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Effects of Combination Native and Modified Starch on The Rheological and Sensory Characteristics of Ice Cream

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Abstract: The taste and texture of ice cream is deteriorated by the recrystallization due to fluctuating temperature during handling, storage and distribution. The recrystallization causes the ice cream to become harder and this unpleasant texture reduces the consumers' acceptance. The combination of native and modified starch was used to overcome the recrystallization and improved the limitation of native starch. The physicochemical properties such as overrun and melting rate, rheological properties and nutritional analysis were determined. From the result, ice cream with guar gum only has the highest overrun which is about 97.8% and ice cream without starches has the lowest overrun which is about 48.1%. Ice cream with maltodextrin only has the highest melting rate which is about 0.389±0.010g/min and ice cream with 1:1 ratio of guar gum and maltodextrin has the lowest melting rate which is 0.278±0.025g/min. The ice cream with higher concentration of guar gum is more stable to the temperature fluctuation and less crystallization is formed. The ice cream without starch has the highest viscosity which is 2.667±0. 711Pa.s and the ice cream with maltodextrin only has the lowest viscosity which is 0.058±0.015Pa.s. The ice cream with a ratio 1:1 guar gum and maltodextrin has the highest overall sensory acceptance which received 7.09±1.28 points.

Keywords: Ice Cream, Native Starch, Modified Starch, Guar Gum, Maltodextrin

1. Introduction

Ice cream is a sweet frozen dessert that is rich in proteins, carbohydrates, fats, vitamins, minerals and phytochemicals. Ice cream is generally processed by agitation of milk or cream, sweetener,

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stabilizer, coloring, flavoring, and emulsifier [1][2]. Ice cream is rich in phosphorus and calcium which is good for bone, teeth and muscle health [3]. Adequate calcium intake reduces weight and prevents weight gaining. Besides that, ice cream also helps to maintain reproductive health of women [4]. Ice cream contains a lot of lactoferrin and cytokines that can raise immunity against various illnesses such as influenza [5].

According to Food Regulation 1985, Regulation 116, an ice cream product shall be made from milk product with milk fat, vegetable fat, cream or butter with sugar and some permitted coloring, flavoring substance, and food conditioner. The ice cream ingredients shall be efficiently heat-treated and the overrun of ice cream in frozen condition shall be more than 43% [6]. The overrun represents the percent of the expansion of ice cream achieved from the volume of air incorporated into ice cream during whipping and freezing. High overrun provides a smooth and creamy textural properties of ice cream. However, the recrystallization influences the texture and acceptability of ice cream [7]. The temperature fluctuation during handling, storage, transportation and distribution lead to thawing and recrystallization of ice crystals [8].

Native starch has limited functionality and application due to its natural extraction. To improve the functionality and properties such as texture, solubility, viscosity, and thermal stability of native starch, the starch has been modified physically or chemically according to the usage purposes [9]. The combination of native and modified starch is believed to improve the limitation of native starch as well as inhibit the recrystallization in ice cream at fluctuating temperature. In this research, application of native and modified starch in controlling recrystallization of ice cream was studied. The evaluations such as physicochemical properties, rheological properties, sensory evaluation and nutritional analysis were conducted in this research.

2. Materials and Methods

2.1 Materials

The materials of this research are non-dairy creamer, Stevia extract with erythritol, glycerol monostearate (INS 471), guar gum (INS 412), maltodextrin (INS 1400), vanilla-flavored powder and vanilla essence.

2.2 Preparation of Ice Cream

The powdery ingredients were dissolved in hot water. Then, the vanilla essence was added into the ice cream mix. The ice cream mixture was transferred into the ice cream machine (Model ICM12, Brand Kolice and Sanyo compressor) and ran for 40 minutes of whipping and freezing. Then, the volume of the semi-frozen ice cream mixture was measured and the ice cream was packaged and stored at -18°C.

2.3 Formulation ice cream

The five formulations of optimized ice cream with a controlled formulation were shown in Table 2.1.

Table 2.1: Formulation of combination ratio of native and modified starch in ice cream

Sample	Ice cream with guar gum	Ice cream with a ratio of 3:1 guar gum and maltodextrin	Ice cream with a ratio of 1:1 guar gum and maltodextrin	Ice cream with a ratio of 1:3 guar gum and maltodextrin	Ice cream with maltodextrin only	Ice cream without starch
Water (%)	66.9	66.9	66.9	66.9	66.9	67.2
Non-dairy creamer (%)	26.8	26.8	26.8	26.8	26.8	26.8
Stevia with erythritol (%)	5.1	5.1	5.1	5.1	5.1	5.1
Glycerol monostearate (%)	0.27	0.27	0.27	0.27	0.27	0.27
Guar gum (%)	0.27	0.2	0.135	0.07	0	0
Maltodextrin (%)	0	0.07	0.135	0.2	0.27	0
Vanilla powder (%)	0.4	0.4	0.4	0.4	0.4	0.4
Vanilla essence (%)	0.27	0.27	0.27	0.27	0.27	0.27

2.4 Physicochemical Properties

Physicochemical analysis of ice cream determined the overrun and melting rate. The overrun of ice cream was computed after whipping and freezing. A 25g of ice cream sample was placed on the wire mesh screen above a pre-weighed beaker at room temperature [7]. The first dripping time (s) of the ice cream sample was taken. The weight of ice cream melted (g) was recorded at 10 min time intervals for 60 min. The melting rate of ice cream was calculated [10]. In addition, the ice cream samples were placed outdoors for 10 minutes, 30 minutes and 60 minutes of temperature fluctuation. Then, the samples were refrozen for 24 hours. The changes of appearance of ice cream were observed and compared to ice cream before melting. These samples were placed outdoors again for the second temperature fluctuation and freezed for another 24 hours. Another set of samples was placed at room temperature overnight. The changes of appearance were observed.

2.5 Rheological Properties

The rheological properties were determined by using a rheometer DHR3 with a 40 mm cone and plate geometry with cone angle 1°. The formulated ice cream samples were sheared constantly at a rate ranging from 0.1 to $200s^{-1}$. The time-dependent and viscoelastic properties at 4°C were determined. The ice cream mix used for the rheological measurements were allowed to rest for 2 minutes after running for structure recovery and temperature equilibrium [7].

2.6 Sensory Evaluation

Sensory evaluation of six different formulated ice cream was participated by 75 untrained panelists. The sensory panel was carried out by using a Hedonic rating test with a 9-point hedonic scale. The 9-point hedonic scale of ice cream includes evaluation of appearance, smoothness, melting resistance, creaminess and overall acceptability [7] [11]. All the panelists were requested to evaluate six ice cream samples and rate their acceptability to each sample by using a 9 hedonic scale (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely) for each attribute of the sample. The data was analyzed statistically by using the ANOVA analysis at a significance level of $p<0.05$ [7].

2.7 Nutritional Analysis

The nutritional analysis of optimized ice cream includes the determination of energy, protein, total carbohydrate, total fat and total sugar. The analysis method for energy and total carbohydrate were according to the Method of Analysis for Nutrition Labeling (1993). The protein content was determined by using the Kjeldahl method (AOAC 976.05). The total fat was determined according to In-house Method Based On Pearson's Chemical Analysis of Foods (1990). The total sugar content was determined via Lane and Eynon method (AOAC 923.09 & 968.28) [12].

3. Results and Discussion

3.1 Physicochemical Properties

Based on Table 3.1, ice cream with guar gum only has the highest overrun which is 97.8% followed by ice cream with a ratio of 1:3 guar gum and maltodextrin (95%) and ice cream with a ratio of 3:1 guar gum and maltodextrin (87.2%). Ice cream without starches has the lowest overrun which is 48.1%. This proves that addition of starch in ice cream contributes to higher overrun. The overrun is proportional to the shear stresses during whipping. As more air is incorporated in the ice cream during whipping, more small bubbles are produced, thus, the overrun of the ice cream becomes higher. High overrun ice cream has better shelf life stability [13].

Table 3.1: Overrun properties of ice cream

Sample	Ice cream with guar gum only	Ice cream with a ratio of 3:1 guar gum and maltodextrin	Ice cream with a ratio of 1:1 guar gum and maltodextrin	Ice cream with a ratio of 1:3 guar gum and maltodextrin	Ice cream with maltodextrin only	Ice cream without starch
Overrun (%)	97.8	87.2	67.8	95.0	63.4	48.1

Based on Table 3.2, ice cream with guar gum only has the longest first dripping time which is 300.7±170.2s followed by ice cream with a ratio of 3:1 guar gum and maltodextrin (252±66.5s) and ice cream with a ratio of 3:1 guar gum and maltodextrin (225.7±115.9s). Ice cream with maltodextrin only has the shortest first dripping time among the samples which is 132±45s. At the same time, Ice cream with maltodextrin only has the highest melting rate which is 0.389±0.010g/min. However, ice cream with a ratio of 1:1 guar gum and maltodextrin has the lowest melting rate which is 0.278±0.025g/min followed by ice cream with guar gum only (0.283±0.067g/min) and ice cream with a ratio of 3:1 guar gum and maltodextrin (0.292±0.035g/min).

This proves that guar gum has better ability in decreasing heat shock effects than maltodextrin. The optimum usage concentration of guar gum is in a range of 0.1 to 0.2% [14]. Hence, ice cream with a ratio of 3:1 guar gum and maltodextrin with 0.2% and ice cream with a ratio of 1:1 guar gum and maltodextrin with 0.135% of guar gum concentration would be the optimum formulation in reducing the melting rate of ice cream. The application of guar gum promotes a slow melting rate that aids to retain ice cream shape and desirable quality [15]. The melting rate of the ice cream may be affected by many terms such as overrun, functionalities of emulsifiers used, total solids, ice crystals size, and the fat and protein content in ice cream [7]. Besides that, melting rate is also related to viscosity, hardness and overrun of ice cream [16]. The ice cream with lower overrun melted faster than the ice cream with higher overrun. Thus, the ice cream with higher overrun has higher melting resistance [17]. This is because the rate of heat transfer to ice cream decreases as there is a large amount of air bubbles present in the high overrun ice cream [18].

The melting properties are affected by the thermal diffusivity which is the ability of heat to transfer into the ice cream [19]. The ice cream with higher viscosity has higher melting resistance than those with lower viscosity and without application of starches [20].

Table 3.2: The first dripping time and melting rate of ice cream sample

Sample	First dripping time (s)	Melting rate (g/min)
Ice cream with guar gum only	300.7±170.2	0.283±0.067
Ice cream with a ratio of 3:1 guar gum and maltodextrin	252±66.5	0.292±0.035
Ice cream with a ratio of 1:1 guar gum and maltodextrin	225.7±115.9	0.278±0.025
Ice cream with a ratio of 1:3 guar gum and maltodextrin	162.3±94.9	0.333±0.017
Ice cream with maltodextrin only	132±45	0.389±0.010
Ice cream without starches	173.5±10.6	0.375±0.012

The ice cream before temperature fluctuation had uniform color and good shape retention. Ice cream with a ratio of 1:3 guar gum and maltodextrin, ice cream with maltodextrin only and ice cream without starches formed a layer of crystallization at the bottom of the ice cream due to melting after a second 10 minutes' temperature fluctuation. All ice cream samples that experienced twice 10 minutes temperature have greater shape destruction than the ice cream samples that experienced temperature fluctuation once. Ice cream with a ratio of 1:1 guar gum and maltodextrin, ice cream with a ratio of 1:3 guar gum and maltodextrin, ice cream with maltodextrin only and ice cream without starches formed a layer of crystallization after the first 30 minutes temperature fluctuation and the crystallization layer thicker as less guar gum content was used. After the second 30 minutes of temperature fluctuation, ice cream with guar gum only and ice cream with a ratio of 3:1 guar gum and maltodextrin also formed crystallization. By comparing the first and second time 30 minutes temperature fluctuation, the crystallization layer in ice cream was becoming thicker. All ice cream samples formed crystallization after the first 60 minutes of temperature fluctuation. The crystallization layer became thicker after the second 60 minutes temperature fluctuation. The crystallization layer in ice cream with guar gum only, ice cream with a ratio of 3:1 guar gum and maltodextrin and ice cream with a ratio of 1:1 guar gum and maltodextrin after the second temperature fluctuation were darker than the first temperature fluctuation. When the ice cream was placed at room temperature overnight, ice cream with guar gum only, ice cream with a ratio of 3:1 guar gum and maltodextrin and ice cream with a ratio of 1:1 guar gum and maltodextrin had cream foaming on the top of the ice cream. This foam consists of fat globules in creamer. This foam is generated by the whipping and freezing process in ice cream making [21]. The yield of foam in ice cream is affected by the increase of fat content, application of emulsifier or stabilizer, high overrun and the exposure time at the outside freezer [22]. Guar gum has a good foaming and foam-stabilizing properties [23]. The presence of guar gum prevents the destabilization of air bubbles in ice cream [14]. However, these foaming properties accelerate the separation of fats content from other compositions in ice cream.

3.2 Rheological Properties

According to Table 3.3, ice cream without starches has the highest viscosity among the samples which is 2.667±0.711Pa.s. Ice cream with guar gum only has higher viscosity which is 0.303±0.006Pa.s followed by ice cream with a ratio of 3:1 guar gum and maltodextrin (0.269±0.030Pa.s) and ice cream with maltodextrin only has the lowest viscosity which is 0.058±0.015Pa.s. Addition of starches in ice cream formulation has significantly reduced the viscosity of ice cream due to their ability to bind water as well as reduce formation of large ice crystals and enhance melting resistance [24]. The ice cream with starch has smaller air bubbles size due to shear force as less entrapment of air in bubbles [14]. The viscosity of ice cream with starches decreased as less guar gum and more maltodextrin were added.

Table 3.3: Viscosity of ice cream sample

Sample	Viscosity (Pa.s)
Ice cream with guar gum only	0.303±0.006
Ice cream with a ratio of 3:1 guar gum and maltodextrin	0.269±0.030
Ice cream with a ratio of 1:1 guar gum and maltodextrin	0.183±0.004
Ice cream with a ratio of 1:3 guar gum and maltodextrin	0.090±0.018
Ice cream with maltodextrin only	0.058±0.015
Ice cream without starches	2.667±0.711

3.3 Sensory evaluation of ice cream

The sensory evaluation was participated by 75 untrained panelists who consisted of 15 male panelists and 60 female panelists. The panelists were presented at the age range of 15 to 39. The appearance, smoothness, melting resistance, creaminess and overall acceptance of the ice cream were evaluated in this sensory panel. The results were analyzed using a one-way ANOVA analysis.

Table 3.4: Sensory acceptance of formulated ice cream

Coded Sample	Appearance	Smoothness	Melting resistance	Creaminess	Overall acceptance
Ice cream with guar gum only	7.16±1.53	7.11±1.57	6.48±1.61	6.88±1.52	6.81±1.57
Ice cream with a ratio of 3:1 guar gum and maltodextrin	7.43±1.32	7.45±1.08	6.51±1.56	7.08±1.23	7.04±1.10
Ice cream with a ratio of 1:1 guar gum and maltodextrin	7.36±1.30	7.16±1.28	6.81±1.37	7.13±1.07	7.09±1.28
Ice cream with a ratio of 1:3 guar gum and maltodextrin	7.40±1.33	7.17±1.29	6.63±1.54	6.92±1.08	7.00±1.17
Ice cream with maltodextrin only	7.29±1.42	6.99±1.47	6.65±1.59	6.56±1.43	6.75±1.62
Ice cream without starches	7.12±1.39	6.40±1.46	6.12±1.81	5.95±1.28	6.33±1.48

Based on Table 3.4, ice cream with a ratio of 3:1 guar gum and maltodextrin has the highest acceptance of appearance which received 7.43±1.32 points, followed by ice cream with a ratio of 1:3 guar gum and maltodextrin which received 7.40±1.33 points. Ice cream without starches received the lowest acceptance on the appearance with 7.12±1.39 points. For smoothness attributes, ice cream with a ratio of 3:1 guar gum and maltodextrin has the highest acceptance which received 7.45±1.08 points followed by ice cream with a ratio of 1:3 guar gum and maltodextrin which is 7.17±1.29 points. Ice cream without starches has the lowest acceptance of smoothness, receiving only 6.40±1.46 points. For the melting resistance attributes, ice cream with a ratio of 1:1 guar gum and maltodextrin has the highest acceptance which received 6.81±1.37 points whereas ice cream without starches has the lowest acceptance which received 6.12±1.81 points. For the creaminess attributes, ice cream with a ratio of 1:1 guar gum and maltodextrin has the highest acceptance which received 7.13±1.07 points followed by ice cream with a ratio of 3:1 guar gum and maltodextrin which received 7.08±1.23 points. Ice cream without starches has the lowest acceptance of creaminess, receiving 5.95±1.28 points only. Last but not least, ice cream with a ratio of 1:1 guar gum and maltodextrin has the highest overall acceptance among the panelists which received 7.09±1.28 points, followed by ice cream with a ratio of 3:1 guar gum and maltodextrin which is 7.04±1.10 points and ice cream with a ratio of 1:3 guar gum and maltodextrin which received 7.00±1.17 points. Ice cream without starches has the lowest overall acceptance which only received 6.33±1.48 points.

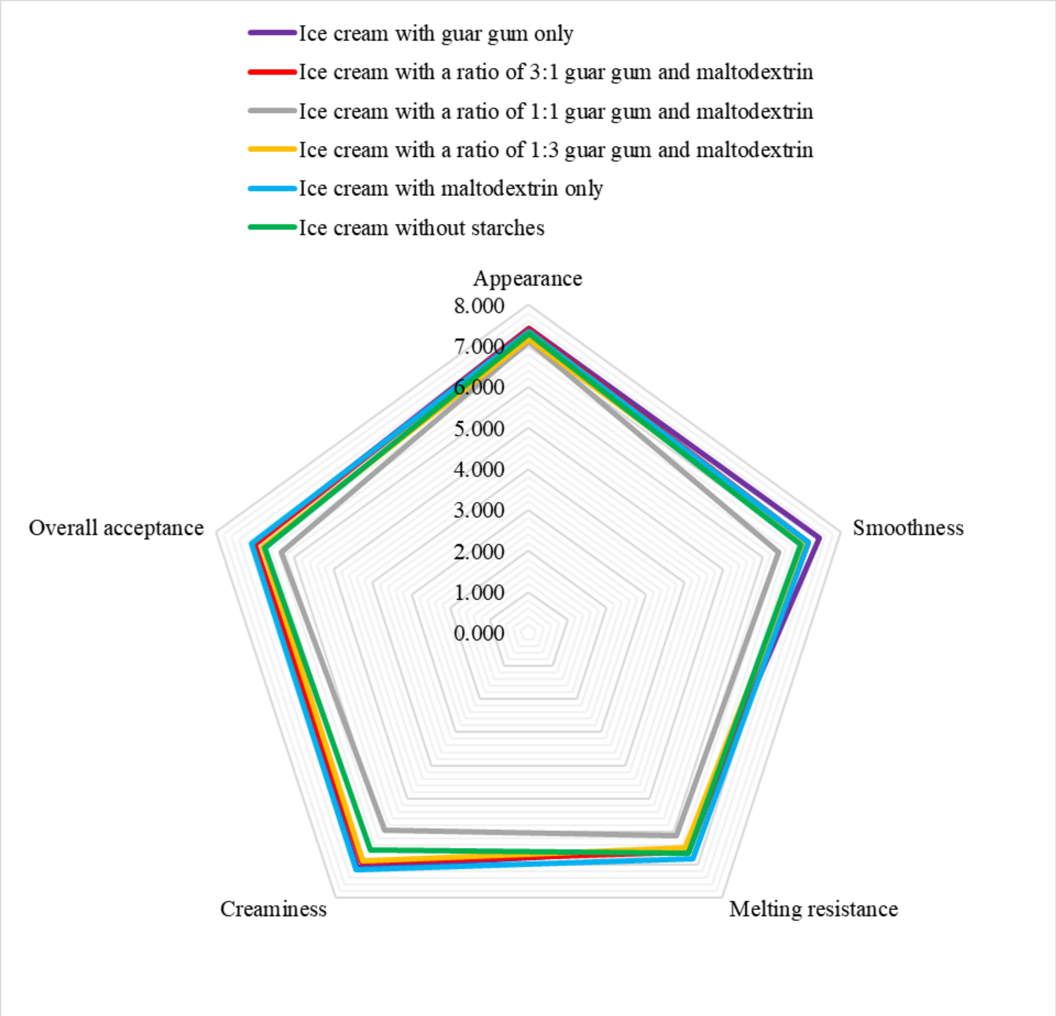

Figure 3.1: Sensory evaluation based on appearance, smoothness, melting resistance, creaminess and overall acceptance

The results of the appearance and melting resistance are not significant at $p<0.05$. The appearance of the vanilla flavored ice cream was presented in white and no or slightly melting occurred during the handling and transportation. Hence, the color and appearance of ice cream were in an uniform and well-mixed condition. The melting resistance of ice cream might be influenced by the room temperature and the tasting time and turn. The results of smoothness, creaminess and overall acceptance of ice cream are significant.

3.4 Nutritional analysis

The nutritional value of ice cream with a ratio of 1:1 guar gum and maltodextrin was compared with two commercial vanilla-flavored ice cream and the results were shown in Table 3.5. Commercial brand A and commercial brand B are the brands that are popular with vanilla-flavored ice cream in the market. Based on Table 4.6, the ice cream with a ratio of 1:1 guar gum and maltodextrin is estimated to consist of 202 kcal of calories, 27.1 of total carbohydrates, 1.0g of protein, 10.0g of total fats and 5.9g of total sugar in 100g portions. The protein content and total sugar content of the ice cream with a ratio of 1:1 guar gum and maltodextrin per 100g are lower than commercial ice cream brands A and B. The substitution of stevia with erythritol reduces the total sugar content and calories significantly. The calories and total fats content of the ice cream with a ratio of 1:1 guar gum and maltodextrin per 100g is higher than commercial brand A and lower than commercial brand B. The total carbohydrate content of the ice cream with a ratio of 1:1 guar gum and maltodextrin is higher than commercial brand A and B.

Table 3.5: Comparison nutrition facts of formulated ice cream and commercial vanilla ice cream

Sample (per 100g)	Calories (kcal)	Total carbohydrate (g)	Protein (g)	Total Fats (g)	Total Sugar (g)
Ice cream with a ratio of 1:1 guar gum and maltodextrin	202	27.1	1.0	10.0	5.9
Commercial brand A	168	20.0	2.2	6.7	17.8
Commercial brand B	207	23.6	3.5	11	21.2

4. Conclusion

The ice cream with a combination of native and modified starch has been successfully formulated. The application of starch increases the overrun of ice cream. Based on all results obtained, the ratio of 1:1 guar gum and maltodextrin is the most optimal in ice cream. Ice cream with a ratio of 1:1 guar gum and maltodextrin has the lowest melting rate (0.278±0.025 g/min), moderate viscosity (0.183±0.004 Pa.s) and highest overall sensory acceptance (7.09±1.28 points). The protein and total sugars content of ice cream with a ratio of 1:1 guar gum and maltodextrin is lower than commercial brand A and B. The calories and total fats of ice cream with a ratio of 1:1 guar gum and maltodextrin is higher than commercial brand A but lower than commercial brand B. The total carbohydrate content of the ice cream with a ratio of 1:1 guar gum and maltodextrin is higher than commercial brand A and B.

Acknowledgement

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Appendix A

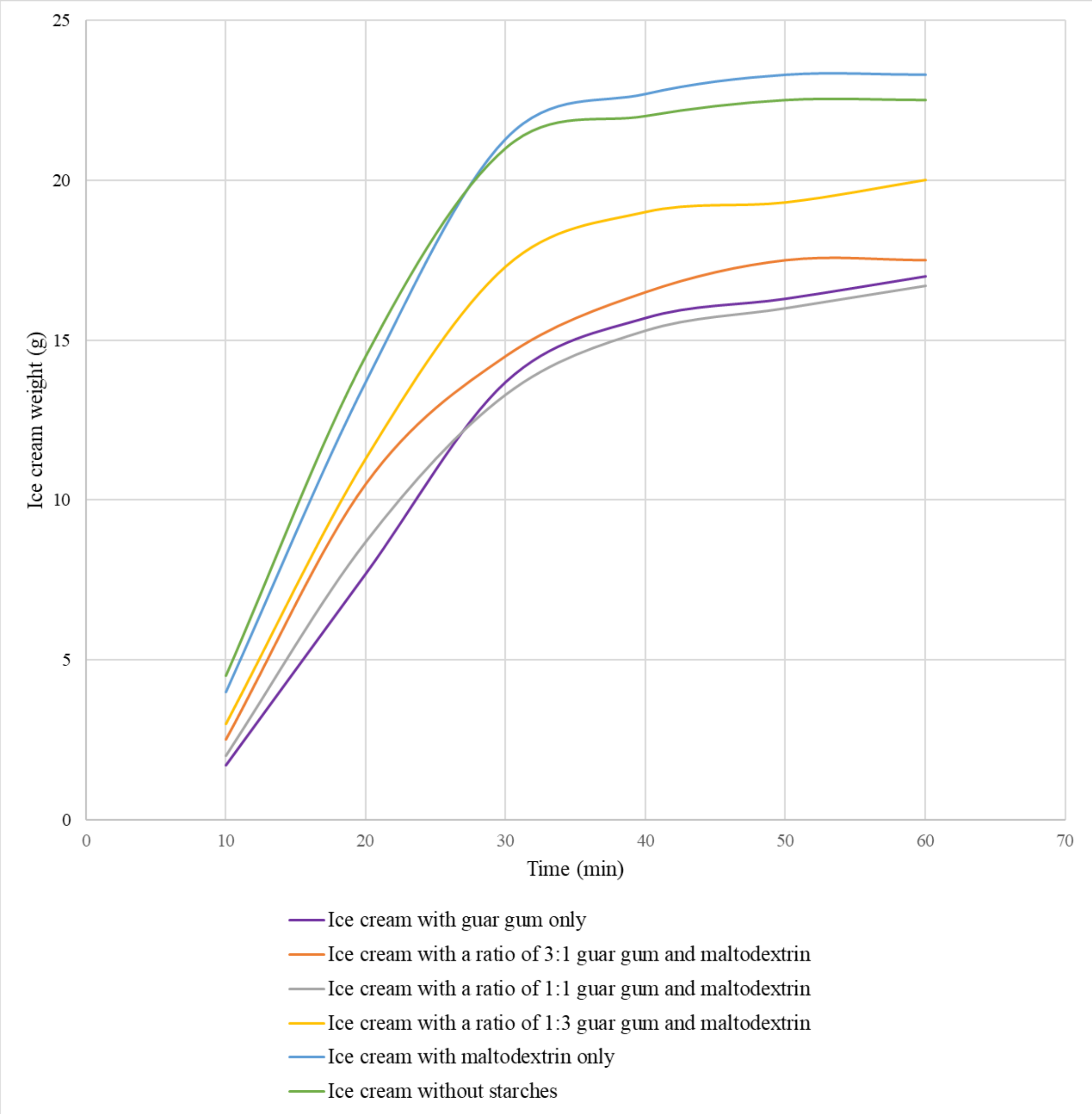

Figure A1 : The weight of the ice cream melted at 10 min time intervals

Appendix B

Table B1 : One-way ANOVA analysis of sensory evaluation

Response variables	Sum of square	Degree of freedom	Mean square	F value	Probability	Significance
Appearance						
within groups	6.107	5	1.221	0.639	0.6704	Not significant
between groups	849.173	444	1.913			
Total	855.280	449				
Smoothness						
within groups	46.473	5	9.295	4.975	0.0002	Significant
between groups	829.547	444	1.868		<0.05	
Total	876.020	449				
Melting resistance						
within groups	20.693	5	4.139	1.645	0.1468	Not significant
between groups	1117.307	444	2.516			
Total	1138.000	449				
Creaminess						
within groups	73.727	5	14.745	9.019	0.0164	Significant
between groups	725.893	444	1.635		<0.05	
Total	799.620	449				
Overall acceptance						
within groups	29.691	5	5.938	3.104	0.0091	Significant
between groups	849.467	444	1.913		<0.05	
Total	879.158	449				

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