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Acacia honey lime ice cream: physicochemical and sensory characterization as effected by different hydrocolloids

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Abstract

The present work was aimed to determine the physicochemical and sensory properties of *Acacia* honey lime ice cream incorporated with various types of hydrocolloids, including guar gum (GG), xanthan gum (XG), and carboxymethyl cellulose (CMC). The overrun, melting rate, hardness, colour, total soluble solid, microstructure, moisture content, pH, and sensory acceptability of the ice creams produced were characterised. The addition of 15% *Acacia* honey to the ice cream led to improvements in several characteristics as the hydrocolloids were incorporated. There were no significant differences in terms of total soluble solids, lightness, yellowness, pH and moisture content among all ice cream formulations. However, the overrun, melting rate, hardness, and redness values of ice cream experienced significant changes as hydrocolloids were added. Ice cream incorporated with GG had the highest overrun (9.30%), melting rate (48.33 mL/min) and a^* (-1.68 ± 0.13) values. Meanwhile, ice cream incorporated with CMC was higher in hardness (1729.30 g), but lowest in terms of overrun (5.00%), melting rate (28.33 mL/min) and a^* (-2.03 ± 0.35) values. An examination of the microstructure found differences in air cell sizes at the interfaces of different types of hydrocolloids. Sensory acceptability showed a significant difference between GG and other formulations. In conclusion, CMC in *Acacia* honey lime ice cream led to strong improvements in its physicochemical properties.

Introduction

Awareness among consumers on healthier and functional food has led to the introduction of ice cream with nutritional and physiological properties, incorporating probiotics, dietary fibre, and alternative sweeteners (Barot Amit *et al*., 2014). Ice cream is a frozen and aerated dairy-based dessert usually associated with happiness, pleasure, and fun. It is popular among all types of people, especially children. According to Goff and Hartel (2013), ice cream and most other frozen desserts generally contain seven types of ingredient: fat, milk solid non-fat (MSNF), sweeteners, stabilisers, emulsifiers, water and flavours. Ice cream is typically sweetened by sugar and is a low-nutrition food (Greenbaum and Aryana, 2013). In order to fulfil demand, natural sweeteners such as honey may be used in ice cream production.

Honey is a more natural sweeter than processed sugar. In ice cream formulations, honey can be used as a sugar replacement, flavouring and supplement. In the lowland rain forests of Peninsular Malaysia, there are many types of honey such as *Tualang*, *Gelam* and *Acacia* honey (A-Rahaman *et al*., 2013). Such honey are now commonly used in many products such as baked goods and as an ingredient in sesame paste (Gharehyakheh *et al*., 2013; Babajide *et al*., 2014). Honey has also been used in the development of frozen desserts.

The characteristics of ice cream, including overrun, melting rate, hardness, colour, total soluble solid, microstructure, moisture content, pH and sensory were investigated. The quality of ice cream is determined based on its overrun, texture and melting rate. In addition, good quality ice cream can be obtained with the addition of hydrocolloids to obtain a better texture and melting rate. Hydrocolloids improve stability and have several additional beneficial effects during manufacture, storage and

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consumption. Hydrocolloids may also be added to ice cream in order to obtain a better texture (Soukoulis *et al*., 2010).

Hydrocolloids commonly used in ice cream manufacturing include guar gum, xanthan gum, carboxymethyl cellulose and carrageenan. Generally, the purpose of using hydrocolloids in ice cream is to stabilise the mix, aid in suspension of flavouring particle, produce stable foam, provide uniformity and produce smoothness in texture during consumption (Marshall *et al*., 2003). In addition, stabilisers offer several beneficial effects such as smoothness in texture and reduction in the rate of meltdown (Clarke, 2004).

The flavour of honey mixes well with other flavours, and is highly demanded by consumers (Marshall *et al*., 2003). Ice cream flavours are diverse, including chocolate, strawberry, vanilla, peanut butter, mint, cinnamon, coffee, berry, lemon and lime. Lime is used in many foods including beverages, confectionary, cookies and desserts such as ice cream. Therefore, the present work was aimed to determine the physicochemical and sensory properties of *Acacia* honey lime ice cream as affected by different types of added hydrocolloids.

Materials and methods

Materials

Acacia honey was provided by Flora Bee Hive, Bukit Tangga, Kedah. The raw materials used in ice cream production were obtained from a local market in Kuala Nerus, Terengganu. Hydrocolloids including guar gum, xanthan gum, and carboxymethyl cellulose were purchased from Sigma Aldrich (USA).

Methods

Production of Acacia honey lime ice cream

Ice cream formulations were prepared following the method described by Shukri *et al*. (2014) with some adjustments. In ice cream preparation, 7% (w/w) egg yolk as emulsifier was mixed by using a hand mixer until light. About 45% (v/v) mixture of milkfat and 23% (v/v) double cream as milk solid non-fat were mixed together with the beaten mixture of egg yolk. The ice cream mixtures were heated for 15 s until reaching 80 ± 2°C for sterilisation, then immediately cooled before hydrocolloids were added. The mixtures were cooled to less than 37°C before honey was added to avoid browning. Then, lime juice was added before storage in a blast freezer for aging. After 5 min in blast freezer, the mixture was taken out and mixed again for 5 min. Finally, the ice creams were kept at -24°C for hardening. The ice creams were produced at different formulations based on the percentage (w/w) of honey added. The four formulations were Formulation 1 (F1; 5% honey added), Formulation 2 (F2; 7.5% honey added), Formulation 3 (F3; 10% honey added), and Formulation 4 (F4; 15% honey added). Then, the sensory properties were determined for the selection of the best formulation. Then, different hydrocolloids were added into the ice cream mixtures. Hydrocolloids such as carboxymethyl cellulose (CMC), guar gum (GG), and xanthan gum (XG) were chosen and added at 0.3% (w/w) each. The control sample was ice cream with no hydrocolloids added.

Characterisation of Acacia honey lime ice cream

Overrun determination

In order to determine overrun, the sample was weighed before and after the ice cream mixture was frozen. The same volume of ice cream was placed in the container once the ice cream mixture was frozen. The percentage of overrun was calculated using Eq. 1 (Laaman, 2011):

$$\text{Overrun (\%)} = [(W_A - W_B) / W_B] \times 100 \qquad \text{(Eq. 1)}$$

where, W_A = weight of mix for fixed volume, and W_B = weight of finished product for fixed volume

The samples were measured in triplicate, and the results obtained were expressed as mean ± SD.

Melting rate determination

The melting rate of ice cream mixture was measured as described by Shukri *et al*. (2014), with some modification. About 50 g of each sample was weighed and placed on a 2 cm cooling rack above a small aluminium bowl, which was used to collect the melted ice cream. The timing of the melt began when the first drop of material that melted touched the bottom of the bowl. The amount of melted sample was recorded every 5 min until the ice cream had completely melted. First dripping and complete melting times of the samples were measured in seconds. The melting rate was determined based on graphs of the melted portion as a function of time. The samples were measured in triplicate, and the results obtained were expressed as mean ± SD.

Colour determination

The colour intensities of the ice cream samples were measured according to Shukri *et al*. (2014) using a colorimeter (Minolta Chromameter Model CR-400) calibrated with a white tile. The samples were placed in a small transparent plastic bag (6 × 6 cm) and placed on the platform to measure colour. The screen on the glass light projection tube was pressed on the sample for light penetration. The results were shown on the screen of the colorimeter and recorded according to the value of lightness (L^*), greenness/redness (a^*) and blueness/yellowness (b^*). The samples were measured in triplicate, and the results obtained were expressed as mean ± SD.

Hardness determination

The hardness of ice cream samples was determined following Halim *et al*. (2014), using a texture analyzer (TA.XT plus, Stable Micro Systems, UK) with a load cell of 5 kg in a cylinder probe. The samples were cut into cubes shape and compressed at a speed of 10 mm/s at room temperature. The hardness of the samples was determined as the peak of compression force in grams, which was detected when the probe penetrated to 30% into the ice cream. The values have been presented as the means ± SD of triplicate analyses of different sample. The data were analysed using the Texture Expert software program.

Total soluble solid determination

A digital refractometer (Milwaukee MA871) was used to measure the total soluble solid (TSS) of ice cream which provided the °Brix value according to Halim *et al*. (2014). The lens of the digital refractometer was calibrated using distilled water. Then, one drop of liquid ice cream was placed on the prism of the refractometer and the °Brix value was recorded. The samples were measured in triplicate, and the results obtained were expressed as mean ± SD.

Microstructure determination

The microstructure of ice cream with different hydrocolloids added were determined to compare the size of air cells formed in each sample. A Hitachi TM-100 tabletop scanning electron microscopy (SEM) was used to determine the air cells and fat globules in the ice cream. A freeze drier (LABCONCO) was used to dry the ice cream. The dried ice cream samples were placed in an aluminium tube, and sputter coated with a 30 nm layer of gold using an auto fine coater (JOEL JFC-1600). The specimens were viewed at 10 kV accelerating voltage and an objective lens aperture of 10 µm (Shukri *et al*., 2014).

Moisture content determination

The moisture content was determined based on AOAC (2000) using the oven drying method. The crucible used was initially dried in the oven for 30 min at 100°C. The crucible was then weighed after being cooled in the desiccator. Then, 2 g of sample was added into the crucible. Then, the sample was oven dried for 3 h at 100°C. After drying, the dish was transferred with a partially covered lid to the desiccators to cool. Finally, the dish and its dried sample were weighed. The moisture content of ice cream was calculated using Eq. 2:

$$\text{Moisture (\%)} = [(W_1 - W_2) / W_1] \times 100 \qquad \text{(Eq. 2)}$$

where W_1 = weight (g) of sample before drying, and W_2 = weight (g) of sample after drying

The samples were measured in triplicate, and the results obtained were expressed as mean ± SD.

pH determination

The pH of the ice cream was measured using a pH meter (Cyberscan series 600, New York) according to Halim *et al*. (2014). The ice cream sample (10 ± 1 g) was dissolved in distilled water (90 mL). The pH meter was calibrated, the electrode rinsed with distilled water and immersed in the sample before the pH value was measured and recorded. The samples were measured in triplicate, and the results obtained were expressed as mean ± SD.

Sensory analysis

The acceptance test employed a hedonic scale for sensory evaluation. The sensory characteristics assessed on a scale from extremely like (9) to extremely dislike (1). For this test, 30 untrained panellists from among the Universiti Malaysia Terengganu's students were chosen to evaluate the sample. They were instructed on how to fill out the score sheet. Four different formulations of ice cream samples were evaluated in terms of colour, texture, odour, taste and overall acceptance. This was followed by second sensory evaluation for acceptance of hydrocolloids in the ice cream before characterisation of each ice cream were conducted. The hydrocolloids used were carboxymethyl cellulose, guar gum and xanthan gum at concentration of 0.3% (w/w).

Statistical analysis

Statistical analysis was performed using software MINITAB14 for Windows to calculate the mean ± SD for each sample. All data were analysed using the one-way ANOVA method and the level of significance used was 95% ($p < 0.05$).

Results and discussion

Production of Acacia honey lime ice cream

Sensory evaluations involving 30 UMT students as panellists were conducted in order to find the best formulation of *Acacia* honey lime ice cream. Table 1 shows the mean scores for colour, flavour, sweetness, sourness, texture and overall acceptance for different percentages of *Acacia* honey. There were no significant differences reported for colour, flavour, sweetness, texture and overall acceptance among all formulations. However, the sourness showed a significant difference ($p < 0.05$) between F1 with F2, F3 and F4. All formulations were accepted by the panellists; however, F4 scored the highest for overall acceptance. F4 only contained 15% honey, while other formulations contained both sugar and honey. F4 was preferred because the flavour of honey and lime was strong as compared to other formulations. Honey is sweeter than sugar because it contains more fructose as compared to glucose. Fructose is slightly sweeter than sucrose and glucose (White and Doner, 1980). Table 1 shows that flavour (sweetness and sourness) influenced the overall acceptability of each formulation. The highest *Acacia* honey concentration (15%) contributed to the sweetness and sourness of ice cream produced. The softness of ice cream increased with increasing percentage of *Acacia* honey, which consequently affected their acceptability among the panellists. According to Aimar *et al*. (1997), the smoothness of ice cream has a strong correlation with the amount of fat in the ice cream. The acceptability of texture of ice cream may be directly related to its hardness. Ice cream with the least *Acacia* honey had a better texture. F4 was selected for further characterisations, including overrun, melting rate, hardness, colour, total soluble solid, microstructure study, moisture content, pH analysis and sensory evaluation with the addition of different hydrocolloids (GG, XG, and CMC).

Overrun

Table 2 shows the overrun properties of ice cream as affected by different hydrocolloids. The highest overrun was control (10.66%) followed by GG (9.30%), XG (7.50%) and CMC (5.00%) added sample. There were no significant differences in overrun value for ice cream between control and GG-added. However, there was a significant difference ($p < 0.05$) for ice cream between CMC-added with control and GG-added, but not for XG-added ice cream. Overrun is defined as the percentage of ice cream volume increase in relation to the liquid mix used. It is related to the amount of air incorporated during the manufacturing process (Cruz *et al*., 2009).

The overrun value obtained in the present work was higher as compared to that of Halim *et al*. (2014); however, low values were reported as compared to Soukoulis *et al*. (2008). Halim *et al*. (2014) found that the overruns for control, GG, XG, and CMC were 3.67%, 4.27%, 4.76% and 2.56%, respectively. The lower values of ice cream overrun were due to the sticky characteristics of honey, which made it difficult to mix well. In addition, the overrun of honey ice cream decreased as compared to the ice cream with sugar because the proportions of total solid decreased when sugar was replaced with honey (Rashid and Thakur, 2012). Higher overrun means better quality ice cream. In conclusion, the addition of hydrocolloids in ice cream did not affect or improve the overrun value of the *Acacia* honey lime ice cream.

Table 1: Sensory evaluation (1) on ice cream formulations.

Ice cream formulation	Colour	Flavour	Sweetness	Sourness	Texture	Overall acceptance
F1 (5% honey)	6.70 ± 1.37^a	6.20 ± 1.83^a	4.23 ± 1.68^a	7.00 ± 1.44^a	5.27 ± 1.91^a	5.63 ± 1.54^a
F2 (7.5% honey)	6.63 ± 1.85^a	5.90 ± 1.71^a	4.77 ± 1.83^a	5.90 ± 1.90^b	4.83 ± 1.95^a	5.60 ± 1.87^a
F3 (10% honey)	6.37 ± 1.54^a	5.87 ± 1.87^a	4.33 ± 1.63^a	6.00 ± 1.89^b	5.00 ± 1.64^a	5.17 ± 2.10^a
F4 (15% honey)	5.93 ± 1.89^a	6.27 ± 1.82^a	4.67 ± 2.17^a	5.83 ± 2.09^b	4.43 ± 2.05^a	5.77 ± 2.25^a

Means with the same superscript within rows are not significantly different ($p > 0.05$)

Table 2: Analysis of *Acacia* honey lime ice cream formulations incorporated with various types of hydrocolloids.

Ice cream formulation	Overrun (%)	Melting rate (%)	TSS (°Brix)	Texture (g)	pH	Moisture content (%)
Control	10.06 ± 1.03^a	75.67 ± 5.508^a	41.67 ± 0.93^a	706.10 ± 94.20^c	3.06 ± 0.09^a	76.33 ± 4.19^a
F1 (GG)	7.97 ± 1.51^a	48.33 ± 3.215^b	30.77 ± 0.51^b	791.40 ± 84.10^c	2.93 ± 0.04^b	68.83 ± 7.08^b
F2 (XG)	6.44 ± 1.06^{ab}	41.67 ± 7.024^b	31.43 ± 1.72^b	1198.70 ± 636.40^b	2.91 ± 0.02^b	64.00 ± 16.58^b
F3 (CMC)	4.31 ± 0.60^b	28.33 ± 3.215^c	29.27 ± 2.83^b	1729.30 ± 143.60^a	2.90 ± 0.03^b	58.67 ± 14.58^c

Means with the same superscript within rows are not significantly different ($p > 0.05$). GG: guar gum; XG: xanthan gum; and CMC: carboxymethyl cellulose.

Melting rate

Table 2 shows the melting rate of ice cream as affected by different types of hydrocolloids. The time required for the first drop exhausted from ice cream was 5 min for XG while control and GG was 10 min and CMC was 15 min. The higher melting rate was in control (75.67 mL/min) followed by GG (48.33 mL/min), XG (41.67 mL/min) and CMC (28.33 mL/min). There were significant differences ($p < 0.05$) between control and formulations added with hydrocolloids. However, there was no significant difference between GG and XG, while the CMC was significantly different ($p < 0.05$) among all formulations. Hydrocolloids decreased the melting rate, and the melting times were dependent on particle size. However, the melting rate of ice cream was affected by types and amount of sweetener (Muse and Hartel, 2004). The ice cream formulations with fructose syrup as sweetener generally presented a higher melting rate when compared to ice cream made from glucose syrup (Rashid and Thakur, 2012). This is because the fructose syrup reduces the freezing point, thus producing a very soft ice cream under usual storage conditions. Therefore, the addition of hydrocolloids is recommended in order to control ice cream texture.

Adding CMC produces a good quality ice cream because it has high water holding capacity and is easily dissolved in the mix (Marshall *et al*., 2003). The addition of CMC improves the melting rate and resistance to dripping due to greater fat stabilisation (Phillips and Williams, 2000; Rosalina *et al*., 2004). The ice cream with only CMC added showed the highest amount of fat aggregates and highest melting resistance. The results obtained in the present work agree with those of Halim *et al*. (2014), who found that the higher melting rate was control (83.0 mL/min), followed by GG (65.5 mL/min), XG (51.0 mL/min) and CMC (27.0 mL/min). Those with lower overruns were harder than those made with high overrun, but melted more rapidly. These findings are also supported by Rosalina *et al*. (2004), who found that higher overrun decreases the hardness and increases the melting rate of ice cream.

Texture analysis

Table 2 shows the results obtained for texture determination of *Acacia* honey lime ice cream with different types of hydrocolloids added. The highest hardness values were ice cream with CMC (1729.30 g), followed by XG (1198.70 g), GG (791.40 g) and control (706.10 g). There was no significant difference between control and GG. However, there was a significant difference ($p < 0.05$) between all hydrocolloid added formulations. The hardness of ice cream is strongly correlated to its melting rate and overrun value. This finding showed that the lowest overrun value lead to a slow melting rate and higher hardness. According to Goff *et al*. (1995), the harder the ice cream, the lower of melting rate and overrun value, while softness in ice cream leads to a higher melting rate and overrun value.

Hardness is used to measure the ice crystals growth, and the hardness of ice cream increases the ice crystals during storage. However, hardness may depend on the ingredients used and processing condition applied to the final frozen product (Guinard *et al*., 1997; Muse and Hartel, 2004). Fructose syrup has a higher melting rate than glucose syrup and affects the hardness of ice cream. Using honey as a sweetener in ice cream can cause the proportion of total solids to decrease, making the texture not as smooth (Rashid and Thakur, 2012). These findings can be improved with comparisons between stevia and honey in terms of sweetness in different ice creams. According to Pon *et al*. (2015), the hardness of stevia ice cream was higher than that of honey ice cream.

In addition, ice cream with GG showed the lowest value of hardness because it acted as a poor cryoprotectant. The function of a cryoprotectant is to control water diffusion and the formation of ice crystals by steric hindrance and water holding (Regand and Goff, 2003). GG causes high levels of galactose residue, which prevents interactions of strong chains because the unsubstituted clear area has the minimum number of galactose to form the junction zone (Phillips and Williams, 2009). Furthermore, ice cream with XG and CMC showed the highest values of hardness because both hydrocolloids were stable at acidic pH. However, Halim *et al*. (2014) reported that ice creams with GG and CMC were highest in hardness as compared to XG and control. In conclusion, the best results for hardness were found when CMC was added, because it could conserve the texture and inhibit ice crystal formation while slowing the meltdown rate (Murray *et al*., 2000).

Colour analysis

Table 3 shows the L^*, a^*, b^* values as affected by different types of hydrocolloids added in *Acacia* honey lime ice cream. The quality of ice cream was determined by lightness values. The highest lightness value was shown by control (90.63) and followed by GG (89.83), XG (89.39) and CMC (88.67). The highest redness value was shown by control (-1.47) and followed by GG (-1.68), XG (-1.78) and CMC (-2.03) added. The highest yellowness value was GG and CMC (16.62) and followed by control (15.45) and XG (13.60) added. There were no significant differences among lightness and yellowness between the control formulation and all hydrocolloid added formulations. However, CMC was significantly different ($p < 0.05$) in redness as compared to control, GG and XG. Thus, the addition of different hydrocolloids in honey lime ice cream did not affect the lightness of the ice cream. Halim *et al*. (2014), reported that there were no significant differences in the lightness value with the addition of GG (94.43), XG (93.10) and CMC (93.37). The results indicated that GG had higher lightness values as compared to XG and CMC. The increase in lightness was affected by the increase in the volume of ice cream. As stated by Sharma and Hissaria (2009), GG in ice cream will increase the volume of the ice cream mixture, while increasing its concentration will result in an increase of lightness.

Table 3: Colour parameters of Acacia honey lime ice cream formulations incorporated with various types of hydrocolloids.

Ice cream formulation	L^* (lightness)	a^* (redness)	b^* (yellowness)
Control	90.63 ± 0.52^a	-1.47 ± 0.20^b	15.45 ± 0.48^a
F1 (GG)	89.83 ± 0.55^a	-1.68 ± 0.13^b	16.62 ± 1.74^a
F2 (XG)	89.39 ± 1.71^a	-1.78 ± 0.33^b	13.60 ± 2.16^a
F3 (CMC)	88.67 ± 1.03^a	-2.03 ± 0.35^a	16.62 ± 1.59^a

Means with the same superscript within rows are not significantly different ($p > 0.05$). GG: guar gum; XG: xanthan gum; and CMC: carboxymethyl cellulose.

Total soluble solid (TSS)

Table 2 presents the total soluble solids (TSS) of *Acacia* honey lime ice cream with different types of hydrocolloids added. The highest reading of TSS was control (41.67°) which did not contain any hydrocolloid, then followed by XG (31.43°), GG (30.77°) and CMC (29.27°). There was a significant difference ($p < 0.05$) between control formulations with all hydrocolloids added formulation in TSS. However, there were no significant differences between ice creams with GG, XG and CMC.

The value of TSS depends on the ingredients used such as types of sugar, and types of milk. More honey contributed to a higher TSS value. Besides, the addition of honey may cause an increase in TSS (Rashid and Thakur, 2012). This is because honey contains more fructose than glucose and fructose is sweeter than glucose. However, the addition of hydrocolloids causes TSS to decrease. This may be due to the fact that sweetness degrades when hydrocolloids are added (Marshall *et al*., 2003).

A study conducted by Pon *et al*. (2015) showed that the TSS of stevia ice cream (20% to 22%) was lower as compared to the findings obtained in the present work. The TSS of the ice cream is contributed to by the addition of sweeteners. Sweeteners also provide essential bulk, texture and body to ice cream (Buchheim, 1998). Ice cream with lower TSS may have proportionately more water to freeze, contributing to greater ice crystal formation (Flores and Goff, 1999). In conclusion, TSS levels depend on the types of sweetener used.

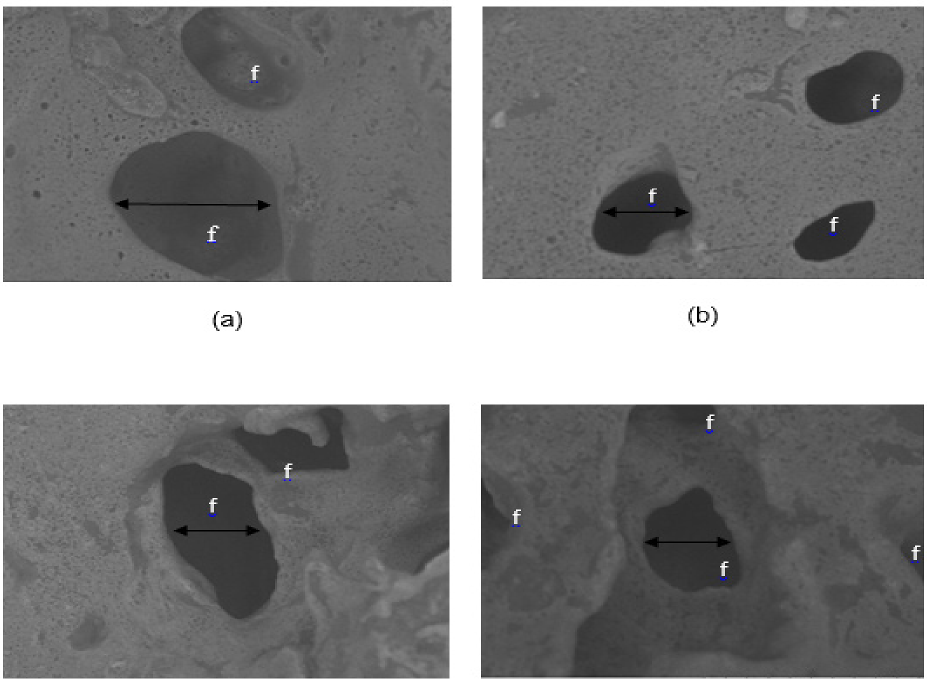

Figure 1: Microstructure of different hydrocolloids of *Acacia* honey lime ice cream in (a) control, (b) guar gum, (c) xanthan gum, and (d) carboxymethyl cellulose. f: fat globules indicating the air cell size.

Microstructure

Figure 1a shows the air cell size of control, and Figures 1b, 1c and 1d show the air cell sizes of *Acacia* honey lime ice cream with different types of hydrocolloids added. The function of stabilisers was the formation of small ice crystals by immobilising and binding the water.

The ice cream with no hydrocolloids had larger air cells than ice cream with hydrocolloids added. The fat absorption at the air interfaces can affect different air bubbles depending on the difference types of hydrocolloids (Halim *et al*., 2014). Ice cream with GG showed smaller and uniform air cell size. According to Sharma and Hissaria (2009), GG has shear thinning characteristics that can help to maintain the size of air bubbles during freezing thereby stabilising the ice cream structure.

However, the air bubbles of ice cream with XG were slightly bigger as compared to GG, but smaller than control. XG quickly dispersed into the mixture and bound the water. Then, the air cells of XG are smaller during freezing time (Naresh and Shailaja, 2006). Ice cream with CMC showed smaller air bubbles than XG and control and slightly larger bubbles than GG (Figure 1). The results obtained in the present work agree with that of Halim *et al*. (2014), who showed that the sizes of air bubbles of GG and XG added are uniform and smaller as compared to control (no hydrocolloids added). However, they also reported that air bubbles in ice cream with CMC added were difficult to explain. In the present work, it was shown that CMC produced larger air bubbles as compared to GG.

pH analysis

The pH values of ice cream incorporated with hydrocolloids are presented in Table 2. Control showed the highest pH (3.06), followed by GG (2.93), XG (2.91) and CMC (2.90). There was a significant difference ($p < 0.05$) between control and hydrocolloids added. However, there were no significant differences between GG, XG and CMC. These findings disagree with that of Choo *et al*. (2010), who found that the normal pH of ice cream is pH 6.3.

From the results, the pH values obtained exceeded the normal pH. This may be due to the acid content of *Acacia* honey and lime. According to Moniruzzaman *et al*. (2013), *Acacia* honey had the highest acidic (3.53) value since it contains organic acids (oxalic, malic, lactic) that can increase acidity, while the lactose gets converted into lactic acid (Rashid and Thakur, 2012). In addition, the ice cream with lime saw increases in pH, as the pH of lime is 2.2. The combination of *Acacia* honey and lime in ice cream resulted in higher pH levels.

The pH values may decrease as honey concentrations increase (Rashid and Thakur, 2012). The hydrocolloid which acts as a stabiliser can cause increases in pH values. Regand and Goff (2003) reported that a stabiliser must be used in acidic frozen dairy desserts such as ice cream due to the weakness of stabilisers to acidic conditions.

Moisture content

The moisture contents of different hydrocolloids in *Acacia* honey lime ice cream formulations are presented in Table 2. The highest moisture content was obtained by control (76.33%), followed by GG (68.83%), XG (64.00%) and CMC (58.67%) added. The moisture content of normal ice cream is 61.0 (Marshall *et al*., 2003).

However, there were no significant differences ($p < 0.05$) in moisture content between GG and XG. The addition of hydrocolloids in the ice cream did not significantly affect the moisture content of ice cream. In addition, the addition of hydrocolloids decreased the moisture content. According to Laaman (2011), hydrocolloids are used to control water mobility and provide certain finished product body characteristics. However, moisture content may decrease with an increase of the amount of honey in a product (Rashid and Thakur, 2012).

Sensory evaluation

Table 4 shows the sensory evaluation of *Acacia* honey lime ice cream with different hydrocolloids added. There were no significant differences ($p > 0.05$) among all formulations in terms of colour, flavour, body and texture and resistance to melting. This means that each hydrocolloid showed similar acceptability for each attribute. The colour of ice cream was contributed by the *Acacia* honey itself. There were no significance differences in colour values for all ice cream formulations. However, the flavour of ice cream is probably its most important quality. Flavour is manipulated through sweetness and natural and artificial flavours. Sweetness comes from honey and other ingredient such as milk, and cream, while sourness comes from *Acacia* honey and lime. CMC showed the highest flavour score followed by control, XG and GG. Resistance to melting and texture were the highest for control followed by GG, CMC, and XG. The melting rate can affect the texture of ice cream, because a slow melting rate can affect firmness. Additionally, the overall acceptance of ice cream incorporated with GG was significantly different ($p < 0.05$) between XG, CMC, and control. However, the most acceptable was the control, while GG was the least accepted by the panellists.

Table 4: Sensory evaluation (2) on *Acacia* honey lime ice cream formulations incorporated with various types of hydrocolloids.

Ice cream formulation	Colour	Flavour	Body and texture	Resistance to melting	Overall acceptance
Control	6.60 ± 1.63^a	6.27 ± 1.57^a	5.17 ± 1.76^a	5.60 ± 1.94^a	6.13 ± 1.63^a
F1 (GG)	6.63 ± 1.90^a	5.80 ± 2.27^a	4.93 ± 2.00^a	5.07 ± 2.18^a	4.83 ± 2.12^b
F2 (XG)	5.70 ± 2.28^a	6.03 ± 1.92^a	4.47 ± 1.96^a	4.90 ± 2.30^a	5.80 ± 1.69^a
F3 (CMC)	6.13 ± 1.63^a	6.47 ± 1.48^a	4.63 ± 1.96^a	4.87 ± 1.89^a	5.93 ± 1.86^a

Means with the same superscript within rows are not significantly different ($p > 0.05$). GG: guar gum; XG: xanthan gum; and CMC: carboxymethyl cellulose.

Conclusions

The addition of CMC in *Acacia* honey lime ice cream led to good quality ice cream in terms of melting rate and hardness. Ice cream with XG was the highest in hardness but was low in overrun and melting rate values. In terms of sensory acceptability, all formulations were accepted by the panellists, but the highest mean score on overall acceptance of *Acacia* honey lime ice cream was the control formulation with no addition of hydrocolloids. There were no significant differences in terms of acceptable levels of the other three hydrocolloids in ice cream.

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