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Physicochemical and Rheology Properties of Ice Cream Prepared from Sunflower Oil and Virgin Coconut Oil

Linda Trivana[1], Nugraha Edhi Suyatma[2], Dase Hunaefi[2], S. Joni Munarso[3], Adhitya Yudha Pradhana[1], Barlina Rindengan[4]

[1]Postharvest Technology, Indonesian Palmae Crops Research Institute (IPCRI), Manado, Indonesia
[2]Department of Food Science and Technology, IPB University, Bogor, Indonesia
[3]Research Centre Agroindustry, Serpong, Indonesia
[4]Research Centre for Food Technology and Processing, Gunung Kidul, Indonesia

Email: lindatrivana@gmail.com

Abstract

In the last decade, increasing trends towards the consumption of healthier foods have forced processors of high-fat products (ice cream) to shift their formulations to higher proportions of unsaturated or "healthier" fats. Vegetable oils such as sunflower oil and VCO can be used as a substitute for milk fat, milk solids not fat (skim milk powder), sweeteners, stabilizers and emulsifiers, and mineral water in making ice cream. A study was carried out to determine the effects of the use of the ratio of sunflower oil: virgin coconut oil with palm fruit as a stabilizer in the production of ice cream on physicochemical properties (pH, proximate, *overrun*, viscosity, and melting rate). The use of palm fruit is based on the content of galactomannan in palm fruit. Premium ice cream with five different ratios of SO and VCO (15:0), (10:5), (7.5:7.5), (5:10), (15:0). The ice cream production involves mixing, pasteurization, homogenization, aging, and freezing. The physicochemical result shows ice cream sample with a ratio SO:VCO (5:10) obtained good physical properties, the lowest first-time drop/ shape retention, and a low melting rate compared to the others. The rheological behavior of ice cream is the non-Newtonian fluids with a pseudoplastic behavior. The apparent viscosity decreased with increasing shear rate.

Keywords: ice cream, physicochemical properties, rheology properties, sunflower oil, virgin coconut oil

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Introduction

Ice cream is one of the most consumed dairy products worldwide. The formulation of the original mixture is given by lipids, proteins, and functional elements such as carbohydrates, stabilizers, and emulsifiers. The right combination of these ingredients and their interaction confer the best texture with its complex microstructure to the finished product (Goff & Hartel, 2013). However, it is generally poor in functional ingredients, and it should be consumed moderately due to its high content of simple sugars and lipids, which are also abundant in short-chain saturated fatty acids (Kurt & Atalar, 2018; Sacchi et al., 2019). The main components of ice cream are high levels of saturated fatty acids are always associated with increased risks of obesity and coronary heart diseases (Guo et al., 2018).

The fatty acid composition of milk fat is characterized by the high proportion of saturated fatty acids (60-70%) appreciable amount of monounsaturated fatty acids (25-35%) and a small amount of polyunsaturated fatty acids (about 4%). Milk fat also contains 0.25-0.38% cholesterol (Nadeem et al., 2010). The interest in functional foods has forced the design of new formulations to improve the nutritional properties of ice cream by using ingredients with enhanced health benefits (Raffaele et al., 2019) such as by substituting butter fat with vegetable oils as sunflower oil (unsaturated fatty acid) and virgin coconut oil (saturated fatty acid) (Nadeem et al., 2010).

In the last decade, increasing trends towards the consumption of more healthy foods have forced processors of high-fat products to shift their formulation to a higher proportion of unsaturated or "healthier" fats. Sunflower oil is rich in unsaturated fatty acids. In ice cream, unsaturated or liquid fat are unable to create a similar structure and results in a product with less body. In the absence of saturated/ solid fat, the droplets lack the necessary strength to retain their identity during aggregation (Mendez-Velasco & Goff, 2011). This can be solved by adding other vegetable oils that have a high solid fat content such as virgin coconut oil (VCO) to obtain an optimal solid fat content in the oil mixture. The use of oil blends consisting of coconut oil and sunflower oil may enable the ice cream mix emulsions containing coconut oil with some liquid fat to form partly crystalline fat droplets after aging and induce the formation of an optimal partial coalescence during the subsequent freezing stage (Mendez-Velasco & Goff, 2011).

In addition to the formation of partial coalescence, the type of stabilizer also affects the physical properties of ice cream. Stabilizers are useful for reducing the formation of ice crystals and lactose during heat shock, resulting in soft ice cream, and melting resistance (Kurultay et al. 2010). The stabilizer commonly used in ice cream is gelatin. Gelatin is a protein from skin collagen, membranes, bones, and other collagenous body parts that can be used as a gelling agent, thickener, and stabilizer (Cahyadi, 2008). Consumption of gelatin from year to year continues to increase, while gelatin is still mostly imported from Japan, the United States, and New Zealand. The import volume of gelatin can be reduced by utilizing hydrocolloids. One of the hydrocolloids that can be used is galactomannan (Herawati, 2018). Galactomannan can be obtained from coconut pulp about 61% (Rindengan, 2015), palm fruit 4.58% (Tarigan, 2012), and fenugreek 25-30% (Mathur, 2005). Galactomannan is a polysaccharide consisting of mannose and galactose chains. Galactomannan is a good thickener and emulsion stabilizer and can reduce the risk of entering toxins (Winarno, 2004). The utilization of galactomannan sources in palm fruit is still very limited. To increase the utilization of galactomannan from palm fruit it is used as a stabilizer in the manufacture of ice cream.

The objective of this study was to investigate the effects of different solid fat contents of oil blends consisting of coconut oil and sunflower oil at various ratios on the properties of ice cream mix emulsions.

Materials and Methods

This research was conducted in the Laboratory of the Indonesian Center for Agricultural Post Harvest Research and Development in January-April 2021. The materials used were Virgin Coconut Oil (VCO) obtained from Indonesian Palmae Crops Research Institute (IPCRI), sunflower oil (Tropical Slim), palm fruit, mineral water, mono-diglyceride (E471), skim milk, sucrose, and salt.

Ice cream preparation

Ice cream mixes were prepared in 1 L batches with a base formulation of 15% fat, 10% milk solids not fat (skim milk powder), 14% sucrose, 0.3% palm fruit powder, 0.3% MDG, 0.15% salt, and 60.25% mineral water (Table 1). The composition of 15% fat and 10% MSNF is based on commercial frozen desserts by formulation premium ice cream category (Goff and Hartel, 2013). The 15% fat is the treatment ratio of sunflower oil and VCO namely 15:0, 10:5, 7.5:7.5, 5:10, and 0:15.

Ice cream is produced by five different steps: 1. mixing ingredients, 2. pasteurization, 3. homogenization, 4. aging, and 5. freezing. The mixing process is designed to blend mix A and mix B. Mix A is dry ingredients (MSNF, salt, and sucrose) which were dissolved in water, then added fat content treatment slowly. The mix B stabilizer was dissolved in water while heated at 40°C because galactomannan can dissolve in water forming highly viscous and stable aqueous solutions (Dos Santos et al., 2015). The physicochemical properties of galactomannan depend on the proportion of mannose and galactose in the galactomannans (Tako et al., 2018). Mix A and B are mixed and stirred until they became homogeneous. Each ice cream mix was initially pasteurized at 65-70°C for 30 minutes. After pasteurization, the mixes were then homogenized in a 2-stage homogenizer was carried out with an Ultra-Turrax Homogenizer is 15000 rpm for 5 min and 10,000 rpm for 5 min (Lim et al. 2010). Immediately aged for 24 h at 4°C. It was followed by whipping and hardening at -20°C for storage.

Fatty acid analysis

Analysis of fatty acid in VCO and sunflower oil by Gas Chromatography with column CP-SIL 88 (Colom length: 30 m, diameter: 0.32 mm), Flame Ionization Detector (FID), injector and detector temperature on 230°C, Initial column temperature is 120°C and then programmed to be 200°C with temperature gradient 8°C/minute, and nitrogen gas pressure of 3 kg/cm^2.

Acidity and Overrun determinations

The pH of ice cream emulsion samples was measured by pH-meter. Overrun index values of ice cream samples were determined according to the method described by Marshall et al. (2003). A known volume of ice cream mix and ice cream were weighed and overrun calculated according to the formula:

$$\text{Overrun (\%)} = \frac{\textit{Vol of ice cream - vol of mix used}}{\textit{volume of mix used}} \times 100\%$$

Rheological properties

Rheological measurement was conducted according to the method of Fuangpaiboon and Kijroongrojana (2015) with modification on the shear rate. For the determination of rheological characteristics of aged ice cream samples at 4°C for one night, a controlled stress rheometer (Rotational rheometer, RheolaQC, AntonPaar, Austria), equipped with a

Table 1. The Formulation of Ice Cream

Sample	SO:VCO ratio (g)	Palm Fruit Powder (g)	Mono-diglyceride (E471) (g)	Salt (g)	*Milk Solid Non-Fat (MSNF) (g)*	Sucrose (g)	Water (g)
F1	15:0	0.3	0.3	0.15	10	14	60.25
F2	10:5	0.3	0.3	0.15	10	14	60.25
F3	7.5:7.5	0.3	0.3	0.15	10	14	60.25
F4	5:10	0.3	0.3	0.15	10	14	60.25
F5	0:15	0.3	0.3	0.15	10	14	60.25

temperature control unit was used. A cone-plate configuration with a cone radius of 35 mm, an angle of 4°, and a gap of 0.140 mm between the cone and plate was utilized for rheological measurements. The measurements were performed over a shear rate range of 1-100 s^{-1} at 20°C and apparent viscosity values of samples generally were seated at a constant shear rate in this range (50 s^{-1}, the approximate shear rate of mouth, Bourne, 2002). Plots of log shear stress versus log shear rate were created from each flow curve. From these plots calculation of flow behavior (n) and consistency coefficients (K) values were obtained from the Power Law model for each mix. The Power Law model was used to describe the data of shear-induced behavior of the ice cream (Karaca et al., 2009):

$$\tau = K\,\dot{y}^{n}$$

where τ is shear stress (Pa), ẏ is the shear rate (s^{-1}), K is the consistency index ($Pa.s^n$), and n, the flow behavior index, is dimensionless and also reflects the closeness to Newtonian flow.

Melting test

To study the melting ice cream behavior, the first dripping time and melting rate were considered, as proposed by Soukoulis et al. (2008) with some modifications. The ice cream samples ±2 g (slightly varied in terms of dimension from one ice cream to another) were put on a wire screen mesh and allowed to melt at room temperature. All samples were kept at -19±1°C until tested. The time required for the dripping of the first drop of melted ice cream was recorded. The weight of the material passed through the screen was recorded at 5 min time intervals for 60 min. the weight of the drained sample was measured, to calculate the percentage of melted ice cream after 60 min at room temperature. Finally, a graph was drawn taking into consideration time (expressed in minutes, on the abscissa) and quality of drained ice cream (expressed in grams, on the ordinate).

Proximate analysis

The ice cream mix was analyzed for its proximate content (fat, protein, and carbohydrate). The content of fat in the sample was determined by the Mojonnier fat extraction following an AOAC Official Method 989.05. The protein content of ice cream was determined by Kjeldhal method. The carbohydrate by difference method is 100% - (water content+ash content+protein+fat).

Data Analysis

The data obtained were analyzed using SPSS software and if there were differences between treatments, it was continued with the DMRT test.

Results and Discussion

Fatty acid analysis

The physical characteristics of fat are determined by the nature of the triacylglycerol species it contains. Oils containing triacylglycerols of higher-melting fatty acids tend to show cloudiness or remain solid at room temperature while oils containing unsaturated fatty acids will be in liquid form (Reena et al., 2008). The composition of fatty acids in VCO and sunflower oil is shown in Table 2. Based on Table 2, the dominant fatty acid found in VCO is saturated fatty acid, namely lauric acid (47.083%). While sunflower oil is an unsaturated fatty acid, namely linoleic acid (56.789%) and oleic acid (27.799%). Coconut oil provides higher amounts of SFA while oils from sunflowers provide more PUFA.

Fats are the main constituent element of partial coalescence and contribute to the formation of ice cream structure via the clusters of crystalline fat droplets (Chalermnon, 2013). The development of a structural fat network in ice cream is influenced by the solid:liquid fat ratio (Sung & Goff. 2010). Fat also exerts good effects on the body, texture, palatability, flavor intensity, emulsion formation, and maintenance of melting point (Syed et al., 2018). The formation of partial coalescence determines the structure of ice cream and greatly affects the texture, melting rate, overrun, and viscosity of ice cream (Goff & Hartel, 2013).

Table 2. Composition of fatty acid in VCO and sunflower oil

Parameter	Fatty acid (%)			
	Sunflower oil commercial	*Sunflower oil* (Katja DG 2012)	VCO Dalam Palu	APCC standard
Caprylic acid (C8:0)	nd	nd	8.583	5.0-10.0
Capric acid (C10)	nd	nd	6.447	4.5-8.5
Lauric acid (C12:0)	nd	nd	47.083	43.0-53.0
Myristic acid (C14:0)	0.061	0.05	16.678	16.0-21.0
Palmitic acid (C16:0)	5.713	5.36	8.481	7.5-10.0
Stearic acid (C18:0)	3.566	1.57	4.197	2.0-4.0
Oleic acid (C18:1)	27.799	16.39	5.589	5.0-10.0
Linoleic acid (C18:2)	56.789	67.86	1.096	1.0-2.5
α-Linolenic acid (C18:3)	1.132	1.02	Nd	nd

Note: nd (not detected)

Coconut oil has a solid fat content in the range between 64% and 76% at 20°C, while sunflower oil contains 0% solid fat content at the range between 20°C and 35°C (Benjamins et al. 2009). The amounts of solid fat content expected to be present in the ice cream mix at 4°C at the ratio of two different oil blends (SO:VCO 15:0, 7.5:7.5, 5:10, and 15:0) were approximately 0%, 45%, 68%, and 90%, respectively (Chalermnon, 2013). Fats become crystallized as temperature decreases below their melting points (Vanapalli & Coupland, 2001). A low proportion of solid fat in fat droplets leads to the inhibition of partial coalescence (Marshall et al., 2003). A high rate of partially coalesced fat droplets usually occurs when the solid fat content (SFC) in oil droplets is between 10-50% (Davies et al., 2000; Marshall et al., 2003). The SFC becomes lower when fats contain a lesser amount of saturated fatty acids (Vereecken et al., 2009).

Overrun and pH

Overrun which refers to the ability of the ice cream structure to hold air bubbles was investigated by measuring a percentage increase in the volume of ice cream due to the whipping of the ice cream mix during the freezing process (Muse & Hartel, 2004). Air bubbles are formed during the production process as a result of stirring the ice cream mixture (Sung & Goff, 2010). The air bubbles in ice cream distribution result in smooth texture and affect the physical properties of melting and hardness of ice cream (Sofjan & Hartel, 2004). Ice cream with good fat structures usually has high overrun, melting resistance, and shape retention. The overrun and pH value of the ice cream sample are shown in Table 3.

The overrun value in the treatment of F3, F4, and F5 was in accordance with the ice cream quality requirements based on SNI 01-3713-1995 for a household scale of 30-50%. The high ability to hold air cells in the cream made from the ice cream mixes containing a blend of SO and VCO ratio at 5:10 could be due to the presence of a fat aggregated network enhancing the foam stability (Eisner et al., 2005). The optimal amount of liquid oil is present to bond the collision droplets together to form a continuous structural network to stabilize air cells (Fredrick et al., 2010). Similar results have been reported by Mendez-Velasco and Goff (2012) that the overrun of ice creams that contained a mixture of saturated palm kernel fat and unsaturated sunflower oil 60-80% could increase with increasing solid fat content. Sung and Goff (2010) also reported that the percentage of overrun in ice cream containing fat blends of palm kernel oil and sunflower oil increased as the solid fat content increased.

The foamability of ice cream decrease with increasing unsaturated liquid oil (SO) at a level of >50% SO, resulting in a low overrun (Mendez-Velasco & Goff, 2012). The presence of too much liquid oil leads to the collapse of air cells in the ice cream (Marshall et al., 2003). As a result, the least overrun was observed in the ice cream containing 100% SO which only had a 5% overrun. A higher overrun results in higher

Table 3. Effect of SO:VCO ratio on overrun and pH ice cream

Sample	SO:VCO Ratio	Parameter	
		Overrun (%)	pH
F1	15:0	5.06±0.09a	6.81±0.01a
F2	10:5	10.90±0.91a	6.82±0.01a
F3	7.5:7.5	46.39±0.95b	6.81±0.01a
F4	5:10	55.08±1.12c	6.65±0.01b
F5	0:15	46.46±1.07b	6.63±0.02b

Note: Numbers followed by the different letters in the same column are significantly different at 5% of DMRT air content leading, to a higher apparent viscosity, greater fat destabilization, and low meltdown (Halim et al., 2014; Sofjan & Hartel, 2004). Overrun plays an important role in lowering the melting rate of ice cream (Halim et al., 2014; Sofjan & Hartel, 2004). In other words, the high ability to hold air cells observed in the ice creams made from the ice cream mixes containing 100% or 75% CO could be due to the presence of a fat aggregated network enhancing the foam stability (Eisner et al. 2005). The pronounced reduction in the overrun of the ice cream with a high ratio VCO (100% VCO). This may be due to the solid fat content is too high, the rigidity of the solidified fat disrupts those fat droplets to form a proper fat structure (Fedrick et al., 2010; Rousseau, 2002). An increase in the overrun value leads to an increase in the apparent viscosity of the ice cream mixture during freezing as more air is introduced (Chang and Hartel, 2002).

The sunflower oil:VCO ratio treatment influences the pH value of the resulting ice cream. This is because of the difference in the pH value of sunflower oil and VCO. The results of the ice cream pH analysis were obtained around 6.63-6.81. According to Arbuckle and Marshall (1996), the normal pH of ice cream is 6.3. The increase in the pH value may be due to the increase in the sunflower oil ratio added, the sunflower oil pH value of 7.38 (Awogbemi et al., 2019) and the VCO pH value of 6.50 (Suryani et al., 2020).

Rheological Properties

Rheology, the study of deformation and flow, is an essential physical property that relates to the processability of material and is primarily affected by the molecular weight and size of the components (Li et al., 2020). For liquids, the viscosity becomes the most important aspect of rheology. Viscosity, the resistance of a liquid to flow, is the internal friction that tends to resist the sliding of one element of fluid over another. It is defined as the shear stress divided by the rate of shear (Goff & Hartel, 2013).

The rheological behavior of ice cream is much more complicated than that of simple liquid (Scholten, 2014). The matrix is a solution of small (sugar) and large (polysaccharides) molecules, in which particles of other phases (ice crystals, fat droplets, and air bubbles) are suspended (Scholten, 2014). The effect of fat blends on the steady shear viscosity obtained from the flow curve of the ice cream emulsion after one-night aging. Flow behavior analyses of ice cream samples were performed to evaluate apparent viscosity and shear stress in response to shear rate. The apparent viscosities of ice cream emulsions were shown in Figure 1.

The results show that the apparent viscosity for the fresh ice cream mixes that were aged overnight decreased with increasing shear rate over the whole tested shear rate between 20 s-1 and 100 s-1, reflecting the non-Newtonian fluids with a pseudoplastic behavior (Vlachopoulos and Polychronopoulos, 2012), indicating the formation of weak droplet network structure (Zhao et al., 2020). Ice cream is an emulsion formed by four phases (cryo-concentrate, ice crystals, fat globules, and air) with complex composition and when submitted to a shear stress the new rearrangement of particles decreases resistance to flow and apparent viscosity (Anjo et al., 2020). The ice cream mixes with different ratios of SO and VCO showed significant effects on the reduction in viscosity with increasing liquid oil content (i.e., SO). The ice cream mix with 100% sunflower oil had the lowest viscosity. In other words, the higher amount of solid fat content (VCO) was responsible for the increased viscosity and the reduced flowability.

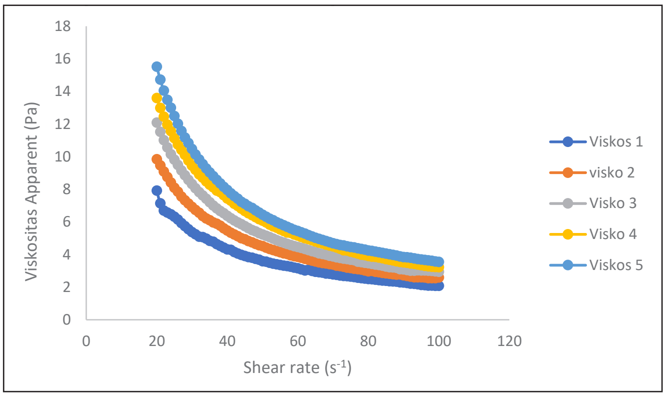

Figure 1. The apparent viscosities of ice cream emulsions

Table 4 presents the yield shear stress (τ0), consistency coefficient (k), and flow behavior index (n) of the ice cream samples. The consistency coefficient (k) is related to the viscosity and affects the body and texture of the ice cream mix (Javidi et al., 2016).

Table 4. Rheological properties of the ice cream samples

SO:VCO Ratio	Viscosity Coefficient: k (Pa s	Flow Behavior index: n	R^2
15:00	0.0812	0.205	0.9871
10:05	0.1267	0.1464	0.9871
7.5:7.5	0.1698	0.1119	0.9523
5:10	0.2032	0.1004	0.9661
0:15	0.2348	0.0837	0.8757

The consistency index of the emulsion significantly increased with the increasing concentration of VCO. All flow behavior indexes were lower than 1.0, due to the shear-thinning nature of the emulsions which was confirmed by flow index (n) values ($0.08 \leq n \leq 0.20$). The viscosity of the ice cream emulsion gradually increased with the increasing VCO concentration. At the same time, viscosity coefficient (k) values increased but n values decreased. Viscosity and k values increased with the increasing concentration of VCO, indicating that a more structured emulsion was formed.

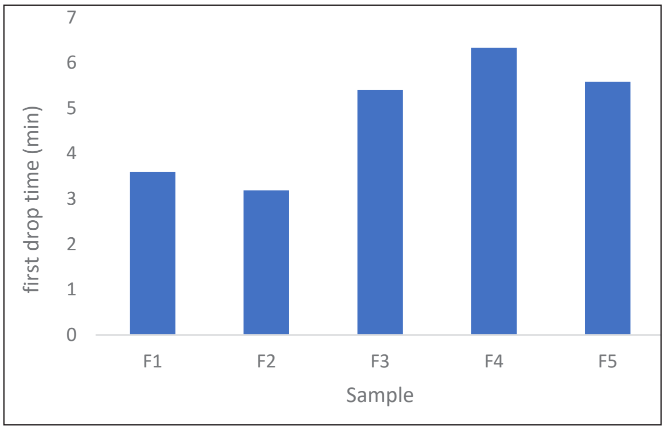

Figure 2. The first drop of ice cream

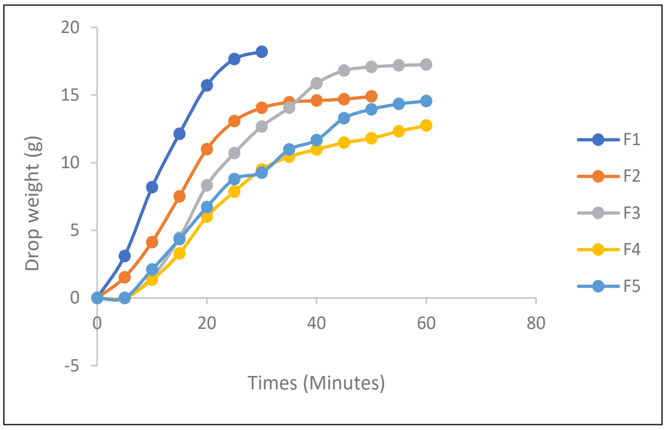

Figure 3. The melting rate of ice cream samples

Melting and Dripping

The melting rate is an important parameter used to evaluate the physical stability of ice cream (Guo et al., 2018). The first drop of ice cream samples is shown in Figure 2.

Figure 2 shows that sample F4 has a good retention shape with the longest first drop time in the 6th minute. This is due to the resistance of the ice cream structure which is formed from optimal partial coalescence. The optimal partial coalescence formation results in a good fat aggregate network structure which can increase the stability of the foam in the ice cream, thereby increasing the melting resistance of the ice cream. The extent of partially coalesced fat network ice cream determines shape retention and the melting rate of ice cream (Marshall et al., 2003). Partially coalesced fat droplets play an important role in stabilizing air cells (Zhang & Goff, 2005), therefore ice cream with high melt resistance may determine the high extent of partial coalescence. Ice cream with good fat structures usually has high overrun, melting resistance, and shape retention.

Ice cream with palm fruit as a stabilizer has a good retention shape because according to Shukri et al. (2014), hydrocolloids improve the resistance to melting due to their enhancement of water-holding and viscosity of ice cream. Galactomannan hydrocolloids in palm fruit would bind water and form a gel-like network resulting in immobilizing the water within it to form a rigid structure that is resistant to flow (Maity & Saxena, 2016). Therefore, the water molecules become immobilized and unable to move freely among other molecules of the mixes leading to retarding product melting (Fuangpaiboo & Kijroongojana, 2015; Lomolino et al., 2020).

The melting rate has the greatest significance to the consumer when the product is eaten from a cone or stick. If the product melts too fast, a messy situation often ensues. A fast-melting product is undesirable also because it tends to become heat shocked readily. The melting rate of ice cream samples is shown in Figure 3.

Figure 3 shows the melting rate of the ice cream samples at 25°C, ice cream containing 100% SO (F1) melts faster compare to the others sample. This indicates that the F1 sample has almost no structural network formed in the ice cream. In other words, the level of fat agglomeration that occurs is very low which results in a weak structure in the ice cream. Ice cream made with a high proportion of sunflower oil could not effectively stabilize air cells due to minimal fat flocculation and resulted in a high meltdown rate (Lim et al., 2010). They observed that VCO increased the stability of the samples, providing greater resistance to ice cream melting compared to the SO. This result can be attributed to the polymerization of the milk proteins by the action of saturated fatty acid (VCO) which led to an increase in the stability of the ice cream. The ice cream with higher solid fat concentrations showed greater resistance to melting.

The slow melting rate of the ice cream containing >75% VCO, is because VCO has a melting point in the range of 23-26°C (Gunstone, 2004) which is higher than that of the melting point of SO (Mendez-Velasco & Goff, 2012). The melting point of SO is -18°C (Rowe et al., 2009), and a low melting point is the primary cause of rapid melting. Products containing a high amount of air (high overrun) or fat tend to melt slowly. Air cells act as an insulator. Fat stabilizes foam structure.

The ice cream sample (F4) with ratio SO:VCO (5:10) has the lowest melting rate. This may be due sample F4 having an optimal solid fat content, so the formation of partial coalescence is optimal to form ice cream with a good tissue structure. The stability is increased by the aggregation of the fat globules around the air bubbles (Chalermnon, 2013). To enhance the effect of the aggregates, the droplets preferably are of small particle size. The homogenization step and the aging strep in the production process are important (Marshall et al., 2003). The homogenization step ensures a decrease in the droplet size, which increases the surface areas needed for partial coalescence to take place (Marshall et al., 2003). To increase the coalescence, the proteins from dairy are removed, which is accomplished in the aging step (Chalermnon, 2013). During the aging step, the emulsifiers replace the proteins from the surface, which enhances the coalescence, leading to partially coalesced fat aggregates (Scholten, 2014).

Proximate composition of ice cream samples

The moisture content, protein, fat, ash content, and crude fiber of ice cream samples are shown in Table 5. The highest

Table 5. The proximate composition of ice cream samples

Sample	Parameter				
	Moisture	Ash	Fat	Protein	Carbohydrate
F1	62.18±0.57b	0.95±0.01a	9.32±0.13d	3.80±0.05d	23.76±0.51a
F2	64.10±1.06b	0.96±0.03a	2.03±0.18*a	3.56±0.05c	29.34±1.31b
F3	63.66±0.86b	0.91±0.03a	5.95±0.03b	3.73±0.12cd	25.75±0.68a
F4	59.31±0.81a	0.97±0.81a	5.99±0.03b	3.02±0.03a	30.71±0.83b
F5	64.06±0.95b	0.97±0.95a	6.80±0.01c	3.31±0.06b	24.86±1.05a

Note: Numbers followed by the different letters in the same column are significantly different at 5% of DMRT.
*Did not fulfill the SNI 01-3713-2018 quality standards

fat content was found in ice cream containing 100% sunflower oil (9.32%) while the lowest was in the F2 sample (2.03%).

The results of ANOVA one-way analysis that sample F2 did not fulfill the SNI ice cream 01-3713-2018 causing fat content <5%. This may be due to the F2 sample did not form a homogenous emulsion or separate occurs so that it affected the calculation of fat content in the sample.

The moisture content was converted to ice crystals during ice cream production. The protein content of the ice cream samples was in the range of 3.02-3.80%, which is the typical range for ice cream reported by many studies (Cruxen et al., 2017; Kurt et al., 2018). The functions of protein in the mixes are fat emulsion stabilization by interacting at the oil-water interface during homogenization, encapsulation of the air cells, and control of the destabilization of fat during freezing (Abdel-Haleem & Awad, 2015).

Conclusion

The ice cream contains sunflower oil: VCO ratio (5:10) with palm fruit as stabilizer had good physical properties, the lowest first-time drop/ shape retention, low melting rate, and the highest overrun compared to the others. The sample F4 has a good retention shape with the longest first drop time due to the resistance of the ice cream structure which is formed from optimal partial coalescence. The rheological behavior of ice cream is the non-Newtonian fluids with a pseudoplastic behavior. The apparent viscosity decreased with increasing shear rate.

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