Research Article

Development of Normal and Reduced Fat Formulas of Coconut and Gac (*Momordica cochinchinensis* Spreng) Aril Flavored Ice Cream

Suthida Akkarachaneeyakorn* and Rawisara Sungpuak
Department of Agro-Industrial, Food, and Environmental Technology, Faculty of Applied Science, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

* Corresponding author. E-mail: suthida.a@sci.kmutnb.ac.th DOI: 10.14416/j.ijast.2017.05.004
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Abstract
This research aimed to develop normal and reduced fat formulas of coconut and gac aril flavored ice cream. It was determined that the suitable formula for developing the normal of coconut and gac aril flavored ice cream based on the most acceptable to consumers and has the lowest melting rate was 34.85% gac aril juice, 45.15% coconut milk, and 20% sugar. For the development of the reduced fat formula that could reduce the highest amount of fat while giving the highest acceptance scores, the variables studied were the type of fat replacer (soy protein, maltodextrin, and soy protein mixed with maltodextrin in a ratio of 1:1) and amount of fat replacer (30, 50, and 70% of fat in ice cream). It was found that the use of soy protein mixed with maltodextrin as a fat replacer at 50% was suitable for the production of the reduced fat formula of coconut and gac aril flavored ice cream (average overall acceptance was 6.53±1.43 points). The results showed that consumers cannot distinguish the differences of the normal and reduced fat formulas of coconut and gac aril flavored ice cream. For the melting rate, the reduced fat formula ice cream had a significantly lower melting rate than the normal formula ice cream.

Keywords: Beta-carotene, Fat replacer, Gac aril flavored ice cream, Maltodextrin, Soy protein

1 Introduction

Momordica cochinchinensis Spreng belongs to the melon family (Cucurbitaceae) and is indigenous to Southeast Asia [1]. The gac aril from ripened gac has high beta-carotene (718 µg/g FW), lycopene (2227 µg/g FW), and unsaturated fatty acid (102 mg/g) contents [2]–[5]. The color of the aril of ripened gac is orange to red, adding color to food products, thereby, attracting the attention of consumers. Presently, the aril of ripened gac has been developed into many products, such as frozen gac aril and dried gac aril. Ice cream is a product that consumers like to eat as a dessert. It can provide relief from heat. In addition, researchers want to avoid using dairy products so that those who are lactose intolerant can consume the products. Therefore, many researchers chose to use coconut milk as an ingredient to replace dairy products. Additionally, coconut milk is slightly aromatic and inexpensive [6]–[8]. Therefore, it is appropriate to use coconut milk as an ingredient in coconut and gac aril flavored ice cream.

In recent years, fat replacers have been produced for developing low calorie foods that are now widely used in food products. The reduction of fat content in products increases the amount of water in the products. Therefore, ingredients with properties similar to fat, such as protein, starch, thickeners, emulsifiers, and fiber, are used to replace the texture of fat. The type of ingredients used to replace fat are selected based on the type of products that are made and the amount of fat that is reduced, which must be appropriate and balanced [8]. Soy protein helps increase the ability of

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the food to bind to water, improves the mouthfeel, and improves the texure [9].

Maltodextrin, a polysaccharide, is categorized in a group of carbohydrate compounds. It serves as a bulking agent, anticaking agent, or fat replacer in bakery products and ice cream [10]–[12]. In addition, it is also classified as a prebiotic functional food that can be used in health food products. Therefore, soy protein and maltodextrin are suitable to be used as fat replacers in ice cream products [13], [14].

Gac aril contains nutrients that are beneficial to humans. Using gac aril in processed food products contributes to the increased use of agricultural products and leads to commercial development, which is another way to add value to agricultural products. Coconut and gac aril flavored ice cream is an alternative for consumers and is suitable for people of all ages.

Therefore, this research aimed to develop normal formula of coconut and gac aril flavored ice cream based on the highest sensory attributes score in terms of appearance, color, taste (sweetness), smoothness, oiliness, meltdown, and overall acceptability while the lowest melting rates. And to develop reduced fat formula of coconut and gac aril flavored ice cream based on reducing the highest amount of fat while giving the highest acceptance scores, to study the effect of the type and amount of fat replacer on the physical and sensory properties of the reduced fat formula of this ice cream flavor, and to compare the differences in the sensory attributes, melting rates, beta-carotene contents, lycopene contents, and fat contents of the normal and reduced fat formulas of coconut and gac aril flavored ice cream.

2 Materials and Methods

2.1 *Raw materials*

Frozen gac aril from Yardthip orchard, Ubon Ratchathani, Thailand; 100% coconut milk U.H.T.; sugar; guar gum; mono-di glyceride (emulsifier); soy protein; maltodextrin; water; salt; and aromatic coconut scent.

2.2 *Study of the optimal formula for producing normal (regular fat content) coconut and gac aril flavored ice cream*

2.2.1 Preparation of gac aril juice

Frozen gac aril was thawed at room temperature and then mixed with water at a ratio of 1:1. Gac aril was then used in the next step.

2.2.2 Study of the optimal formula for producing coconut and gac aril flavored ice cream

Coconut and gac aril flavored ice cream was made according to the following procedure. First, 150 g of water (calculated from 15% × 1 kg) was poured into a pot and warmed to 40°C; then, the thoroughly mixed mixture of dry ingredients, including guar gum, emulsifier, sugar, and salt, was added to the pot of water. Then, gac aril juice and coconut milk were added according to the specified formulas from Table 1. The mixture was blended thoroughly using a high-speed blender for 3 min and then pasteurized at 80°C for 2 min while stirring at all times. After 2 min, the mixture was immediately cooled to 4°C, incubated at 4°C for 24 h, and then blended using an ice cream maker (HOM-4002, HOMEMATE, Taiwan) for 30–40 min. The ice cream was then scooped into a cup or desired container and kept at –30°C for 24 h. Finally, the physical and sensory quality of the ice cream was determined as described in sections 2.2.3 and 2.2.4.

Table 1: Formulas used for producing 1 kg of coconut mixed with gac aril flavored ice cream

Formula	Gac Aril Juice (%)	Coconut Milk (%)	Sugar (%)
1	25.00	55.00	20.00
2	52.00	37.05	10.95
3	34.50	48.80	16.70
4	34.50	54.55	10.95
5	44.00	42.60	13.40
6	47.00	36.30	16.70
7	60.00	31.50	8.50
8	44.00	42.60	13.40
9	44.00	42.60	13.40
10	25.00	66.50	8.50
11	52.00	36.30	11.70
12	60.00	30.00	10.00
13	50.00	30.00	20.00

Note: The amounts of other ingredients were held constant for all formulas, including water, guar gum, mono-di glyceride, and salt, at 15, 0.20, 0.20, and 0.15% by weight of all the ingredients, respectively.

2.2.3 Melting rate measurement

The melting rate measurement was adapted from Geilman and Schmidt [15]. The weight of the ice cream that melted every 10 min at 31± 1°C was measured for 90 min. The experiment was performed with three replicates per treatment, and the percentage of melted ice cream was found using equation (1).

$$\text{melted ice cream (\%)} = \frac{\text{melted ice cream (g)} \times 100}{\text{original ice cream (g)}} \qquad (1)$$

2.2.4 Determination of sensory attributes

Determination of the sensory attributes of the ice cream was performed by 30 untrained panelists. The samples were served at 15°C after taking the ice cream out of the freezer for 3–5 min. The sensory attributes were determined by the acceptance test. Each ice cream sample was assigned a random 3-digit code and sorted according to a pre-selected order. Samples were determined under white neon light. Before assessing each sample, the panelists washed their mouth with clean water and ate a cracker each time. Then, they tasted and gave an acceptability score according to a 9-point hedonic scale for the appearance, color, odor, taste (sweetness), smoothness, oiliness, meltdown, and overall acceptability. A score of 1 represents the lowest level of acceptability and a score of 9 represents the highest level of acceptability.

2.2.5 Statistical analysis

In the study of the optimal formula of coconut and gac aril flavored ice cream, the Mixture design method was used for the experimental design, and the factors that were studied were amounts of gac aril juice, coconut milk, and sugar. The amounts of the other ingredients were held constant for all formulas, including water, guar gum, mono-di glyceride, and salt at 15, 0.20, 0.20, and 0.15% by weight of all of the ingredients, respectively. Each formula can produce 1 kg of ice cream. The factors that were studied were assessed in triplicate. The physical and sensory qualities of coconut and gac aril flavored ice cream were determined and statistically analyzed using Minitab 16 software based on the highest sensory attributes score and the lowest melting rates to find the optimal formula of the ice cream to be further developed in section 2.3.

2.3 *Study of the effect of the type and amount of fat replacer on the physical and chemical properties and sensory attributes of the reduced fat formula of coconut and gac aril flavored ice cream*

2.3.1 Analysis of the fat content in starting coconut milk

The fat content in the starting coconut milk was analyzed using the Mojonnier method according to the AOAC method [16] and then calculated to determine the fat content in the normal formula of coconut and gac aril flavored ice cream (formula from section 2.2.5).

2.3.2 Production of the reduced fat formula of coconut and gac aril flavored ice cream

The optimal formula from section 2.2.5 was used to produce the reduced fat formula of coconut and gac aril flavored ice cream by calculating the fat content in the starting coconut milk analyzed in section 2.3.1. The reduction of the fat content was performed by reducing the amount of coconut milk and then adding coconut flavor with aroma coconut scent to replace the lost coconut scent at 0.10% for all formulas. The type and amount of fat replacer were varied. The fat replacers used were soy protein (S), maltodextrin (M), and soy protein mixed with maltodextrin in the ratio of 1:1 (S+M) by using water to adjust the volume of the fat replacer mixture to equal the weight of the control formula of coconut milk (formula from section 2.2.5), and the ice cream was produced according to section 2.2.2. The amount of fat replacer used in the production of the reduced fat formula ice cream is provided in Table 2.

Table 2: The amount of fat replacer used in the production of the reduced fat formula of coconut and gac aril flavored ice cream

Formula	Type of Fat Replacer	Amount of Fat Replacer (%)	Formula Code
1	Soy Protein (S)	30	S30
2		50	S50
3		70	S70
4	Maltodextrin (M)	30	M30
5		50	M50
6		70	M70
7	Soy Protein Mixed with Maltodextrin in the Ratio of 1:1 (S+M)	30	(S+M)30
8		50	(S+M)50
9		70	(S+M)70

2.3.3 Determination of physical properties

1) The melting rate was measured as in 2.2.3.

2) The viscosity was measured using the method adapted from Chang *et al*. [17]. A Brookfield digital viscometer was used to measure the viscosity of the liquid ice cream after incubation at room temperature for 24 h using a no. 7 measuring probe at 50 rpm by controlling the temperature of liquid ice cream while measuring at approximately 4°C. Each treatment was performed twice for 3 samples each.

3) Measurement of the overrun was modified from the method by Arbuckle [12] by weighing the ice cream in a container with a constant volume (47 ml). The liquid ice cream was weighed before and after it was blended in the ice cream blender. Each treatment was performed twice for 3 samples each. The data were then calculated for the overrun percentage using equation (2).

$$\text{Overrun percentage} = \frac{\text{Weight of ice cream prior to blending} - \text{weight of ice cream after blending} \times 100}{\text{Weight of ice cream after blending}} \tag{2}$$

4) The hardness of the ice cream was measured when the ice cream was packaged in plastic cups and frozen for 24 h. The hardness was measured using a texture analyzer with a cylindrical probe (no. P/2) at –30±1°C. Each treatment was performed twice for 3 samples each.

5) The color of the products was measured using the Hunter lab color meter when the ice cream was frozen for 24 h. Each treatment was performed twice for 3 samples each.

6) Acidity was measured using a pH meter, and the total soluble solids were measured using the hand refractometer.

2.3.4 Determination of sensory attributes

Sensory attributes were determined as in 2.2.4.

2.3.5 Statistical analysis of data

The experiments were designed according to 2-way ANOVA. The factors studied were the type of fat replacer (soy protein, maltodextrin, and soy protein mixed with maltodextrin in a 1:1 ratio) and amount of fat replacer (30, 50, and 70% of the fat content in ice cream). A completely randomized design was used for the experimental design, and the experiments were performed in duplicate. Data were analyzed using Minitab 16 software to compare the difference between the mean of each treatment by using Tukey's HSD test at a 95% confidence level.

2.3.6 Selection of the type and amount of fat replacers suitable for producing the reduced fat formula of coconut and gac aril flavored ice cream

The type and amount of fat replacers suitable for producing the reduced formula of coconut and gac aril flavored ice cream were selected according to the highest scores of acceptance in terms of sensory attributes, including appearance, color, odor, taste (sweetness), smoothness, oiliness, meltdown, and overall acceptability.

2.4 *Determination of the beta-carotene and lycopene contents*

Thawed gac aril from suitable normal formula ice cream from sections 2.2.5 and 2.3.6 was analyzed for its beta-carotene and lycopene content using a method modified from the method by Nagata and Yamashita [18].

2.5 *Comparison of the sensory attributes, melting rate, beta-carotene content, lycopene content, and fat content of the normal and reduced fat formulas of coconut and gac aril flavored ice cream*

The sensory attributes, including the appearance, color, odor, taste (sweetness), smoothness, oiliness, meltdown, overall acceptability, melting rate, beta-carotene content, lycopene content, and fat content, of the optimal formula of ice cream from sections 2.2.5 and 2.3.6 were determined to compare the difference of each treatment by using the t-test at the 95% confidence level.

3 Results and Discussions

3.1 *Study of the optimal formula for producing coconut and gac aril flavored ice cream*

Table 3 shows that the coefficient of determination (R^2)

of the data from the determination of sensory attributes in terms of appearance, color, odor, taste (sweetness), smoothness, oiliness, meltdown, overall acceptability, and melting rate, in which R^2 is indicative of the relationship of the independent variables (amount of gac aril juice, coconut milk, and sugar) influencing the dependent variables (appearance, color, odor, taste (sweetness), smoothness, oiliness, meltdown, overall acceptability, and melting rate), showing that the sensory attributes in terms of appearance, color, taste (sweetness), smoothness, oiliness, meltdown, overall acceptability, and melting rate had an R^2 between 58–94%, while the sensory attributes in terms of odor had an R^2 less than 50%. Therefore, the coefficient of determination is not suitable to be used for further analysis of the data.

Therefore, when considering R^2, it can be concluded that the variables that are suitable for analysis to find the optimal formula are the sensory attributes in terms of appearance, color, taste (sweetness), smoothness, oiliness, meltdown, overall acceptability, and melting rate.

Table 3: Coefficient of determination of the sensory attributes and melting rate

Prediction Equation	R^2 (%)
Appearance	76.62
Color	73.47
Odor	37.21
Taste (sweetness)	58.37
Smoothness	93.93
Oiliness	73.82
Meltdown	87.21
Overall Acceptability	67.21
Melting Rate	64.92

The data on the sensory attributes in terms of appearance, color, taste (sweetness), smoothness, oiliness, meltdown, overall acceptability, and melting rate were analyzed to find the formula for coconut and gac aril flavored ice cream that is most acceptable to consumers and has the lowest melting rate. The contour plots of these data were overlaid, as shown in Figure 1 (a)–(h), in which the blue area is the area with the highest sensory scores and a suitable low melting

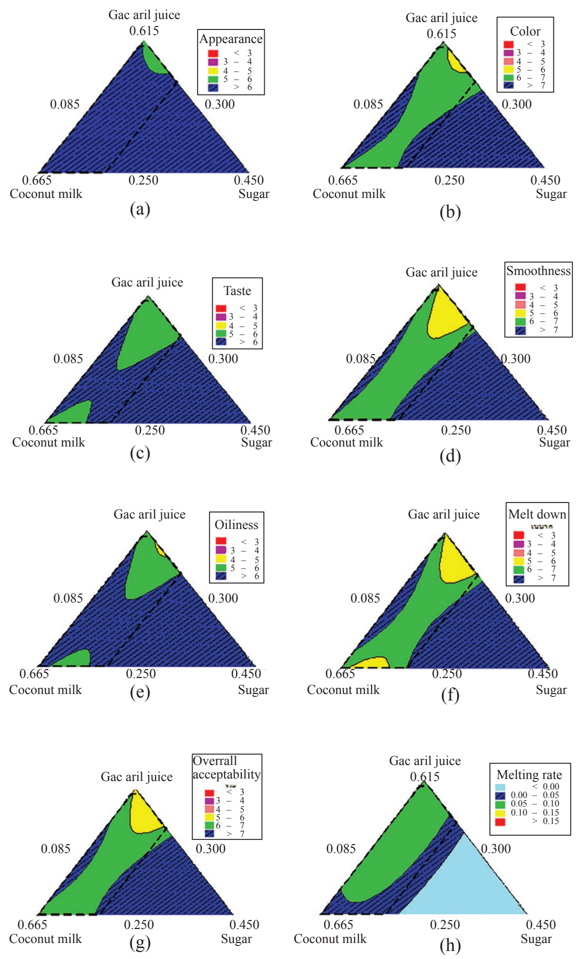

Figure 1: Contour plots of the scores of the sensory attributes in terms of appearance (a), color (b), taste (sweetness), (c) smoothness (d), oiliness (e), meltdown (f), overall acceptability (g), and melting rate (h).

rate. The sensory attribute scores are sequentially lower, and the melting rate is higher in the green, yellow, pink, purple, and red areas. Then, the graphs in Figure 1 (a)–(h) were overlaid to find the area to select the optimal formula, as shown in Figure 2. The optimal areas were chosen by selecting the area with scores higher than 6 for sensory attributes in terms of appearance, taste (sweetness) and oiliness and with scores higher than 7 for sensory attributes in terms of color, smoothness, meltdown, and overall acceptability that also have a melting rate under 0.05% per min as criteria for the optimal formula.

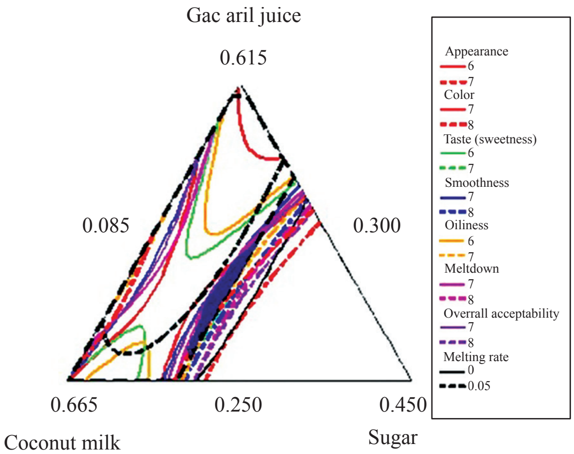

Figure 2: The overlapping area contour plots in which the blue area is the area in which the acceptance scores were higher than 6 in terms of appearance, taste (sweetness), and oiliness and higher than 7 in terms of color, smoothness, meltdown, and overall acceptability and the melt rate of coconut mixed with gac aril flavored ice cream was less than 0.05% per min.

Figure 2 shows the overlapping area (the blue area) in which the scores were higher than 6 in terms of the appearance, taste (sweetness), and oiliness and higher than 7 in terms of color, smoothness, meltdown, and overall acceptability and in which the melt rate of coconut and gac aril flavored ice cream was less than 0.05% per min. The optimal ingredients for producing coconut and gac aril flavored ice cream was 27.20–42.20% gac aril juice, 38–53.30% coconut milk, and 18–20% sugar.

Figure 3 shows the analysis results for the optimal formula for the production of coconut and gac aril flavored ice cream using the Response Optimizer function in Minitab version 16. It was found that the best formula accepted by consumers with the highest scores in terms of appearance, color, taste (sweetness), smoothness, oiliness, meltdown, and overall acceptability and with the lowest melting rate was the formula with a 34.85:45.15:20.00 ratio of gac aril juice:coconut milk:sugar. This formula had predicted scores of 6.97, 7.31, 6.82, 7.61, 7.00, 7.49, and 7.41 for appearance, color, taste (sweetness), smoothness, oiliness, meltdown, and overall acceptability, respectively, and a predicted melting rate of 0.03% per minute.

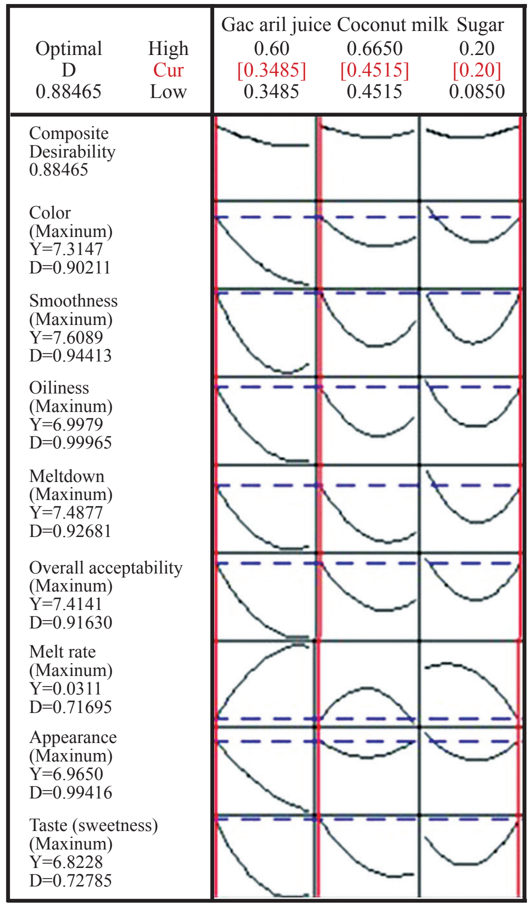

Figure 3: Analysis results of the best ratio of raw materials for the production of coconut and gac aril flavored ice cream (normal formula).

3.2 *Development of the reduced fat formula of coconut and gac aril flavored ice cream*

3.2.1 Fat content analysis of U.H.T. coconut milk used as a raw material

The fat content in the U.H.T. coconut milk used as raw material was approximately 20.40%, which was close to the amount of coconut fat specified on the label on the milk box, 22%. When the fat content in the coconut milk was used to calculate the fat content in the ice cream, it was found that the fat content in the ice cream was approximately 8.50%.

The optimal formula to produce coconut and gac aril flavored ice cream described in section 3.1

was used to study the effect of type (soy protein (S), maltodextrin (M), and soy protein mixed with maltodextrin at a ratio of 1:1 (S+M)) as well as the amount of fat replacer (30, 50, and 70%) on the physical and chemical properties and sensory attributes of the reduced fat formula of coconut mixed and gac aril flavored ice cream; the results are as follows:

3.2.2 Effect of the type and amount of fat replacer on the physical properties of the reduced fat formula of coconut and gac aril flavored ice cream

- Melting rate

The interaction effect between the type and amount of fat replacer did not significantly affect the melting rate of the reduced fat formula of coconut and gac aril flavored ice cream ($p \geq 0.05$), but the type of fat replacer significantly affected the melting rate of the reduced fat formula ($p < 0.05$) (data not shown). Using soy protein and soy protein mixed with maltodextrin as a fat replacer resulted in a significantly lower melting rate than using maltodextrin alone ($p < 0.05$). Because soy protein can absorb a large amount of water and can produce a larger amount of gel than maltodextrin, it increased the viscosity of the ice cream more so than maltodextrin alone and maintained the shape of the ice cream, preventing the ice cream from melting. For the ice cream that used soy protein mixed with maltodextrin, the effect of the soy protein was greater than that of maltodextrin. Therefore, the melting rate of ice cream made with maltodextrin and soy protein was not significantly different from that made using only soy protein ($p \geq 0.05$).

- Viscosity

The interaction effect between the type and amount of fat replacer significantly affected the viscosity of the reduced fat formula of coconut and gac aril flavored ice cream ($p < 0.05$) (data not shown). According to the results, 70% soy protein produced the highest viscosity, and the difference was statistically significant ($p < 0.05$) from all other treatments, as shown in Table 4. Soy protein can absorb a large amount of water and produce a larger amount of gel than maltodextrin, resulting in a higher viscosity than ice cream that was made with maltodextrin alone. When the amount of soy protein was reduced, the viscosity was also reduced.

- Overrun percentage

The interaction between the type and amount of fat replacer significantly affected the overrun of the reduced fat formula of coconut and gac aril flavored ice cream ($p < 0.05$) (data not shown). When comparing ice cream made with 70% maltodextrin to that made with 70% soy protein, ice cream made with 70% maltodextrin had a significantly higher overrun percentage than that made with 70% soy protein ($p < 0.05$) because ice cream made with 70% maltodextrin was less viscous than that made with 70% soy protein, as shown in Table 4. The overrun percentage is related to the viscosity. When the viscosity is high, it is more difficult to add air into ice cream. As a result, the overrun percentage is low. These results are similar to the results reported by Kailasapathy and Songvanich [19], who found that a high viscosity of the ice cream is related to the suitability of air retention and that high overrun is correlated with the foam expansion and foam liquid stability, which will provide a high value as well. The viscosity of the ice cream ingredients must be in a reasonable range to obtain a good overrun value. If the viscosity is too high or too low, it is difficult to push air into the ice cream.

Table 4: The values of viscosity and overrun of fat replacer used in the production of the reduced fat formula of coconut and gac aril flavored ice cream

Formula Code	Viscosity (cP)	Overrun (%)
S30	2459.30 ± 119.70^{bc}	55.75 ± 2.22^{ab}
S50	3725.30 ± 23.10^{b}	37.46 ± 0.31^{cd}
S70	5923.30 ± 1068.20^{a}	28.73 ± 3.85^{d}
M30	2303.20 ± 266.60^{bc}	47.63 ± 5.49^{abc}
M50	2063.00 ± 83.90^{bc}	43.01 ± 0.25^{bcd}
M70	1521.00 ± 450.70^{c}	61.06 ± 9.11^{a}
(S+M)30	2212.00 ± 586.90^{bc}	58.33 ± 1.29^{ab}
(S+M)50	2716.8 ± 498.50^{bc}	47.85 ± 2.42^{abc}
(S+M)70	3145.50 ± 369.40^{bc}	32.23 ± 0.37^{cd}

Note: $^{a–d}$ The difference of the means of data in the same column is statistically significant ($p < 0.05$)

- Hardness

It was found that the interaction between the type and amount of fat replacer did not significantly affect the hardness of the reduced fat formula ice cream ($p \geq 0.05$), but the type and amount of fat replacer significantly affected the hardness of the reduced fat formula of coconut and gac aril flavored ice cream ($p < 0.05$) (data not shown). Considering the type of fat replacer when a content of 30% fat replacer was used, it was found that ice cream using soy protein mixed with maltodextrin or soy protein alone had the highest hardness values (1853.67±0.25 g-force), while ice cream using maltodextrin alone had the lowest hardness value (408.04±176.71 g-force). This result was probably due to the effect of the soy protein, which is more viscous than maltodextrin. As a result, ice cream made using soy protein and soy protein mixed with maltodextrin was harder than ice cream made using maltodextrin. Since soy protein absorbs a large amount of water and forms a gel, it takes more force to impair the shape of ice cream made with soy protein than the control, and the hardness of ice cream made using soy protein is related to the overrun percentage as well. Ice cream with a lower overrun percentage has increased hardness [10], such as in Table 4, in which the use of 70% maltodextrin produced a significantly higher overrun percentage than the use of 70% soy protein ($p < 0.05$). Therefore, the use of maltodextrin produced lower hardness than the use of soy protein and soy protein mixed with maltodextrin.

- Color value

It was found that the interaction between of the type and amount of fat replacer did not significantly affect the L* value of the reduced fat formula of coconut and gac aril flavored ice cream ($p \geq 0.05$), but the type of fat replacer and amount of fat replacer significantly affected the L* value of the reduced fat formula ice cream ($p < 0.05$) (data not shown). The L* value indicates the brightness of the product. Considering the type of fat replacer, it was found that the L* value of the ice cream made using soy protein (57.46 ± 2.53) and soy protein mixed with maltodextrin (56.16 ± 2.14) had significantly higher than ice cream made with maltodextrin (52.76 ± 3.84), probably because coconut and gac aril flavored ice cream had gac aril juice that was red in color and when maltodextrin dissolves in water, the solution is clear and colorless; therefore, the red color of gac aril is very obvious, causing L* or the brightness value to be lower than when using soy protein and soy protein mixed with maltodextrin. However, considering the amount of fat replacer, it was found that when the fat replacer was used at 30% and 50%, the L* value was significantly higher than when the fat replacer was used at 70% ($p < 0.05$) because when the amount of milk, which is white, decreased and was replaced with soy protein, which is yellow, the brightness value decreased. The amount of milk also indicates the fat content because when the fat content increases, the brightness value will increase as well. These findings are similar to the experiments reported by Roland *et al*. [20], in which the color of the ice cream would be more bright white when the fat content increased.

It was found that the interaction between the type and amount of fat replacer and the amount of fat replacer alone did not significantly affect the a* and b* values of the reduced fat formula of ice cream ($p \geq 0.05$), but the influence of the type of fat replacer on the a* and b* values of the reduced fat formula ice cream was significant ($p < 0.05$) (data not shown). The results found that the types of fat replacer with the highest a* and b* values were maltodextrin alone and soy protein mixed with maltodextrin; these types of fat replacers were had significantly higher a* and b* values than when soy protein was used alone ($p < 0.05$). The a* value indicates the redness (positive) - greenness (negative). It could be said that ice cream made using maltodextrin and soy protein mixed with maltodextrin had the highest redness because when maltodextrin dissolves in water, the solution is clear and colorless and it is a fat replacer that can disperse well. Therefore, the red color was obviously from gac aril. Although the amount of coconut milk was reduced, which reduced the cloudy white color of the coconut milk, it did not affect the a* value much. As for ice cream that used soy protein mixed with maltodextrin, maltodextrin was included. It might be that the influence of the maltodextrin was greater than that of the soy protein so that the a* value obtained was not different from using only maltodextrin. Ice cream that used only soy protein had the lowest a* value because of the influence of the yellow color of soy protein, which may cover the red color of gac aril. The b* value indicates the yellowness (positive) - blueness (negative). The ice cream that used maltodextrin and soy protein mixed with maltodextrin had the highest yellowness, probably because when maltodextrin dissolves in water, the solution is clear and colorless so the yellow color of gac aril mixed with coconut milk can be clearly seen. In addition, soy protein is dark yellow, the obtained ice cream was also darker in color, and the value was lower than maltodextrin. Ice cream made with soy protein mixed with maltodextrin had color values that were not different from ice cream made with maltodextrin alone.

It was found that the interaction between the type and amount of fat replacer did not significantly affect the h* value of the reduced fat formula of coconut and gac aril flavored ice cream ($p \geq 0.05$), but the amount of fat replacer significantly affected the h* value of the reduced fat formula ice cream ($p < 0.05$) (data not shown). The h* value of ice cream made with 30% fat replacers (58.51 ± 0.86) and 50% fat replacers (57.86 ± 0.59) had a significantly higher than ice cream made with the 70% fat replacer (56.05 ± 1.61) ($p < 0.05$). The h* value indicates the value of various color tones. The results showed that the h* value was in the range of 45–90 degrees, which was orange red-yellow. That is, if the value is closer to 45 degrees, it indicates that the color is orange red, but if the value is closer to 90 degrees, it indicates that the color is more yellow. It can be said that ice cream made with 30% and 50% fat replacers had less orange-red color than that made with the 70% fat replacer, as the h* value of 30% and 50% fat replacers was further from 45 degrees than that of the 70% fat replacer. This difference in color may be because the ice cream with 30% and 50% fat replacers had more coconut milk than the ice cream made with the 70% fat replacer. Since coconut milk is white, when the amount of coconut milk was high, as in ice cream with 30% and 50% fat replacers, the orange-red color would be less obvious than in ice cream made with the 70% fat replacer.

3.2.3 Effect of the type and amount of fat replacer on Total soluble solids (°Brix) of the reduced fat formula of coconut and gac aril flavored ice cream

The interaction effect between the type and amount of fat replacer did not significantly affect the total soluble solids of the reduced fat formula of coconut and gac aril flavored ice cream ($p \geq 0.05$) (data not shown). The treatment that used 70% maltodextrin, 70% soy protein mixed with maltodextrin, and 70% soy protein had the highest total soluble solids, indicating that the use of fat replacers at 70% would produce a higher amount of total soluble solids than formulas using 30% and 50% fat replacers and that the total soluble solid content would increase as the amount of fat replacer increased. The use of higher amounts of fat replacers made the total soluble solids increase and resulted in a lower water content and thus less water that can be frozen. Therefore, the ice cream was softer. The total solids in ice cream came from ingredients that were water-soluble. Ice cream with a high total solids content would make good ice cream. The total solid content in ice cream increases the viscosity and improves the shape and texture of the ice cream [10].

3.2.4 Effect of the type and amount of fat replacers on the sensory attributes of the reduced fat formula of coconut and gac aril flavored ice cream

- Appearance attribute

The interaction effect between the type and amount of fat replacer significantly affected the appearance attribute of the reduced fat formula of coconut and gac aril flavored ice cream ($p < 0.05$) (data not shown). Ice cream made with 70% maltodextrin was significantly different from all other formulas of ice cream ($p < 0.05$). Ice cream made with 70% maltodextrin had the lowest score because using 70% maltodextrin resulted in a much lower fat content in ice cream, so there was less fat to produce net structures around air [21]. In addition, replacing fat with maltodextrin did not produce a sufficient viscosity to maintain air cells, so more small air cells combined to form larger air cells. As a result, more water molecules combined to form large ice crystals [21], which may give the appearance of ice crystals in ice cream and a lower consumer acceptance.

- Color, oiliness, meltdown, attributes and overall acceptability

The interaction effect between the type and amount of fat replacer did not significantly affect the sensory attributes in terms of color, oiliness, meltdown, and overall acceptability the reduced fat formula of coconut and gac aril flavored ice cream ($p \geq 0.05$), but the amount of fat replacer significantly affected the color attribute ($p < 0.05$) (data not shown). At 30% and 50% fat replacer contents, the sensory attributes in terms of color scores were highest, while at 70%, the sensory attributes in terms of color scores were minimal (Figure 4). This effect was because in ice cream made with 30% and 50% fat replacers, the amount of coconut milk was higher than in those made with 70% fat replacers. When cloudy white coconut milk

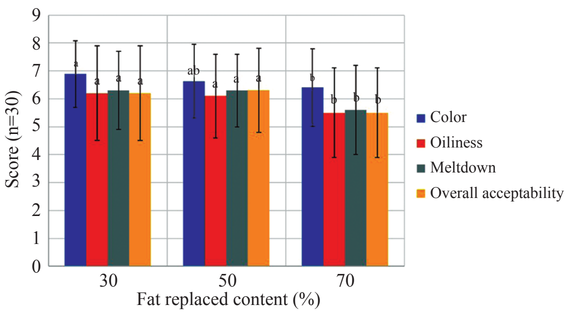

Figure 4: Overall acceptability and attribute rating for the reduced fat formula of coconut and gac aril flavored ice cream with fat replaced at 30, 50, and 70%.

mixed with dark red gac aril, the ice cream became orange. As the amount of coconut milk increased, the color became lighter. This showed that consumers prefer ice cream with soft colors over ice cream with dark colors.

At 30% and 50% fat replacers, the oiliness attribute were significantly higher than at 70% fat replacer ($p < 0.05$), as shown in Figure 4. When the amount of coconut milk was reduced, the fat content was also reduced, and the fat content indicates the oiliness in the ice cream. Therefore, at 30% and 50% fat replacers, the fat contents were higher, meaning that the oiliness was higher than at 70% fat replacer, and consumers may prefer ice cream at 30% and 50% fat replacers in terms of oiliness.

For the sensory attribute in term of meltdown, at 30% and 50% fat replacers, the fat contents were higher than at 70% fat replacer, as shown in Figure 4. Fat will make net structures around air cells, so the movement of the small air cells to combine and form larger air cells decreases. As a result, fewer water molecules move together to form large ice crystals, and the shape of the ice cream can be maintained, so it melts slowly [21]. Therefore, the meltdown also slows down. This shows that at 30% and 50% reduction of fat and replacement with fat replacers, meltdown is more preferable to consumers than when the fat is replaced at 70%. A too slow meltdown could be a drawback of ice cream as well [10]. Nevertheless, reducing the fat in the formula and then replacing it with fat replacer did not produce much difference in meltdown of the ice cream, as described in the experiments by Ohmes *et al*. [22]; they found that the panelists could not tell the difference in the meltdown of the control formula ice cream from the formula that used Simpless as a fat replacer even though the melting rate at 25°C of the control formula was lower.

As for the overall acceptability, it was found that at 50% and 30% fat replacers, the overall acceptability scores of the ice cream were significantly higher than at 70% ($p < 0.05$), as shown in Figure 4. At 50% and 30% fat replacers, the amount of coconut milk in the ice cream was higher than at 70% fat replacer and therefore had more of the characteristics of coconut milk that the consumers want, such as odor, oiliness, smoothness, etc. Therefore, consumers gave the highest overall acceptability ratings to ice cream with 30% and 50% fat replacers.

- Odor and taste (sweetness) attributes

It was found that the interaction effect between the type and amount of fat replacers and effects of the type of fat replacer and amount of fat replacer alone did not significantly affect the taster attribute in terms of the odor and taste (sweetness) of the reduced fat formula ice cream ($p \geq 0.05$) (data not shown). This lack of effect on odor and taste could be due to the addition of coconut aroma to replace the lost coconut milk odor. Therefore, consumers cannot distinguish the odor of the ice cream with and without fat replacers. Leland [23] said that fat was the carrier of odors and flavors or the solvent for hydrophobic odors and flavors. Most odors and flavors are hydrophobic. Therefore, fat plays an important role in releasing odors and flavors. In general, the release of hydrophobic odors and flavors is slow, and the maximum concentration of these compounds is received more slowly than hydrophilic odors and flavors, and the odors and flavors change over time [24]. For taste (sweetness) attribute, each treatment of ice cream used the same amount of sugar, so the taste (sweetness) attribute of consumers was not different between formulas of ice cream.

- Smoothness attribute

It was found that the interaction effect between the type and amount of fat replacer and the main effect of the type of fat replacer and amount of fat replacer significantly affected the smoothness attribute of the reduced fat formula of coconut mixed with gac aril ice cream ($p < 0.05$) (data not shown). The results showed that ice cream with 70% maltodextrin had the lowest score. This could be because the substitution with 70% maltodextrin caused the fat content in the ice cream to be very low so it lacked fat that would make net structures surrounding air cells [21]. In addition, the use of maltodextrin did not produce sufficient viscosity to maintain the amount of air cells and, therefore, there were movements of small air cells that combined and become larger air cells, allowing water molecules to move and combine to become large ice crystals [21], decreasing the smoothness of the ice cream. Therefore, the smoothness attribute of the consumer decreased. It was observed that the score of the smoothness attribute of the ice cream was related to the score of the appearance attribute of the ice cream.

3.2.5 Selection of the suitable type and amount of fat replacer for the production of the reduced fat formula of coconut and gac aril flavored ice cream

From the physical and chemical properties and sensory attributes of the reduced fat formula of coconut and gac aril flavored ice cream, the suitable type and amount of fat replacer for producing reduced fat formula ice cream can be selected from the highest scores of the sensory attributes in terms of appearance, color, smoothness, oiliness, meltdown, and overall acceptability. The sensory attributes in terms of odor and taste (sweetness) was not be considered because the scores that were obtained were not significantly different ($p \geq 0.05$). The results showed that the amounts of fat replacer that gave the highest scores of sensory attributes in terms of appearance, color, smoothness, oiliness, meltdown, and overall acceptability, as shown in Table 6, were 30% and 50% fat replacer. The 50% fat replacer was selected because it was the formula that could reduce the highest amount of fat while giving the highest acceptance scores. For the type of fat replacer, it was found that all of the sensory attribute scores were not significantly different ($p \geq 0.05$). Therefore, the physical properties, melting rate, and overrun percentage were used to determine the optimal formula as well. It was found that the type of fat replacer that had the lowest melting rate was soy protein and soy protein mixed with maltodextrin. When the overrun was considered, it was found that using soy protein mixed with maltodextrin at 50% had a higher overrun percentage than using 50% soy protein, which produces a higher volume of ice cream from the same weight of raw materials. Therefore, the type and amount of fat replacer suitable for producing the reduced fat formula of coconut and gac aril flavored ice cream was soy protein mixed with maltodextrin at 50% fat replacement.

3.3 *Determination of the beta-carotene and lycopene contents*

The beta-carotene and lycopene contents of the gac aril and normal and reduced fat formulas of coconut and gac aril flavored ice cream were analyzed, and the results are shown in Table 5.

Table 5: Analysis results of the beta-carotene and lycopene contents in the normal and reduced fat formula of coconut and gac aril flavored ice cream

Samples	Beta-carotene Content (mg/100 g fw)	Lycopene Content (mg/100 g fw)
Fresh Gac Aril	0.40±0.01[a]	0.52±0.01[a]
Normal Formula of Coconut Mixed with Gac Aril Flavored Ice Cream	0.12±0.02[b]	0.19±0.03[b]
Reduced Fat Formula of Coconut Mixed with Gac Aril Flavored Ice Cream	0.11±0.02[b]	0.19±0.02[b]

Note: [a,b] The difference of the means of data in the same column is statistically significant ($p < 0.05$)

3.4 *Comparison of the differences of the sensory attributes, including the melting rate, beta-carotene content, lycopene content, and fat content of the normal and reduced fat formulas, of coconut and gac aril flavored ice cream*

From Table 6, the scores of the sensory attributes in terms of the appearance, color, odor, taste (sweetness), smoothness, oiliness, meltdown, overall acceptability, melting rate, beta-carotene content, and lycopene content of the normal formula of coconut and gac aril flavored ice cream were not significantly different from the reduced fat formula ice cream. These results showed that consumers cannot distinguish the differences of the normal and reduced fat formulas of coconut and gac aril flavored ice cream. For the melting rate, the reduced fat formula ice cream had a significantly lower melting rate than the normal formula ice cream ($p < 0.05$) because the reduced fat formula ice cream had both soy protein and maltodextrin as an ingredient, and these two compounds can absorb water and help increase viscosity, slowing down the melting rate of ice cream. The fat content of the reduced fat formula of coconut and gac aril flavored ice cream was significantly lower than that of the normal formula ice cream ($p < 0.05$).

Table 6: Comparison of the differences of the sensory attributes, including the melting rate, beta-carotene content, lycopene content and fat content of the normal and reduced fat formulas, of coconut and gac aril flavored ice cream

Attributes	Formula	
	Normal Formula of Coconut Mixed with Gac Aril ice Flavored Cream	**Reduced Fat Formula of Coconut Mixed with Gac Aril Ice Flavored Cream***
Appearance^{ns}	6.63 ± 1.30	6.23 ± 1.19
Color^{ns}	6.83 ± 1.26	6.47 ± 1.14
Odor^{ns}	6.33 ± 1.58	6.23 ± 1.22
Taste (sweetness)^{ns}	6.63 ± 1.54	6.33 ± 1.56
Smoothness^{ns}	6.57 ± 1.57	6.47 ± 1.53
Oiliness^{ns}	6.67 ± 1.49	6.23 ± 1.61
Meltdown^{ns}	6.87 ± 1.28	6.57 ± 1.38
Overall Acceptance^{ns}	7.00 ± 1.68	6.53 ± 1.43
Melting Rate (%/min)	0.70 ± 0.09^{a}	0.18 ± 0.01^{b}
Beta-carotene Content ^{ns} (mg/100 g fw)	0.12 ± 0.02	0.11 ± 0.02
Lycopene Content^{ns} (mg/100 g fw)	0.19 ± 0.03	0.19 ± 0.02
Fat Content (%)	8.52 ± 0.01^{a}	4.26 ± 0.01^{b}

Note: ^{a,b} The difference of the means of data in the same row is statistically significant ($p < 0.05$)

^{ns} The difference of the means of data in the same row is statistically insignificant ($p \geq 0.05$)

*The reduced fat formula ice cream made with 50% soy protein mixed with maltodextrin in a ratio of 1:1.

4 Conclusions

4.1 The suitable formula for the production of coconut mixed with gac aril ice cream that gave the highest scores of sensory attributes was 34.85% gac aril juice, 45.15% coconut milk, and 20% sugar for the main ingredients, with constant amounts of minor ingredients, including water, guar gum, mono-di glyceride (emulsifier), and salt at 15, 0.20, 0.20, and 0.15% by weight of the ingredients, respectively.

4.2 The type and amount of fat replacer suitable for producing the reduced fat formula of coconut and gac aril flavored ice cream were soy protein mixed with maltodextrin at 50%.

4.3 The reduced fat formula of coconut and gac aril flavored ice cream did not have significantly different scores of sensory attributes in terms of appearance, color, odor, taste (sweetness), smoothness, oiliness, meltdown, overall acceptability, beta-carotene content, and lycopene content ($p \geq 0.05$) from the normal formula of coconut and gac aril flavored ice cream, but it had a significantly different melting rate and fat content from the normal formula of coconut and gac aril flavored ice cream ($p < 0.05$). Therefore, the use of soy protein mixed with maltodextrin as a fat replacer at 50% was suitable for the production of the reduced fat formula of coconut and gac aril flavored ice cream (average overall acceptance was 6.53±1.43 points corresponding to hedonic scale "liked slightly to moderately").

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