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Development of Purple Sweet Potato-Based Ice Cream Product

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ABSTRACT

The popularity of ice cream is increasing in tropical countries such as in Thailand. Purple sweet has high anthocyanin content which provides an attractive purple appearance for ice cream consumption. The purposes of this study were to determine the effects of the ratio of purple sweet potato mash and water, and concentration of carboxymethyl cellulose (CMC) as a stabilizer on the properties of ice cream. The different ratios of purple sweet potato mash and water at 40:60, 50:50, and 60:40 were investigated. The results showed that the ratios of purple sweet potato mash and water had a significant effect ($p \leq 0.05$) on physical properties. The overrun, a^* and b^* values, and melting rate decreased with an increase in purple sweet potato mash. There was a significant ($p \leq 0.05$) difference in sensory characteristics scores of appearance, taste, texture, and overall acceptance. The scores decreased with an increase in purple sweet potato mash. Therefore, the selected ratio was 40:60 between purple sweet potato mash and water. In another study, the concentration of CMC at 0.2, 0.3, and 0.4% of total ingredients on the properties of ice cream was observed. The results demonstrated that overrun and melting rates decreased with an increase in CMC. In addition, an increase in CMC showed significantly ($p \leq 0.05$) superior taste and texture scores. Therefore, the selected condition for product development of purple sweet potato-based ice cream was the ratio of purple sweet potato mash and water at 40:60 and 0.4%CMC.

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1. Introduction

Sweet potatoes are starchy tubers that have nutritionally beneficial components such as carbohydrates, fiber, minerals, vitamins, and phytochemical compounds [1]. They present an intense purple color due to their anthocyanin contents as cyaniding-based and peonidin-based [1]. These components provide various biological properties; they have an antioxidant property [1] that can reduce inflammation; they help prevent blood vessels lower cholesterol; they reduce the risk of cancer, heart disease and stroke [3]. Purple sweet potato anthocyanins can be used as a natural food edible colorant [1]. The anthocyanin content in purple sweet potatoes was more stable than anthocyanin of other fruits and vegetables [2]. Therefore, in recent years, purple sweet potatoes have gained attention in several areas of Thailand due to their benefits. Several previous studies have focused on the utilization of purple sweet potato for flour and its application such as in snacks [1] and the replacement of wheat flour in crackers [4]. The utilization of purple sweet potato could be increased by developing a product that is suitable for consumption. Ice cream is one of the most favorite dairy products in the world [5] but the ice cream available commercially generally lacks natural colors and polyphenols [5]. Thus, it is of interest to explore the possibility of improving the nutritional attributes of ice cream by using natural colorants as ingredients with health benefits.

Ice cream is a frozen product as a combination of milk, sugar, and other additives such as flavorings, stabilizers, emulsifiers and coloring ingredients [2, 3]. The components in the production of ice cream are solids from both fat and non-fat [2]. The fat globules, ice crystals, and air cells are the three main structural components of ice cream. This complex colloid is frozen below its freezing point thus it is smooth and creamy [6].

Stabilizers are generally referred to as a group of chemicals that act as fillers, holders, binders, and hydrocolloids. The main purpose of applying stabilizers in the ice cream production is to prevent the formation of ice and lactose crystal during storage (or mask the impacts of crystal growth), form a smooth body, especially during periods of temperature fluctuation, known as heat shock, and to provide uniformity to the ice cream and resistance to melting [7, 9]. These advantageous results are also contributed by milk proteins. Generally, stabilizers lead to increase the viscosity of the serum phase and influence lower overrun (OR) but provide higher resistance of the product to drainage [7]. The increase in the water solute concentration offers a decrease in the freezing point and an increase in the melting rate. Therefore, the samples that are high in solids and fat melt faster than the samples that are low in fat and solids [7]. Some previous studies have used some hydrocolloids such as carboxymethyl cellulose (CMC), xanthan gum, and carrageenan [7, 8, 9]. The results indicated that soy milk ice cream showed the highest overrun and less melting rate [8]. In addition, CMC increased the viscosity of ice cream mix and limited the growth rate of ice crystal during recrystallization compare to guar gum [7] and the use of 0.5%CMC provided the soft texture in lemongrass extract ice cream with high preference mouthfeel score [9]. Thus, the concentration of CMC on the qualities of ice cream was investigated in this recent study.

This present study was to develop purple sweet potato ice cream by studying the effect of the ratio of purple sweet potato to water and CMC on the quality of ice cream to increase the choice of products due to the consumption of ice cream in Thailand has gained attention continuously because of the hot weather in Thailand.

2. Material and method

2.1 Materials

Purple sweet potato (*Ipomea batatas* L.) was obtained from the domestic market located in Rongkwang District, Phrae province, Thailand. Pasteurized plain milk (Meiji Co., Ltd.), refined sugar (Thai Roongrueng Co., Ltd.), honey (Doi Kham Food Products Co., Ltd.), Salt (Thai Refined Salt Co., Ltd.), Whipping cream (Shinerood brand, Siam Bakeryland Co., Ltd.) and fresh egg yolk were used in this study, sodium carboxymethyl cellulose (CMC) was acquired from Union Science Co., Ltd., Chiangmai, Thailand.

2.2 Experimental Design

A completely randomized design (CRD) was conducted to evaluate the effects of the ratio of purple sweet potato mash and water at 40:60, 50:50, and 60:40 on the properties of ice cream. The selected ratio from first study (40:60 of purple sweet potato mash and water) was used for further study of the effect of the concentration of CMC as a stabilizer. The concentration of CMC at 0.2, 0.3 and 0.4% of total ingredients was observed. Data of physical properties were collected to Analysis of Variance (ANOVA) using SPSS for Window version 24. Duncan's Multiple Range Test (DMR) at the 95% confidence level ($p \leq 0.05$) was used in comparing mean differences.

2.3 Making Ice Cream

The basic purple sweet ice cream formulation was chosen according to our preliminary experiment. The ice cream ingredients are shown in Table I.

For the second study of the effect of CMC, three different levels of CMC at 0.2, 0.3 and 0.4% were performed.

Table 1. *Formulations of Ice Cream*

Ingredients (%)	Ratios of purple sweet potato mash and water		
	40:60	**50:50**	**60:40**
Potato mash	7.43	9.285	11.14
Water	11.14	9.285	7.43
Pasteurized plain milk	46.43	46.43	46.43
Whipping cream	23.21	23.21	23.21
Sugar	9.29	9.29	9.29
Egg yolk	2.41	2.41	2.41
Salt	0.09	0.09	0.09
Total	100.00	100.00	100.00
CMC (% of total ingredients)	0.20	0.20	0.20

The ice cream was manufactured using the following steps according to [2] with slight modification; fresh purple sweet potatoes were washed thoroughly with tap water, steamed for 15 minutes. The cooked potatoes were then peeled and mixed with water (the ratio based on treatment). The mixture of potatoes and water was crushed by blending until smooth and homogeneous and allowed to cool. All ingredients were mixed and homogenized using a blender (Philips, Model HR2061, Indonesia) for 5 minutes. The homogenized dough was pasteurized at 65°C for 5 minutes and then allowed to cool. The homogenized ice cream dough was placed in the refrigerator for 4 hours. The aged ice cream dough was then frozen for 20 minutes with an ice cream maker (Nemox, Model Gelatissimo Exclusive, Italy). The next step was packaging and hardening in the freezer at -18 to -20˚C for 24 hours.

2.4 Method of Analysis

Overrun: The volumes of mix and ice cream were weighed. The overrun was the measure of how much it was reduced and expressed in percent [5], as in:

$$\text{Overrun (\%)} = \{(\text{weight of ice cream mix}) - (\text{weight of ice cream})\} * 100 * (\text{weight of ice cream})^{-1} \quad (1)$$

Color: The ice cream was analysed using a colorimeter (HunterLab, Model ColorFlex EZ, USA). Results were presented in L* a* and b* values (CIELAB).

Melting rate: The sweet potato ice cream samples were kept at -18 °C overnight. The samples were then put on a stainless-steel sieve (No.25) at room temperature. At regular time intervals of 10 minutes, the weight of the melted sample was recorded. The graph of the percentage of the melted ice cream versus time was plotted, the slope of the linear part of the graph demonstrating the melting rate (%/min) [10].

Sensory evaluation: Sensory characteristics were evaluated by 30 untrained panelists who are program members of Food Technology, Maejo University-Phrae Campus, Thailand. The level of preference for purple sweet potato ice cream was scored by a 9-points hedonic scale test. All panelists were advised before initiating the evaluation. The 30 panelists obtained samples and were requested to rate them based on degree of liking on a 9-point hedonic scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, and 9=like extremely) to evaluate the product characteristics including appearance, color, flavor, taste, texture, and overall acceptance. Panelists scored the samples in an individual evaluating area and were informed to rinse their mouths with water between samples to remove any residual effect [11]. The randomized complete block design (RCBD) was used for sensory evaluation due to untrained panelists. The analysis of variance, and comparing the difference between the average by Duncan's New Multiple Range Test method at the 95% confidence level was performed.

3. Results and Discussion

3.1 The effect of the ratio of purple sweet potato mash and water on the properties of ice cream

The properties of the purple sweet potato ice cream were measured. The parameters investigated for evaluation include overrun, the color value of lightness (L*) redness (a*) and yellowness (b) shown in Table II, melting rate as Fig. 1. And sensory characteristics in Table III.

Table 2. *The Effects of The Ratio of Purple Sweet Potato Mash and Water on Overrun and Color of Ice Cream*

Properties	Ratios of purple sweet potato mash and water		
	40:60	**50:50**	**60:40**
Overrun (%)	30.13±0.06^{c}	29.19±0.03^{a}	29.75±0.08^{b}
L*^{ns}	67.06±0.38	68.24±1.12	67.21±0.17
a*	7.17±0.10^{c}	6.65±0.18^{a}	6.95±0.29^{b}
b*	5.27±0.10^{c}	3.60±0.19^{b}	1.43±0.32^{a}

Mean ± standard deviation values followed by a different letter within the same row are significantly different ($p \leq 0.05$) by Duncan's multiple range test

ns not significant ($p > 0.05$) different within the same row by Duncan's multiple range test

From Table II, ANOVA shows significantly different physical properties of overrun, redness (a*) and yellowness (b*). The overrun of ice cream was found to decrease with increasing purple sweet potato mash. However, the results found in this study contrast with the previous study. [2] who found that the more the amount of purple sweet potato mash, the higher the overrun and report that at this point, the water in the ice cream mixture bound with amylose and amylopectin of purple sweet potato in gelatinization mechanism that causes the water absorbed in the starch granule (gelatinization process). The starch content in a purple sweet potato consists of 30-40% amylose and 60-70% amylopectin and high levels of fiber, which is 4.72% [12]. This present study could be related to the potato as a source of carbohydrate which may provide higher viscosity of ice cream mix. If the viscosity of the mix is high, less air enters the ice cream during the manufacturing process [13]. However, these results contrast with the result found by [2] which showed the increase of overrun with an increase in sweet potato mash. The results demonstrated that redness (a*) and yellowness (b*) of ice cream decrease with an increase in the amount of purple sweet potato mash due to its color. The purple sweet potato is found in anthocyanin substances; it can reduce inflammation due to its antioxidant properties [3] so it could be used as a natural colorant in food products. In general, the overrun of ice cream produced on an industrial scale ranged from 70 to 80%, while the one on the household scale ranged from 30 to 50% [2]. Therefore, this study was still comparable based on the home industry scale. The ice cream with a low overrun produced a super hard ice cream texture, and otherwise, if the overrun was too high, the texture of the ice cream could be too soft and melted rapidly [2]. The melting rate of ice cream shows in Fig. 1.

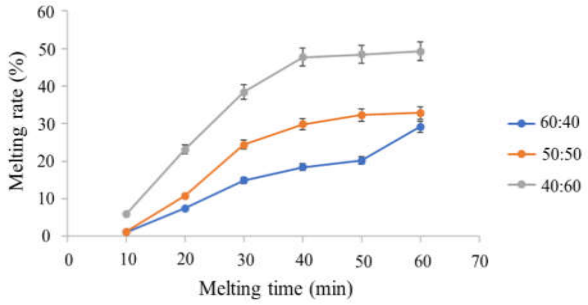

Fig. 1. *The Effect of ratios of purple sweet potato mash and water on melting rate of ice cream*

As can be seen in Fig 1, the melting rate of ice cream is lower with a higher amount of purple sweet potato due to a lower in overrun indicating a harder texture. Overrun affects the texture and density of ice cream. The presence of air in the ice cream forms air cavities released with melting ice cream immediately [2]. Therefore, this can be concluded that high overrun causes more air cavities affecting the ice cream to melt quickly [2]. This result is in agreement with [5]. Sensory characteristics were tested to evaluate acceptance by the untrained panelists as shown in Table III.

Table 3. *Effect of Ratios of Purple Sweet Potatoes and Water on Sensory Characteristics of Ice Cream*

Attributes	Ratio of purple sweet potato mash and water		
	40:60	**50:50**	**60:40**
Color^{ns}	6.63±1.12	6.36±1.42	6.63±1.06
Appearance	6.76±1.22^{b}	6.43±1.10^{a}	6.43±1.43^{a}
Flavor^{ns}	6.20±1.32	5.70±1.36	6.03±1.56
Taste	7.00±1.48^{b}	6.00±1.55^{a}	6.76±1.88^{b}
Texture	7.30±1.11^{b}	6.50±1.45^{a}	6.50±1.54^{a}
Overall acceptance	7.23±1.27^{b}	6.60±1.49^{a}	6.90±1.56^{ab}

Mean ± standard deviation values followed by a different letter within the same row are significantly different ($p \leq 0.05$) by Duncan's multiple range test
ns not significant ($p > 0.05$) different within the same row by Duncan's multiple range test

Table III demonstrates that there was a significant ($p \leq 0.05$) difference in score of appearance, taste, texture and overall acceptance affected by the ratio of purple sweet potatoes and water. An increase in purple sweet potato mash tends to decrease sensory scores. However, there was no significant ($p > 0.05$) difference between the ratio of 50:50 and 60:40. This may be due to the higher potato mash offering the lower overrun as shown in Table II which less air cavity in ice cream then provided harder texture meanwhile panelists prefer softer ice cream. In addition, it can be seen that flavor attributes obtained the lowest score compared to other attributes. The panelists informed that the incorporation of purple sweet potato was inferior to the flavor of ice cream. Therefore, the selected ratio for the next step was 40:60 between purple sweet potato mash and water.

3.2 The effect of carboxymethy cellulose (CMC) on property of ice cream.

Carboxymethyl cellulose (CMC) was used as a stabilizer for ice cream products. The effect of CMC on overrun and color of ice cream is shown in table IV.

Table 4. *The Effect of CMC Concentration on Overrun and Color of Purple Sweet Ice Cream*

Properties	Concentration of CMC (%)		
	0.2	**0.3**	**0.4**
Overrun (%)	32.24±0.06^{c}	31.11±0.07^{b}	29.22±0.08^{a}
L*^{ns}	67.06±1.38	65.37±1.17	66.09±0.09
a*	7.17±0.10^{c}	4.08±0.20^{b}	3.32±0.07^{a}
b*	5.27±0.10^{c}	4.60±0.07^{b}	3.43±0.32^{a}

Mean ± standard deviation values followed by a different letter within the same row are significantly different ($p \leq 0.05$) by Duncan's multiple range test

ns not significant ($p>0.05$) different within the same row by Duncan's multiple range test

Results in Table IV reveal that CMC had a significant ($p\leq 0.05$) impact on overrun, redness (a^*) and yellowness (b^*) of ice cream. The overrun, redness (a^*) and yellowness (b^*) decreased with an increased CMC. The decrease in overrunning could be related to CMC which acts as a stabilizer and increases the viscosity of the serum phase leading to lower overrun [7]. This result presents a similar trend to [14] who demonstrated that the higher gelatin as a stabilizer would provide lower overrun. The more stabilizers were added it will thicken the mixture of ice cream by forming the matrix gel and holding the dispersion of the liquid part. The decrease of redness and yellowness may be due to lower in overrun which less air trapped then led samples intense in color. The results agree with previous study of [7].

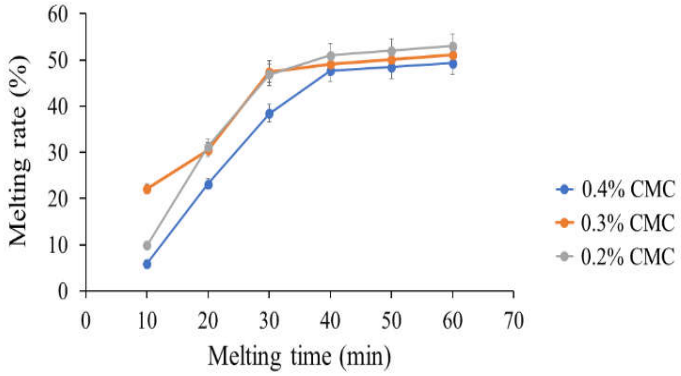

Fig. 2. *The Effect of CMC concentration on melting rate of purple sweet ice cream*

Fig. 2. presents the melting rate of ice cream. The results show the decrease in melting rate with an increase of CMC due to it increasing the viscosity of the serum phase leading to lower overrun but offering greater resistance of the product to drainage [7]. The purple sweet potatoes contain starch of approximately 18% [15] which is attributed to the gelling property by improved binding with water molecules and forming particle gel network to provide the firmness the melting rate tends to decrease. Stabilizers prevent ice cream melting because their water holding ability and micro-viscosity enhancement [16]. The effect of CMC on sensory characteristics of ice cream was presented in Table V. The parameters used as the assessment benchmarks include color, appearance, flavor, taste, texture, and overall acceptance of the product.

Table 5. *The Effect of CMC Contration on Sensory Characteristics of Purple Sweet Ice Cream*

Attributes	**Concentration of CMC (%)**		
	0.2	**0.3**	**0.4**
Color^{ns}	6.13±1.22	6.13±1.33	6.16±1.26
Appearance^{ns}	6.33±1.09	6.10±1.29	6.10±1.15
Flavor^{ns}	5.83±1.31	5.96±1.21	5.86±1.50
Taste^{ns}	6.30±0.34	6.57±1.15	6.83±1.17
Texture^{ns}	6.63±0.99	6.77±1.23	6.87±1.34
Overall acceptance^{ns}	6.46±0.86	6.53±0.97	6.63±1.16

Mean ± standard deviation values followed by a different letter within the same row are significantly different ($p\leq 0.05$) by Duncan's multiple range test

ns not significant ($p>0.05$) different within the same row by Duncan's multiple range test

Table V shows the score for the acceptance level of ice cream. The results obtained showed that there were no significant differences ($p>0.05$) between each CMC for all characteristics. However, sensory evaluation was conducted within 10 min therefore the shape of the ice cream has not been lost yet. When ice cream is exposed to the warm environment, heat transfer occurs. The penetration of heat starts from the external surface of the ice cream and the ice starts to melt and ice cream will lose its shape. Therefore, to maintain the quality of ice cream, 0.4% CMC was selected for ice cream production. Although the increase in CMC provided a positive impact on the quality of ice cream only a small amount of CMC is preferred to be utilized to achieve its functionality to ice cream body and condition. 0.5% w/w is the highest amount of stabilizer in ice cream [15].

4. Conclusions

The results from this study indicate that the ratio of potato mash and water had a significant effect on overrun, redness (a^*) and yellowness (b^*). The overrun, redness and yellowness of purple sweet ice cream decreased with increased potato mash. In addition, increased potato mash provided a lower melting rate which is related to the firmness of ice cream. The sensory characteristics are affected by the increase of potato mash. The score for taste, texture and overall acceptance decreased by the increase in potato mash. The study of CMC affecting ice cream found that the increase of CMC presented the same trend with potato mash. Increasing CMC offers lower overrun, redness and yellowness but can prevent ice cream from loss of shape so the melting rate slows down. However, there was no impact on sensory characteristics. Therefore, the optimum ratio for the production of ice cream was purple sweet potato mash and water at 40:60 and CMC at 0.4%. The present findings can be used for the development of purple sweet potato-based ice cream to be an alternative utilization of purple sweet potato tubers.

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