2013 2nd International Conference on Nutrition and Food Sciences
IPCBEE vol.53 (2013) © (2013) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2013. V53. 6

Effects of Low Glycemic Index Sweeteners on Coconut Milk Ice Cream Qualities

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Abstract. The development of a low glycemic index (GI) coconut milk ice cream by replacing 12% sucrose with xylitol, erythritol or inulin (DP= 2-5) at the same sweetness was carried out. The use of inulin led to the most pronounced increase of consistency coefficient and the highest hardness, but the lowest melting rate and overrun ($p<0.05$). GI of the control had the highest value, whereas those of samples with xylitol, erythritol and inulin were 59%, 75% and 79% lower than that of the control, respectively. Acceptance test revealed that among all sucrose substitution samples, the ice cream with erythritol obtained the highest overall liking scores ($p<0.05$). However, this sample (6.77±1.01) had lower scores than the control (7.50±0.86) ($p<0.05$).

Keywords: Coconut milk ice cream, Glycemic index, Sweeteners, Physical properties, Acceptance test

1. Introduction

In Thailand, coconut ice cream is an alternative ice cream product for Thai manufacturers, since the main raw material is an economic plant. Ice cream is a highly complex food matrix, containing proteins, fat, sugars, air, minerals, etc. and countless interfaces between the different constituents [1]. Sugars or sweeteners are of the most importance ingredient for the structural and sensorial characteristics of ice cream as well as for its storage stability [2]–[4]. However, sucrose, the most widely used sweeteners in ice cream, provides high calories and moderately high GI, which are limitation for consumers concerning for health or suffering from diabetes and obesity. Thus, replacement of sucrose, with low GI sweetener such as maltitol, tagatose, xylitol and erythritol can be alternative ways of development of coconut milk ice cream that meet consumers need. However, no report has been published on formulation low GI coconut milk ice cream. Aim of this study was to investigate the effect of low GI sweeteners with various types on sensory and physical properties of coconut milk ice cream.

2. Materials and Methods

2.1. Materials

The mature coconut meat (*Cocos nucitera* Linn.) throughout this research was grown in Narathiwat province, Thailand. The coconut milk was prepared by pressing coconut meat using a hydraulic press (Thai Sakaya-A2, Sakaya, Thailand). The obtained coconut milk consisted of 19% fat, 2.73% protein, 57.74% moisture, 0.82% ash and 19.71% carbohydrate. Milk solid not fat (MSNF) was purchased from Fa'avae Enterprises Co., Ltd. (Woodridge Brisbane, Queensland, Australia). Mono-diglycerides, locust bean gum, xylitol and fructose were obtained from Dupont™ Danisco® Co., Ltd. (Terre Haute, IN, USA). Erythritol was purchased from Zibo Green Biotech Co., Ltd. (Zibo, China). Inulin (Orafti®HP, DP 2-5) was obtained from Beneo-Orafi Co., Ltd. (Tienen, Belgium). Sucrose was purchased from Mitr Phol Co., Ltd. (Bangkok, Thailand).

2.2. Methods

2.2.1. Coconut Milk Ice Cream Preparation

Coconut ice cream formulation (control) is shown in Table I (Modified from [5]).

The ice cream mix was prepared by dispersing the stabilizer, sweeteners, emulsifier and MSNF dry blend into the liquid materials at 50 ℃ for 10 min. The mixture was heated up to 60 ℃ and homogenized using homogenizer (APV-Gaulin, Minilab 8.30H, Massachusetts, USA) for 2 min, then pasteurized at 80°C for 2 min using water bath (W350 Memmert, Frankfurt, Germany). The ice cream mix was rapidly cooled at 4 ℃ and remained at constant temperature for 24 h to be aged. Some part of the aged mix was subjected to rheological properties, overrun and thermal behavior determinations. The lest was pre-whipped using a batch freezer (Taylor, Model 104-40, Illinois, USA) at a set draw temperature of -20°C. The ice cream was then packed into 50 mL high density polyethylene (HDPE) containers, covered with plastic lid and stored at -20 ℃ for at least 24 h.

Each sweetener, 12.83% xylitol (SE = 87-100) or 19.51% erythritol (SE = 53-70) or 24% inulin (SE = 40-60) [6] was substituted sucrose in the formulation. The substituted formulations were calculated to obtain the same sweetness as 12% sucrose equivalent (SE) as depicted in Table I.

Table I: Constituents of various sweeteners used for production of low GI coconut ice creams

Ingredients (%)	Control	Treatment 1	Treatment 2	Treatment 3
Fat (from coconut milk)	8	8	8	8
Sucrose	12	-	-	-
Inulin	-	24	-	-
Erythritol	-	-	19.51	-
Xylitol	-	-	-	12.83
MSNF	10	10	10	10
Locust bean gum	0.1	0.1	0.1	0.1
Mono-diglycerides	0.1	0.1	0.1	0.1

2.2.2. Physical Properties

-Rheological properties

Rheological measurements were conducted according to the method of [7] using a rheometer (Haake, RS75, Duisburg, Germany) with a coaxial cylindrical system coupled with a Peltier/Plate TCP/P temperature control unit (Haake GmbH, Karlshure).

-Hardness

The hardness was conducted using a TA.XT2i (Texture Analyzer, Stable Microsystems, Surrey, England) (Modified from [8].

-Overrun

Overrun was measured by comparing the weight of mix and ice cream in a fixed volume container and was calculated as follows: % Overrun = [(weight of mix - weight of ice cream) × 100] / (weight of ice cream) [6].

2.2.3. Chemical Analyses

-Total sugar

Total sugar was quantified by Lane and Eynon and Volumetric method [9]; titration with Fehling reagents.

-Glycemic index (GI)

GI was calculated from proportional available carbohydrate according to [10].

2.2.4. Acceptance Test

The acceptance of ice cream was judged by 30 panelists who commonly consume coconut milk ice cream using a 9-point Hedonic Scale for appearance, flavor, texture and overall.

2.2.5. Statistical Analysis

Experiments were run in triplicate using three different lots of samples. A completely randomized design (CRD) was used for the statistical analysis of physical and chemical analysis A randomized complete block design (RCBD) was performed for the analysis of acceptance test. Data was subjected to analysis of variance (ANOVA). Mean comparisons were carried out by Duncan's multiple range test at a significant level $p < 0.05$ using the Statistical Package for Social Science (SPSS 10.0 for windows, SPSS Inc., Chicago, IL, USA).

2.3. Results and Discussion

2.3.1. Physical Properties of Coconut Milk Ice Cream

The effects of low GI sweeteners on the physical properties of ice cream mixes are displayed in Table II. The use of inulin led to the most pronounced increase of consistency coefficient ($p<0.05$). Reference [11] reported that water holding capacity, degree of polymerization and branching were among the most critical factors influencing viscosity development in ice cream mixes. The increase of viscosity of the samples containing inulin seems to be caused by the increase of serum concentration, due to contribution of the soluble matter to the composition of the aqueous phase [12] and by formation of inulin gel [13].

Ice cream hardness is an objective measurement related to many parameters including overrun, viscoelasticity of serum phase, thermal properties, etc. [14]-[15]. It can be seen that the substitution of sucrose with inulin and erythritol obtained higher hardness values and approximately 7 and 5 times, respectively higher than the control ($p<0.05$). This may be due to the high total solid of sample with inulin (52.99%), erythritol (47.56%) compared with the control (42.02%) and sample with xylitol (41.26%). Reference [12] reported that hardness score were minimized in moderate total solid (16%).

The overrun of inulin added sample was the lowest ($p<0.05$) due to a high viscosity as previously mentioned. The overrun value of the control ice cream sample was the highest ($p<0.05$). Reference [16] also reported the highest overrun value of sample with sucrose compared with sample added maltitol, sorbitol and high fructose corn syrup. Reference [8] revealed that sugars and macromolecular carbohydrates might affect foam formation and stability through their impact on the viscosity increase of ice cream mix during the whipping-freezing process as well as due to their contributions to the formation of entanglements which entrap and stabilize air cells, decrease overrun.

Table II: Physical properties of coconut milk ice cream with various sweeteners

Sweeteners	Consistency coefficient, K ($Pa.s^n$)	Hardness (g)	Overrun (%)
Sucrose	0.015 ± 0.002^b	862.9 ± 26.5^c	31.00 ± 2.66^a
Inulin	0.148 ± 0.006^a	6165.6 ± 685.4^a	23.16 ± 0.83^b
Erythritol	0.018 ± 0.001^b	4563.5 ± 374.0^b	28.88 ± 1.05^a
Xylitol	0.014 ± 0.000^b	558.3 ± 43.3^c	27.15 ± 2.96^a

All values are means ± standard deviation from 3 determinations for each of triplicate runs.
[a-c] In a column, mean values followed by the same superscript are not significantly different ($p>0.05$).

2.3.2. Chemical Properties of Coconut Milk Ice Cream

- Total sugar

The use of different sugars in the ice cream production significantly affected the sugar contents of ice cream samples ($p<0.05$) as shown in Table III. Total sugar content of ice cream substituted with inulin was the highest while that of samples with erythritol and xylitol was approximately three times lower than that of the control (sucrose) ($p<0.05$). A quantitative determination of total sugar is a measurement of aldose oxidized to aldonic acid [17]. During acid hydrolysis, inulin could be converted into D-fructose which is classified as aldose group. Most of total sugars of erythritol and xylitol substitution samples were contributed from lactose in the formulation. Nevertheless, erythritol and xylitol are polyhydric alcohols with the formula of $(CHOH)_2(CH_2OH)_2$ and $(CHOH)_3(CH_2OH)_2$, respectively and may not take part of that reaction.

- Glycemic index

Table III is shown the impact of low GI sweeteners on GI value of coconut milk ice cream. Researchers at the University of Sydney have classified foods as low, medium, or high glycemic using the following GI ranges based on the glucose reference: low = 55 or less; medium = 56–69; high = 70 or more [18]. GI of the control had the highest value, whereas GI values of ice creams substituted sucrose with erythritol or xylitol or inulin were 75, 59 and 79% lower than that of the control, respectively. Due to the fact that xylitol, erythritol, inulin are low GI with the value of 7, 0 and 0, respectively, whereas sucrose has GI value of 59 [6].

Table III: Total sugar and GI of coconut milk ice cream with various sweeteners

Sweeteners	Total sugar	Glycemix index
Sucrose	17.64 ± 0.14^{b}	51.358
Inulin	21.62 ± 0.07^{a}	10.656
Erythritol	5.51 ± 0.25^{c}	12.852
Xylitol	4.82 ± 0.02^{d}	20.954

All values are means ± standard deviation from 3 determinations for each of triplicate runs.
$^{a-d}$ In a column, mean values followed by the same superscript are not significantly different (p>0.05).

2.3.3. Acceptance Test

Liking scores of coconut milk ice cream with various sweeteners are demonstrated in Table IV. Ice cream substituted sucrose with inulin obtained the lowest scores of all attributes (p<0.05). Inulin decreased coconut milk flavor and gave rise to hard texture of the ice cream due to the gelling properties of inulin. Moreover, sample containing inulin had the lowest sweetness score. Sweet taste is of particular importance for the overall acceptability of ice cream [2], [19]. Similarly, the sample containing xylitol had lower liking score of all attributes than the control (p<0.05). This effect may be due to the color (pale yellow) and cooling effect of xylitol [20]. Appearance and flavor liking scores of sample with erythritol were not significantly different from the control (p<0.05). However, texture and overall liking scores of that sample were slightly lower than those of control (p<0.05). As mentioned before, the addition of erythritol increased the hardness and may lead to inferior texture of ice cream compared with the control.

Table IV: Liking scores of coconut milk ice cream with various sweeteners

Attributes		Mean scores		
	Sucrose	Inulin	Erythritol	Xylitol
Appearance	7.57 ± 0.68^{a}	6.63 ± 1.67^{b}	7.60 ± 0.62^{a}	6.77 ± 1.33^{b}
Flavor	7.20 ± 0.92^{a}	4.97 ± 1.90^{c}	6.80 ± 1.19^{ab}	6.43 ± 1.36^{b}
Texture	7.50 ± 0.82^{a}	4.70 ± 1.66^{d}	6.83 ± 1.12^{b}	5.83 ± 1.53^{c}
Overall	7.50 ± 0.86^{a}	4.90 ± 1.45^{d}	6.77 ± 1.01^{b}	6.10 ± 1.24^{c}

All values are means ± standard deviation from 3 determinations for each of triplicate runs.

$^{a-d}$ In a row, mean values followed by the same superscript are not significantly different (p>0.05).

2.4. Conclusion

Substitution sucrose with each of low GI sweeteners (12.83% xylitol or 19.51% erythritol or 24% inulin) at the same sweetness as 12% sucrose in coconut ice cream production significantly affected the physical and chemical properties of the coconut milk ice cream samples (P<0.05) and led to lower acceptance score when compared to the control (sucrose). Based on acceptability, erythritol seemed to be to most promised sweetener for low GI coconut ice cream production.

3. Acknowledgements

The financial support of PSU research fund (AGR 5503265), Prince of Songkla University, Thailand is gratefully acknowledged. Authors would also like to thank Asst. Prof. Dr. Piyarat Siriwongpaisarn for her technical assistance with rheological measurements.

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