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Use of Modified Starch as Fat Replacer in Reduced Fat Coconut Milk Ice Cream

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ABSTRACT

Coconut milk has been added as an ingredient in various Thai food and dessert since ancient times. Coconut ice cream is one of the most popular dessert in Thailand. But nowadays consumers are health conscious and avoid high fat products. So reduced fat coconut ice cream would meet their needs. In this study, the amount of coconut milk fat was reduced to different levels (1-8%) and a carbohydrate-based fat replacer (α-Starch or MT-01) was then added to replace the fat. Samples were kept at –28°C and tested for viscosity, overrun, deforming force, melting rate, pH and sensory evaluation. The results showed that reducing fat level and increasing fat replacer tended to increase the viscosity, overrun and deforming force of ice cream but had no significant effect on the melting rate and pH. When emulsifiers were then added to improve the samples' quality, sensory evaluations revealed that the ice cream with 1% fat and 0.1% mono- and diglycerides was the most acceptable and had the lowest cost.

Key words: modified starch, fat replacer, reduced fat coconut milk ice cream, ice cream

INTRODUCTION

An ice cream is a frozen mixture composed of milk, sweetener, stabilizer, emulsifier and flavoring. The ingredients : egg products, colorings, and starch hydrolysates may be added. The mixture is pasteurized and homogenized before freezing. Freezing involves a rapid removal of heat while agitating vigorously to incorporate air, thus imparting the desirable smoothness and softness to the frozen product (Marshall and Arbuckle, 1996).

Coconut milk ice cream is one of the most popular frozen dessert especially in tropical countries. Coconut milk is a major ingredient and contains about 32.2% fat (Popper *et al.*, 1966). The major fatty acids found in coconut fat are lauric acid (12-C) and myristic acid (14-C) at 47.1 and 18.5%, respectively (Kritchevsky, 1993). The important health effect of these fatty acids is an increment of blood cholesterol levels (Bonanome and Grundy, 1988) which may cause several diseases, such as coronary heart disease, artherosclerosis and high blood pressure. At present, health-conscious consumers try to improve nutritional habits without sacrificing psychological satisfaction. Reduced fat coconut milk ice cream can meet one of these consumer needs. Because fat is the main carrier of flavor compound, low fat ice cream's flavor quality and also other sensory quality are lower when fat is reduced (Plug and Haring, 1993). Thus reduced fat products are not well accepted by consumers.

One way to solve this health problem is by using a fat replacer and flavor intensity may be overcome by addition of more flavoring agent. Fat

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replacers can be classified into 3 groups; fat-, protein-, and carbohydrate-based fat replacers. Tharp and Gottemoller (1990) indicated that maltodextrin was a moderately functional fat substitute in light frozen desserts, but they did not report any sensory effects. Schmidt *et al.* (1993) compared rheological, freezing and melting properties of ice milks prepared with a carbohydrate- and protein- based fat replacers. They found less air was incorporated when using the carbohydrate-based fat replacer than when using milk fat (the control) or when using the protein-based fat replacer. However, quality improvement of ice cream may be achieved by using suitable emulsifiers. The emulsifier has the ability to reduce the surface tension at the interface between oil and aqueous phases, which will then mix and form an emulsion (Dziezak, 1988). Emulsifiers are also effective in producing controlled destabilizing of the coalescensing of fat globules during the freezing of an ice cream mix. These properties allow an emulsifier to enhance desirable quality in ice cream (Arbuckle, 1986; Marshall and Arbuckle, 1996). Arbuckle (1950) found that when only gelatin was used, the ice crystal size in ice cream was 38 µ, but when both gelatin and an emulsifier were used, the ice crystal size was decreased to 31-36 µ and the texture of ice cream was very smooth. In addition, a stabilizer has been used to increase the viscosity of the ice cream mix and also enhance smooth texture thus improving the melting quality of the ice cream (Marshall and Arbuckle, 1996).

The objectives of this research therefore were to determine the effect of modified starch used as fat replacer on the sensory and physical properties of reduced fat coconut milk ice cream and to improve the quality of reduced fat coconut milk ice cream by using emulsifiers.

MATERIALS AND METHODS

Ice cream manufacture

Mix composition: Ice cream mix composition was 8% fat, 10% milk solid not fat (MSNF), 12% sugar, 0.1% stabilizer (carboxymethyl cellulose: CMC) and 0.1% emulsifier (mono-diglycerides).

Ingredients: UHT coconut milk (Hawaii Brand) and sugar were purchased from the market. CMC and carbohydrate-based fat replacer MT-01 were obtained from Adinop Co., Ltd. Mono-diglycerides and distilled mono-diglycerides were received from White Group Public Co., Ltd. Polysorbate 80 was obtained from Nutrition Ltd., Part. Modified strach (α-Starch) was obtained from Thai Wah Alpha Starch Co., Ltd. Coconut flavor was supplied by Vicchi Consolidated Co., Ltd.

Processing procedure: The liquid ingredients were heated to not more than 48°C in a stainless steel pan placed in a water bath. The dry ingredients were weighed and added to the liquid ingredients while they were being stirred. When the temperature of the mix increased to about 65° C it was stirred at high speed in the blender for 2 min and then pasteurized at 80°C for 2 min and cooled rapidly to 15°C before being aged for 24 h at 4°C (modified from Arbuckle, 1986).

Effect of modified starch

Coconut milk ice cream was produced by using UHT coconut milk as a fat source. The amount of coconut milk was reduced to achieve different fat contents (1 to 8%) and carbohydrate-based fat replacers (α-Starch and MT-01) was then added to replace the fat in the ratio of modified starch to fat of 23:100 (fat replacer 23 parts with water 77 parts to replace 100 parts of fat) and 25:100 respectively. Coconut flavor was added at the following levels: 0.10, 0.09, 0.07, 0.06, 0.05, 0.04, 0.02, 0.01 and 0.00% when the amount of fat was 0, 1, 2, 3, 4, 5, 6, 7 and 8%, respectively. The products were investigated as follows.

Sensory evaluation: A Ratio Profile Test was used by panelists (when the score is near 1, the samples' characteristics are approaching the ideal). The sensory attributes evaluated were color, flavor, smoothness, gumminess, melting qualities in the mouth and acceptability.

pH: The pH of samples were determined (4 determinations for each replication) at 25±0.5°C by using a pH meter (OMEGA®: Model PHB-62).

Viscosity: Mix viscosity was measured (4 determinations for each replication) at 4±0.5°C after aging 24 hrs, using a Brookfield Digital Rheometer Model III, with a No. 21 spindle at a velocity of 250 rpm and a shear rate of 233 per second (s^{-1}).

Overrun: Overrun was determined in duplicate (4 determinations for each replication) and calculated according to the following equation.

% overrun =

$$\frac{\text{(net weight of ice cream mix)} \pm \text{(net weight of ice cream)}}{\text{(net weight of ice cream)}} \times 100$$

Melting rate: The melting rate of ice cream was measured in duplicate (3 determinations for each replication) at 25°C according to Garcia *et al*. (1995) but with a modification whereby the ice cream that passed through the screen after 20 and 35 minutes was weighed. The weight of melted ice cream was expressed as a percent of the total weight of the initial ice cream sample.

Resistance to deformation: A Texture Analyser (Model TA/XT2®) with a conical probe was used to determine resistance to deformation of the ice cream chilled at -12±0.5°C at 10 mm depth from the surface. In order to determine the force necessary for the probe to achieve a depth of 15 nm, the load cell was set at 25 kg with an initial rate, test rate, and post rate of penetration of 2, 1 and 1 mm/sec, respectively. Duplicate samples were evaluated (4 determinations for each replication).

Effect of emulsifier

The experiment was divided into 2 groups: α-Starch added and MT-01 added. The lowest acceptable fat content samples were selected for next study. Mono-diglycerides, distilled monoglycerides and polysorbate 80 emulsifiers were added at 0.1 and 0.2%. Samples were subjected to sensory evaluation by using the Ratio Profile Test.

Experimental design and statistical analyses

Balanced Incomplete Block Design (BIB) was used to evaluate the sensory effect of modified starch and emusifier while completely randomized design (CRD) was used to evaluate physical properties. Analysis of variance was used for data interpretation. Estimated means were separated by least squares means in the case of BIB and Duncan's multiple range test was used in CRD. Significant differences were analyzed at $p< 0.05$.

RESULTS AND DISCUSSION

The effect of modified starch as a fat replacer

Sensory evaluation: When α-Starch and MT-01 were used as fat replacers, results (Table 1 and 2) showed no significant differences ($p >0.05$) in color and flavor. The acceptability of reduced fat coconut milk ice cream with α-Starch was not significantly different from the control and except for the fat free ice cream (0% fat), when MT-01 was used, acceptability varied among treatments but most treatments were acceptable. The reason that flavor of reduced fat coconut milk ice cream was still acceptable to the panelists may be due to the addition of the coconut flavor in the formula to replace the coconut milk flavor that had been lost when coconut milk was reduced. In any case, a harsh flavor was received when initially tested and it dissipated rapidly. This harsh flavor in reduced fat ice cream may be partly due to the missing of fat in the form of emulsion and some water soluble flavors when coconut milk was reduced. This is one of the problems with reduced fat products because the fat is the carrier of fat soluble flavors (Leland, 1997). Fat soluble flavor is released slowly in the mouth so when there is not sufficient fat to carry the fat soluble flavor, the flavor is released rapidly into mouth (Labell, 1991). The smoothness of ice cream made using α-Starch and MT-01 were the same, showing there was no significant difference in smoothness between treatments. Fat makes ice cream smooth so, when the fat content is reduced, the texture of ice cream is normally coarser. However, in this experiment, the texture of reduced fat ice cream was smooth because the carbohydrate-based fat replacer could bind water (Whistler and Daniel, 1985), so the amount of water available to change to ice was reduced (Miller-Livney and Hartel, 1997). The quantity of MT-01 had no effect on gumminess and melting in mouth. α-Starch induced small differences between treatments (Specter and Setser

Table 1 Sensory characteristics of reduced fat coconut ice cream with α-Starch.

Treatment	Fat (%)	Sensory characteristics					
		Color	Flavor	Smoothness	Gumminess	Melting	Acceptability
1	0	1.02	0.86	0.98	0.78^{ad}	0.69^{a}	0.45^{a}
2	1	1.01	0.84	0.97	0.88^{cd}	0.92^{b}	0.65^{b}
3	2	1.03	0.96	0.99	0.93^{bc}	0.98^{b}	0.62^{b}
4	3	1.14	0.98	0.99	1.00^{bc}	1.05^{b}	0.70^{b}
5	4	0.89	0.96	1.00	0.81^{c}	0.80^{b}	0.71^{b}
6	5	1.02	0.98	0.96	1.05^{bc}	1.00^{b}	0.69^{b}
7	6	0.89	0.91	0.93	1.00^{bc}	0.91^{b}	0.75^{b}
8	7	1.13	1.07	0.95	1.09^{b}	0.97^{b}	0.61^{b}
Standard	8	0.99	1.06	1.04	1.01^{b}	1.08^{b}	0.67^{b}

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

Table 2 Sensory characteristics of reduced fat coconut ice cream with MT-01.

Treatment	Fat (%)	Sensory characteristics					
		Color	Flavor	Smoothness	Gumminess	Melting	Acceptability
1	0	0.89	0.98	0.98	0.88	0.92	0.40^{ac}
2	1	1.09	0.89	1.02	1.02	1.00	0.98^{b}
3	2	1.23	0.99	0.93	0.94	0.90	0.61^{ac}
4	3	1.01	0.99	0.97	0.98	0.89	0.66^{bc}
5	4	1.04	1.06	1.02	1.05	0.91	0.56^{bc}
6	5	0.91	0.98	0.92	0.97	0.84	0.68^{bc}
7	6	1.05	1.03	1.00	0.98	1.00	0.62^{c}
8	7	0.97	0.98	0.93	0.95	0.97	0.72^{bc}
Standard	8	0.93	1.00	0.91	0.88	0.94	0.59^{bc}

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

1994) although their scores were close to 1, whereas, at 0% fat treatment, the score was farthest from 1 and was significantly different from the others ($p < 0.05$). In terms of acceptability, 0% fat samples containing either α-Starch and MT-01 were farthest from 1 when compared to all other treatments. The results revealed that ice creams with 1% fat was the lowest fat content used had the score closest to 1.

Physical properties: The pH results are shown in Table 3. The pH varied within a narrow range of 6.33-6.46. Schmidt *et al.* (1993) found that, when fat in ice milk was replaced by N-Lite™D or Simplesse®, the pH of some treatments were significantly different and varied in a narrow range of 6.41-6.57. Reducing fat levels in the ice cream had an inverse effect on the viscosity of the ice cream mix (Table 3) in that viscosity was higher for reduced fat samples. Thus samples with 1% fat viscosity measured 77 cps compared to the standard formula with a viscosity of 39 cps. This contradicts Schmidt *et al*. (1993) who found that a reduced fat ice cream mix that used N-Lite™D had lower viscosity than the control. In this study the overrun of ice cream was lower when fat was increased in the formula; for example, in the 1% fat samples, overrun was 61.5% whereas in 8% fat samples, overrun was 48% (Table 3). This agrees with the observations of Tharp and Gottemoller (1990) who noted that when the quantity of fat was 2, 10 and 16%, overrun values were 100, 90 and 70% respectively. The reason for this is that fat provides a barrier to the whipping properties of ice cream (Arbuckle, 1986 ; Marshall and Arbuckle, 1996).

The melting rate determinations at 20 and 35 min (Table 4) showed that 1% fat ice cream showed no significant difference from other treatments and that the percentage of ice cream which melted at 20 and 35 min was 41 and 85% respectively. Specter and Setser (1994) reported that the melting rate of the control formula and the reduced fat formula which used tapioca dextrin or potato maltodextrin was not different. In this study, it was found that the melting rate of the most reduced fat formula was not significantly different from the standard formula because the carbohydrate-based fat replacer could form H-bonds with water which increased the viscosity of the ice cream mix thus increasing its resistance to melting.

Deformation properties of each treatment were not significantly different, but there was a tendency for lower fat content to increase the force

Table 3 pH, viscosity and overrun of reduced fat ice cream mix with α-Starch.

Treatment	Fat (%)	pH	Viscosity(cP)	Overrun(%)
1	0	6.46^{a}	88.25^{a}	64.57^{a}
2	1	6.44^{ab}	77.27^{ab}	61.51^{ab}
3	2	6.42^{bc}	70.95^{abc}	55.80^{abc}
4	3	6.42^{bc}	60.95^{bcd}	55.33^{bc}
5	4	6.39^{cd}	60.60^{bcd}	53.39^{bc}
6	5	6.37^{de}	60.46^{bcd}	52.71^{bc}
7	6	6.37^{de}	49.90^{cd}	51.93^{c}
8	7	6.34^{ef}	42.80^{d}	50.88^{c}
Standard	8	6.33^{f}	38.72^{d}	48.13^{c}

^{a,b,c,d,e,f} Means in the same column with different superscripts are significantly different ($P < 0.05$).

required for deformation (Table 5). For example, 1% fat ice cream deformation force was 10,807 g whereas 8% fat deformation force was only 5,513 g because fat affected the softness of the products (Dunkley, 1982).

Effect of emulsifiers on quality of ice cream

Milk solid not fat (MSNF) ≥ 6% has been reported to produce a stable mix (Govin and Leeder, 1971) though an emulsifier helps stabilizing fat in the mix; however, this mix then destabilizes when the ice cream is frozen and this affects the quality of the ice cream (Marshall and Arbuckle, 1996). On the other hand, in a low fat system the role of emulsifier may be different from that in a full-fat system. The sensory results shown in Table 6 and 7 are for samples containing α-Starch and MT-01 respectively.

The results show that color scores for each treatment were close to 1 (just as was the same case for flavor). Of the two emulsifiers only MT-01 affected the flavor. Baer *et al*. (1997) showed that

Table 4 Melting rate of reduced fat coconut ice cream with α-Starch.

Treatment	Fat (%)	Melting(%)	
		20 min	35 min
1	0	42.14^{ab}	86.55^{ab}
2	1	41.44^{ab}	85.38^{abc}
3	2	38.49^{abc}	85.88^{abc}
4	3	31.51^{c}	76.45^{d}
5	4	45.81^{a}	89.64^{a}
6	5	35.78^{bc}	81.08^{dc}
7	6	42.60^{ab}	90.41^{a}
8	7	40.72^{ab}	81.77^{bc}
Standard	8	44.68^{a}	88.11^{a}

^{a,b,c,d}Means in the same column with different superscripts are significantly different (P< 0.05).

Table 5 Maximum compression force of reduced fat coconut ice cream with α-Starch.

Treatment	Fat (%)	Force(g)
1	0	13,072.44
2	1	10,806.96
3	2	8,171.61
4	3	7,143.56
5	4	6,884.78
6	5	6,759.17
7	6	5,831.43
8	7	5,789.25
Standard	8	5,512.70

No significant difference (P > 0.05) between treatment.

the quantity of emulsifiers did not affect flavor and, in this study, that was also true in most instances. However, the results revealed that treatments using both 0.1 and 0.2% polysorbate 80 produced a harsh flavor compared to all other treatments. Dziezak (1988) also reported that polysorbate 80 gave an abnormal flavor. Moreover, according to Hatchwell (1994), because this ice cream had low fat, it could not hide the unusual flavor.

For α-Starch and MT-01, each treatment's smoothness score was close to 1 because the emulsifier allowed the sample to develop an acceptable texture for the ice cream by reducing the ice crystal size so that the texture of the ice cream was smooth. In addition, in each treatment of α-Starch and MT-01, the scores for gumminess were close to 1. The results showed that, for the same concentration of emulsifiers, MT-01 did not affect gumminess in these samples whereas those samples containing α-Starch showed slight differences in gumminess between treatments supporting the contention of Bear *et al*. (1997) that the quantity of emulsifier did not affect gumminess. In the case of the melting characteristics in the mouth, it was found that neither emulsifiers nor the fat replacer α-Starch and MT-01 had an effect in that regard. In relation to acceptability, different quantities of the same emulsifier did not affect acceptability. However, for treatments that used 0.1 and 0.2% polysorbate 80, the score was the farthest away from 1 for both α-Starch and MT-01

Table 6 Sensory properties of reduced fat coconut ice cream (1%) with α-Starch.

Treatment	Sensory properties					
	Color	Flavor	Smoothness	Gumminess	Melting	Acceptability
Mono-diglyceride 0.1%	0.96	1.01	0.99	1.10	0.98	0.77[a]
Mono-diglyceride 0.2%	1.00	1.00	0.97	1.05	0.97	0.67[a]
Polysorbate 80 0.1%	1.07	1.06	0.92	0.89	0.82	0.54[b]
Polysorbate 80 0.2%	1.02	1.08	1.07	1.17	1.03	0.50[b]
Distilled monoglyceride 0.1%	1.00	0.94	1.04	1.08	1.03	0.68[ab]
Distilled monoglyceride 0.2%	1.04	0.98	1.03	1.05	1.03	0.68[ab]

[a,b] Means in the same column with different superscripts are significantly different ($P < 0.05$).

Table 7 Sensory properties of reduced fat coconut ice cream (1%) with MT-01.

Treatment	Sensory properties					
	Color	Flavor	Smoothness	Gumminess	Melting	Acceptability
Mono-diglyceride 0.1%	1.04[a]	1.01[ac]	0.89[a]	0.95[a]	0.99	0.72[a]
Mono-diglyceride 0.2%	1.00[a]	1.01[a]	0.98[a]	0.97[a]	0.99	0.85[a]
Polysorbate 80 0.1%	1.06[ab]	0.74[b]	0.97[ab]	1.01[ab]	1.05	0.53[b]
Polysorbate 80 0.2%	1.16[b]	0.92[bc]	1.02[ab]	1.03[ab]	1.05	0.50[b]
Distilled monoglyceride 0.1%	0.94[c]	1.02[ab]	0.90[ab]	0.93[a]	0.92	0.73[a]
Distilled monoglyceride 0.2%	1.05[a]	1.00[ac]	1.00[b]	1.04[b]	1.02	0.73[ab]

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

because of the harsh flavor.

Thus the sensory score for each set of samples showed that, for most treatments, the samples had sensory characteristics close to the ideal. Varying the concentration of the same type of emulsifiers (0.1 and 0.2%) had no significant effect on sensory characteristics. However, treatments using 0.1 and 0.2% polysorbate 80 produced samples with sensory scores far away from 1; therefore, using polysorbate 80 as an emulsifier in low fat coconut milk ice cream is not suitable. In the case of distilled monoglycerides, even though the sensory score was close to 1, some panelists could detect a soy bean flavor because the distilled monoglyceride was produced from hydrogenated soy bean oil. So the most suitable emulsifier for ice cream was mono-diglycerides. Furthermore there was no difference in sensory characteristics between samples containing 0.1 and 0.2% mono-diglycerides. Thus, production of low fat coconut milk ice cream using either α-Starch or MT-01 as fat replacer should involve the use of 0.1% mono-diglyceride as an emulsifier for the best quality at the lowest cost.

CONCLUSION

It is possible to reduce the fat content of reduced fat coconut ice cream to 1% (reduced 87.5% from the standard formula) without modifying the standard formulation in regard to sugar, emulsifier, stabilizer, and milk solids. It is necessary, however, to fortify the coconut flavor. Reduction of fat content, when accompanied by an increase in the content of fat replacer, led to an increase in viscosity, overrun and the deformation force for the ice cream but it had no significant effect on the melting rate or pH. When emulsifiers were added to improve quality it was observed that ice cream with 1% fat and 0.1% mono-diglyceride was the most acceptable with lowest cost.

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