured as 46.40±0.12 times of dry weight. It was composed of high amount of water-soluble dietary fiber presenting a gelling property. The gel was able to form a viscous substance without heat (Piyatrakul, 2013; Sukhasem & Kinkajorn, 2017; Vinyoochareonkul, 2012) which mimicked the rheology of fats (Kathryn et al., 2018); therefore, it was used to substitute butter in a cake in this research. Moreover, the gel was able to hold a high content of water, replacing not only butter but milk also.

Fig. 2 Malva nut gel

Table 2 Color value and chemical composition of malva nut gel

Quality	Malva nut gel
Color value	
L*	26.18±0.20
a*	20.54±0.25
b*	39.01±0.45
Chemical composition	
Moisture (%)	97.89±0.07
Protein (%)	0.44±0.01
Fat (%)	0.01±0.00
Ash (%)	0.09±0.01
Carbohydrate (%)	1.57±0.02
Dietary fiber (%)	0.29±0.00
Total calories (Kcal)	8.13±0.17

2. Effects of butter and milk replacement with malva nut gel

Seven samples of sponge cake from different formulae are presented in Fig. 3. The visual characteristics of cakes replacing milk (RM) at 0%, 10% and 20% of milk weight and butter (RB) at 25% and 50% of butter weight in the basic recipe with malva nut gel were compared. It showed that increasing the gel adding caused a fade color of both on the surface and inside of the cake with brown spots, a rough surface, less butter odor, little sweeter, thicker and less fluffy. It was because of high

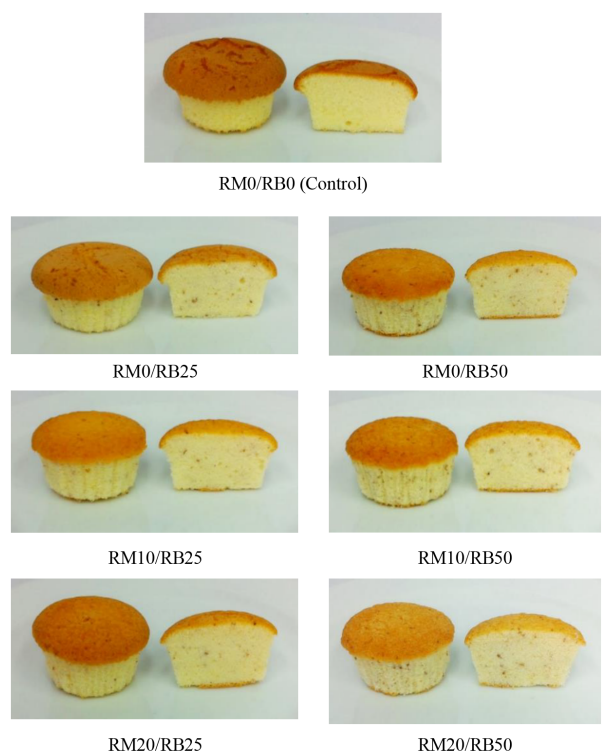

Fig. 3 Sponge cake with malva nut gel replacing milk and butter at different levels

moisture absorption and gum-like properties of the gel. Moreover, reducing fat content led to a weak structure of the cake (Pachekrepapol et al., 2009; Chajeamjen et al., 2017). However, the cake emulsifier in the sponge cake helped to make the mixture compatible. The cake with malva nut gel replacing milk by 10% and 20% and butter by 50% (RM10/RB50 and RM20/RB50) was less fluffy than the others.

2.1 Physical quality

The physical qualities of the selected products are shown in Table 3. Although there was no significant difference in specific volume among the samples ($p>0.05$), those of the experiment were higher than the control ($p \leq 0.05$); while the height of RM0/RB25 and RM0/RB50 cakes (only butter was replaced with malva nut gel) was not different from the control ($p>0.05$). It was caused by the water holding capacity of malva nut gel which accumulated more water in the cake; therefore, adding the gel without reducing milk or liquid materials made the cake formula unbalanced.

As regards the structure of the control cake, a stronger cake structure was found in RM0/RB25 because reducing butter caused more rising and less density (Gray, 2020), while a weaker structure was found in RM0/RB50 because reducing too much butter caused an unbalanced formula; in addition, water in gel replacing butter led to obtain too much gluten; consequently, the cake was too tight. However, the cake batter should be viscous enough to trap gas bubbles during mixing and the bubbles will further be retained when baking. On the other hand, if the batter is too viscous, the cake will have less height with low volume and quality (Huang & Yang, 2019; Zhiguang et al., 2019).

The crust color of the cake with malva nut gel replacing milk and butter is shown in Table 3. Increasing amounts of malva nut gel led to more lightness (L*) and yellowness (b*) of the studied crust cakes but less redness (a*) ($p \leq 0.05$). This was because with less milk, there was also less lactose and protein available to create the color of the product through caramelization and Maillard reaction. Due to a reduction of sugar dissolution in the mixture, there was a recrystallization of sugar causing brown spots on the top of cake; consequently, the crust color of the baked cake was uneven (Gisslen, 2016; Chemmek & Naivikul, 2017). The crumb color of the cakes with malva nut gel had the lightness (L*) near the control ($p>0.05$) except for the formula RM20/RB25. The redness (a*) of all samples was not different ($p>0.05$), but the yellowness (b*) of the RM0/RB25 and RM0/RB50 cake was significantly lower than that of the control ($p \leq 0.05$). The results led to darker and less yellow crumb because butter, which provides yellow color in cake, was reduced. The milk and butter replacement with malva nut gel, which contains more water, caused wheat flour to absorb more water and increased the gluten content. Consequently, the mixture was viscous, and the cake was less rising. These are consistent to the report of Phimolsiripol et al. (2017), revealing that the lightness (L*) and loaf specific volumes of the bread decreased with increased crude malva nut gum levels.

Texture profile analysis presented the hardest and softest textures in the RM0/RB25 and RM20/RB25, respectively. The hardness of RM0/RB50 and RM10/RB25 were not significantly different from the control. In addition, the replacement of milk and butter resulted in a softer cake. Hardness increased when malva nut gel was used to replace 20% milk and 25% butter ($p \leq 0.05$) because of an unbalance of butter and liquid in the mixture. In adhesiveness value, the RM0/RB25 was not significantly different from the control ($p>0.05$) but the RM0/RB50, RM10/RB25 and RM20/RB25 were significantly different ($p \leq 0.05$) in which these values were higher than the control. In contrast, Paseephol et al. (2016) found that butter and/or sugar replacements with malva nut gel resulted in decreasing hardness and increasing firmness and cohesiveness in chocolate cake, which was a butter type of cake.

Table 3 Physical qualities of the products replacing butter and milk with malva nut gel (mean ± standard deviation)

Quality	Replacing butter and milk by malva nut gel				
	Control (RM0/RB0)	RM0/RB25	RM0/RB50	RM10/RB25	RM20/RB25
Height (cm)	3.71^{h}±0.04	3.67^{h}±0.04	3.63^{h}±0.05	3.81^{a}±0.07	3.72^{ah}±0.04
Specific volume ^{ns}	3.67±0.47	3.73±0.29	3.22±0.59	3.47±0.06	3.39±0.20
Color value					
Crust					
- Lightness (L*)	50.16^{c}±0.61	55.26^{ah}±0.77	56.78^{a}±0.49	53.91^{bc}±1.01	54.12^{b}±1.84
- Redness (a*)	15.94^{a}±0.40	15.08^{a}±0.92	13.16^{c}±0.66	13.50^{bc}±1.23	14.73^{ab}±0.59
- Yellowness (b*)	29.92^{b}±1.63	30.91^{b}±0.58	33.99^{a}±1.45	33.93^{a}±0.96	33.10^{a}±1.04
Crumb					
- Lightness (L*)	67.93^{a}±0.71	66.37^{ah}±1.19	67.22^{ah}±1.11	64.08^{ah}±2.44	60.39^{b}±7.56
- Redness (a*) ^{ns}	1.22±0.93	1.64±0.30	1.72±0.51	1.14±0.60	1.06±0.30
- Yellowness (b*)	16.97^{a}±0.40	14.90^{b}±0.23	14.32^{b}±0.44	15.56^{ab}±0.78	15.18^{ab}±1.97
Texture					
Hardness (g)	558.79^{b}±50.95	443.32^{c}±20.91	505.17^{bc}±37.64	532.67^{bc}±18.83	845.15^{a}±9.52
Adhesiveness (N.s)	-5.05^{b}±1.31	-5.25^{b}±0.60	-2.41^{a}±1.64	-1.30^{a}±0.56	-3.02^{a}±1.03
Springiness ^{ns}	1.002±0.001	1.002±0.002	1.002±0.001	1.004±0.001	1.003±0.002

Remark: ^{abc} = Means followed by the same letter in the same row which are significantly different ($p \leq 0.05$)
^{ns} = Means in the same row which are not significantly different ($p > 0.05$)

2.2 Sensory evaluation

The sensory evaluation of the products from the 4 treatments evaluated with the preference test (9-point

hedonic scale) by 55 untrained panelists are shown in Table 4. The result shows that an increased replacement of milk and butter with malva nut gel affected the liking scores of appearance and aftertaste scores ($p \leq 0.05$). The appearance and aftertaste of RM0/RB25 obtained more liking scores than the others ($p \leq 0.05$) with the moderate liking. Moreover, the liking scores of flavor, taste, and overall preference of RM10/RB25 were higher than the others ($p \leq 0.05$). On the contrary, there were no significant ($p>0.05$) differences in color and softness as a moderate liking. Replacing milk and butter with malva nut gel in sponge cake resulted in a decreased milk and butter flavor; however, the odor and aftertaste liking scores were not affected by only milk and butter, but also by eggs in the recipe. (Suppavorasatit, 2014; Gisslen, 2016).

The selection criterion of formula was based on the highest amount of malva nut gel replacing butter and milk with the high panelist preference. Therefore, the product which had replaced 10% of milk and 25% of butter with malva nut gel (RM10/RB25) was the best product from this research. It contained 24.04% of cake flour, 24.03% of eggs, 24.03% of sugar, 13.52% of melted butter, 6.49% of evaporated milk, 5.23% of malva nut gel, 1.81% of cake emulsifier, 0.47% of baking powder, 0.19% of salt and 0.19% of vanilla essence.

Table 4 Average liking score of 55 untrained panelists regarding the sponge cake with butter and milk replaced with malva nut gel

Quality	Replacing butter and milk with malva nut gel			
	RM0/RB25	RM0/RB50	RM10/RB25	RM20/RB25
Appearance	7.20^{a}±1.01	6.74^{b}±0.82	7.15^{ab}±0.76	6.84^{ab}±0.63
Color ^{ns}	6.98±0.53	6.68±0.85	6.94±1.04	6.86±0.87
Flavor	7.02^{ab}±1.03	6.68^{b}±0.86	7.24^{a}±0.94	6.66^{b}±0.22
Taste	7.18^{ab}±0.83	6.90^{b}±0.66	7.40^{a}±0.43	6.94^{b}±1.02
Softness ^{ns}	7.06±0.76	7.10±0.74	7.22±0.98	7.00±1.01
Aftertaste	6.86^{a}±0.85	6.40^{b}±0.55	6.54^{ab}±0.43	6.82^{a}±1.02
Overall	7.18^{ab}±0.83	6.94^{ab}±1.05	7.26^{a}±1.04	6.88^{b}±1.00

Remark: ^{ab} = Means followed by the same letter in the same row which are significantly different ($p \leq 0.05$)
^{ns} = Means in the same row which are not significantly different ($p > 0.05$)

3. Chemical composition of product

The chemical composition of the final product from this research (replaced 25% butter and 10% milk with malva nut gel) and the according values of the control sample are shown in Table 5. Moisture and dietary fiber contents of the developed formulation were higher than the control ($p \leq 0.05$) by 33.10 and 31.80% respectively because mucilage in malva nut seed coats contained a high amount of dietary fiber causing a high moisture absorption (Piyatrakul, 2013). However, protein, fat, carbohydrate, cholesterol content and total calories of this product were lower than the control ($p \leq 0.05$) by 2.18, 23.84, 0.85, 8.35 and 11.06% respectively. The results are in accordance with Chajeamjen, et al. (2017) who reported that cookie bars with malva nuts had less fat and calories than the control ($p \leq 0.05$). In addition, its energy was reduced by up to 11%.

Table 5 Chemical composition of selected sponge cake with malva nut gel

Composition	Replacing butter and milk with malva nut gel	
	Control (RM0/RB0)	RM10/RB25
Moisture (%)	17.07^{b}±0.02	22.72^{a}±0.00
Protein (%)	6.42^{a}±0.02	6.28^{b}±0.01
Fat (%)	21.27^{a}±0.02	16.20^{b}±0.03
Ash ^{ns} (%)	0.87±0.01	0.90±0.02
Carbohydrate (%)	54.37^{a}±0.04	53.90^{b}±0.01
Dietary fiber (%)	2.83^{b}±0.01	3.76^{a}±0.04
Cholesterol (mg)	124.62^{a}±0.00	114.22^{b}±0.03
Total calories (Kcal)	434.59^{a}±0.25	386.52^{b}±0.23

Remark: ^{ab} = Means followed by the same letter in the same row which are significantly different ($p \leq 0.05$)
^{ns} = Means in the same row which are not significantly different ($p > 0.05$)

4. Consumer preference on malva nut gel sponge cake

The preference of consumers in RM10/RB25 tested by 120 consumers are shown in Table 6. Most consumers were 20-29 years old (49%), female (75%), students (35%) and their income was less than 10,000 baht (47%). The consumers preferred this product in appearance, color, flavor, taste, softness and overall characteristics "with a 'very much' liking score". The aftertaste had a moderate liking. Almost all of them used to consume sponge cake (95%), and they did it 1-2 times per month (35.96%) and the places to buy were bakery shops (75%) and department stores (50%). Moreover, 68% of consumers were interested in buying it.

Table 6 Average liking score of 120 consumers to the selected sponge cake with malva nut gel

Quality	Average liking score	Level of liking score
Appearance	7.51 ± 1.37	Like very much
Color	7.64 ± 1.00	Like very much
Flavor	7.60 ± 1.04	Like very much
Taste	7.54 ± 1.56	Like very much
Softness	7.71 ± 1.05	Like very much
Aftertaste	7.08 ± 1.27	Like moderately
Overall	7.66 ± 1.13	Like very much

Conclusion

Malva nut gel was a good ingredient to replace milk and fat in a sponge cake. 10% milk and 25% fat could be substituted with the gel causing a reduction of

energy (calories) up to 11% of the basic formula. Even if the gel affected the changes of the color and texture of a cake, the customers' preference score was still high. The findings from this research were commercially useful for healthy bakery products. To improve the quality of the product, cooperation with other hydrocolloids might be considered.

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