Combination of Sodium Alginate and Kappa-Carrageenan Increases Texture Stability of *Spirulina platensis* Ice Cream

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Abstract. This study aimed to increase the texture stability of *Spirulina* ice cream by addition of double stabilizers, sodium alginate and κ-carrageenan. This study used *Completely Randomized Design* (CRD) with 6 treatments; N1 (sodium alginate 0,1%), N2 (sodium alginate 0,2%), NK1 (sodium alginate 0,09% + κ-carrageenan 0,01%), NK2 (sodium alginate 0,08% + κ-carrageenan 0,02%), NK3 (sodium alginate 0,19% + κ-carrageenan 0,01%) and NK4 (sodium alginate 0,18% + κ-carrageenan 0,02%). The effect of stabilizers on physical properties, chemical characteristics, and consumer preference were measured. Data were analyzed using *One Way Anova* 95% and Duncan test (parametric), *Kruskal Wallis* and *Multiple Comparison* (nonparametric), and correlation test using *Rank Spearman*. The results showed that the use of double stabilizer did not affect ($p>0,05$) color, taste, flavor, emulsion stability and overrun, while it affects ($p<0,05$) texture and first dripping time. Melting rate, hardness, adhesive force, cohesiveness, hardness in scoop, coarseness in scoop, brittleness, iciness, wateriness, sandiness and greasy mouth coating increased during storage period, while gumminess, smoothness and creaminess decreased. NK4 showed the lowest brittleness, wateriness and sandiness value also the highest smoothness value at the end of storage. The use of double stabilizer contain 0,18% sodium alginate and 0,02% κ-carrageenan increased the texture quality of *Spirulina platensis* ice cream.

1 Introduction

Spirulina sp. is a microalgae included in blue green algae [1] which contains high protein 55-70% and source of micronutrients [2]. *Spirulina platensis* can be used to produce functional food because the content of its bioactive compounds can increase nutritional value, but some bioactive compounds contained in *S. platensis* are not resistant to heat, so the processing techniques have to be considered [3].

Ice cream is a milk product that is made by freezing [4], so the addition of *S. platensis* to ice cream is very possible. The previous study of Listyowati [5] examined the ability of cinnamon as an aftertaste agent masking on ice cream fortified with *S. platensis*. Gelatin was used at 0.5% w/w as a stabilizer. The results showed that the use of 0.5% w/w gelatin

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on ice cream fortified with 1% *S. platensis* resulted in a sandy texture of ice cream and easily melted at room temperature [5].

Consumer acceptance of ice cream is determined by texture and taste parameters [6]. The soft texture felt when consuming ice cream depends on the size, amount and shape of ice crystals in ice cream [7]. According to Goff & Hartel [8], the retention period can cause significant changes in the structural elements of ice cream which have an impact on the decline in the quality of ice cream, a bad influence on the texture of ice cream that usually occurs is ice recrystallization. Ice recrystallization is evidenced by an increase of the average size and width of the ice crystal distribution. Large ice crystal sizes are felt as coarse particles in the palate which cause a sensation of rough texture in the mouth [9].

Hydrocolloid in ice cream has an important role because of its influences to the formation of ice crystal structure and its stability during freezing and storage period. Hydrocolloid combinations (0.2-0.5%) are applied to control the ice recrystallization and maintain the structure of ice cream by slowing melting time when consumed [10]. Soukoulis *et al*. examined the use of multiple stabilizers; sodium alginate, CMC, guar gum and xanthan gum with κ-caragenan on vanilla ice cream [6]. The study showed that vanilla ice cream with 0.2% sodium alginate had the lowest melting rate that was significantly different from other treatments, which was 0.39 g/minute. Soukoulis *et al*. prove that κ-carrageenan can increase the first dripping time of vanilla ice cream with sodium alginate significantly, the first dripping time of vanilla ice cream with 0,1% sodium alginate is 19.33 minutes which increased to 23.5 minutes on ice vanilla cream with 0,09% sodium alginate + 0,01% κ-carrageenan [6].

This study will concern at the use of double stabilizers; sodium alginate and κ-carrageenan in ice cream fortified with *S. platensis* during the storage period which can produce a soft, non-sandy *Spirulina* ice cream texture and not easily melt at room temperature. The impacts given by sodium alginate and κ-carrageenan on the sensory properties of ice cream fortified with *S. platensis* can be identified through sensory analysis.

2 Material and methods

2.1 Study design

This study used *Completely Randomized Design* (CRD) with 6 treatments (Table 1); N1 (sodium alginate 0.1%), N2 (sodium alginate 0.2%), NK1 (sodium alginate 0.09% + κ-carrageenan 0.01%), NK2 (sodium alginate 0.08% + κ-carrageenan 0,02%), NK3 (sodium alginate 0.19% + κ-carrageenan 0.01%) and NK4 (sodium alginate 0.18% + κ-carrageenan 0.02%). Some parameters were determined to understand the behaviour of stabilizers in the system. pH, emulsion stability, overrun, melting characteristics, texture analysis by texture analyzer and trained panelist determined with three replication units.

2.2 Ice cream preparation

Ice cream formulation contain emulsifier 0.2%, *Spirulina platensis* 0.1%, cinnamon 0.2%, fresh milk 63%, skim milk 4.9%, whipping cream 15.7%, granulated sugar 13.7%, vanilla essen 1.2% and stabilizers ; sodium alginate and kappa-carrageenan (Table 1). Fresh milk was pasteurized then added skim milk, whipping cream, granulated sugar and vanilla essen, the mixture was homogenized (I) then added *Spirulina platensis*, cinnamon, emulsifier and stabilizer, homogenized (II) then chilled at refrigerator 4ºC for 24 hours (aging),

homogenized (III) for 4x then stirred and freezed with ice cream maker, last freezed on freezer, hedonic, pH and sensory characterization examined at the end.

Table 1. Stabilizer formulation

Sample	Stabilizer percentage (%)		Stabilizer type
	Primary	Secondary	
N1	0.1	-	sodium alginate
N2	0.2	-	sodium alginate
NK1	0.09	0.01	sodium alginate /κ-carrageenan
NK2	0.08	0.02	sodium alginate /κ-carrageenan
NK3	0.19	0.01	sodium alginate /κ-carrageenan
NK4	0.18	0.02	sodium alginate /κ-carrageenan

2.3 Hedonic

Hedonic test is carried out to determine consumer preference of *Spirulina* ice cream. Hedonic tests will be carried out by untrained panelists (adult). Product attributes measured by taste, flavor, color and texture. Hedonic tests are done using a scale of 1-5 (1 = very dislike; 2 = dislike; 3 = rather like; 4 = like; 5 = really like) by 80 untrained panelists. Panelists will be asked to fill out a hedonic test scoresheet [11].

2.4 pH

The pH test is carried out using a pH meter on the ice cream mixture before and after the aging process. The sample was measured by 30 ml, the pH meter was dipped in aquadest and then dipped in a buffer solution to be calibrated, then the pH meter was dipped in aquadest before dipped in the sample. The number figured on the pH meter then recorded as the pH value of the sample.

2.5 Viscosity

Viscosity is carried out on ice cream mix (ICM) before the aging process. The test was carried out using a Brookfield viscometer and using number 6 spindle. The sample was inserted into a glass container by 50 ml then the spindle was immersed into the sample. The speed measured at 2 rpm, 4 rpm, 10 rpm, 20 rpm; then reversed 10 rpm, 4 rpm, 2 rpm respectively [12].

2.6 Overrun

Overrun is the volume difference of ice cream before (ICM volume) and after (ice cream volume) being homogenized. 25 grams of sample was inserted into a measuring cup, then the volume is recorded [13], overrun is calculated using the formula:

$$\% \; overrun = \frac{(\text{ice cream volume} - \text{ICM volume})}{\text{ICM volume}} \times 100\%$$

2.7 Melting characterization

Melting characteristics include two tests, first dripping time and melting rate. The first dripping time of the ice cream sample, initially a 100 gram ice cream sample was placed on a wire screen mesh and allowed to melt at room temperature for 40 minutes. The time needed for the first ice cream to drip through a wire screen mesh is recorded as first dripping time. The weight of the melted ice cream sample through the screen mesh wire is weighed and recorded every 5 minutes using an analytical scale [6].

2.8 Texture analysis

2.8.1 Texture analysis with texture analyzer

Texture analysis is analyzed using texture analyzer (Brookfield Engineering Labs, Inc. TexturePro CT V1.4 Build 17), the attributes are hardness, adhesive force and cohesiveness from ice cream samples. All frozen ice cream samples were left at room temperature for 5 minutes before the test. Texture analysis is carried out with a stainless steel cylindrical probe with a diameter of 6 mm, it will record force required by the cylindrical probe to penetrate the sample to a depth of 10 mm at a speed of 0.5 mm/s [7]. Hardness attribute is obtained from the highest pressure detected by texture analyzer when penetrating the ice cream body, while adhesive force attribute is obtained from the amount of pressure detected by texture analyzer when pulled out of the ice cream body.

2.8.2 Texture analysis with trained panelists

Texture analysis is carried out by trained panelists obtained through panelist selection. Selection of panelists includes receiving, filtering, selecting, training panelists and monitoring panelists' performance. The start of the selection phase is preceded by two triangle tests. The triangle test was carried out with sugar solutions with variations of sugar concentration, panelists were asked to determine one different sample among the three samples based on the level of sweetness [14]. Seven panelists who were able to finish two triangle tests then selected to be trained panelists for sensory evaluation. Before a sensory evaluation was carried out, three training session was conducted using three samples of commercial vanilla ice cream to introduce definitions of sensory attributes [7]. The sensory attributes are hardness in scoop, coarseness in scoop, brittleness, gumminess, iciness, smoothness, wateriness, sandiness, creaminess and greasy mouth-coating (Table 2). Sample assessment is carried out using 1-9 scale; the lower score indicates the characteristics that are unable to be found and the higher score indicates stronger characteristics felt when consuming ice cream. Throughout the panel session, panelists were instructed to drink water before assessing other sample and also to pause each assessment of several samples to avoid fatigue [7].

Table 2. Sensory attributes

Atribute	Definition
Hardness in scoop	Showing durability of small proportion of ice cream (30 g)
Coarseness in scoop	A rough sample is shown as a large amount of ice crystals that can be detected in the texture when scooping ice cream
Brittleness	A crumble ice cream, that is considerably dry, falls apart during scooping
Gumminess	A gummy sample may be described as pastry or sticky, resembles taffy and forms curls during scooping
Iciness	It is referred to lack of smoothness, usually due to presence of large ice crystals, which may accompanied by tongue numbing
Smoothness	A high degree of smoothness means the sample has a smooth and uniform spread onto the palate and no coarse or rough texture is detectable
Sandiness	The ice cream is characterized by grittiness (sand grains texture) which remains after the sample has melted or expectorated.

Source: Bahramparvar *et al*., 2013

2.9 Statistical analysis

All data obtained were analyzed statistically using SPSS Statistics 22. The data were tested for normality using the Shapiro Wilk normality test to determine the normality of the data. Parametric data were analyzed by One Way Anova test (95%) and tested further with Duncan test. Non-parametric data were tested by Kruskal Wallis test and tested further with the Multiple Comparison test. The data were tested for correlation with the Spearman Rank correlation test to determine the correlation characteristics between data.

3 Result and discussion

3.1 Hedonic

Statistical analysis of texture (Fig. 1) showed significant difference ($p<0.05$) on ice cream contained 0.2% double stabilizer. NK3 and NK4 had significant different texture compared to N1, N2, NK1 and NK2. NK3 and NK4 had a higher texture (3.88-3.93) compared to N1, N2, NK1 and NK2 which ranged from 3.14-3.33. In the same score assessment, texture of *Spirulina* ice cream obtained in this study is higher than texture of soy milk ice cream contained 0.3% seaweed stabilizer (*Eucheuma spinosum*) according to Violisa *et al*. (2012) which was 2.84 [15], and also higher than texture of vanilla ice cream contained 0-1.2% alginate stabilizers according to Mulyani *et al*. (2017) which ranged from 1.56-2.76 [16]. This study showed that 0.2% sodium alginate and κ-carrageenan can increase consumer acceptance of texture attribute of *Spirulina* ice cream.
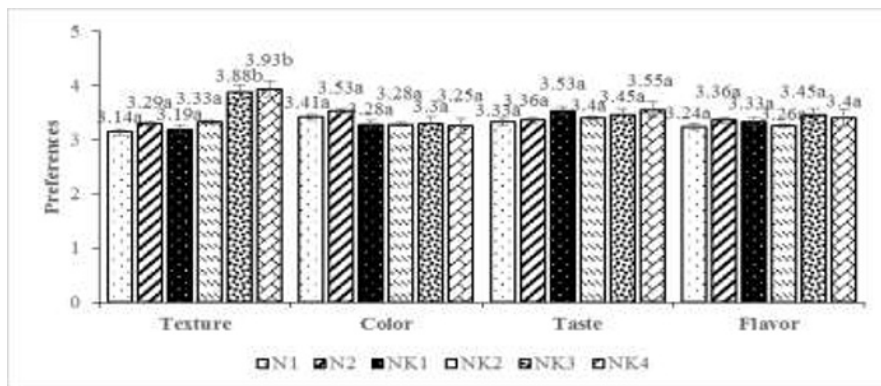
Fig. 1. Consumer preferences of *Spirulina* ice cream

N1, NK1 and NK2 had a rough ice cream texture due to the large size of ice crystals. Those indicate that 0.1% stabilizer is not able to inhibit the ice recrystallization in *Spirulina* ice cream during processing and storage. According to Soukoulis *et al.* (2008), ice cream texture is influenced by the percentage of hydrocolloids contained in product [6]. Ice cream with a higher hydrocolloid content tends to produce a softer ice cream texture, which is related to the frozen phase concentration in the serum phase [6, 17], the higher serum microviscosity phase will be more efficient in controlling free water in the ice crystals to prevent the incorporation of larger ice crystals and inhibits ice recrystallization [6, 18, 19].

The color value showed no significant difference ($p>0.05$) among all treatments, that indicates that the addition of sodium alginate and κ-carrageenan does not affect the color of *Spirulina* ice cream. Based on the results of the study, the green color on *Spirulina* ice cream originated from the concentrated *Spirulina platensis* powder.

The taste value of *Spirulina* ice cream showed no significant difference ($p>0.05$) among all treatments, that indicates that the addition of sodium alginate and κ-carrageenan does not affect the taste of *Spirulina* ice cream. A good stabilizer must have a neutral taste [20]. Taste value of *Spirulina* ice cream obtained in this study is lower than taste value of *Spirulina* ice cream according to Listyowati (2017) which was 4.19. *Spirulina* ice cream has a strong milk flavor combined with the taste of cinnamon and *Spirulina*. Cinnamon is a masking agent that can reduce the bitter aftertaste of *Spirulina platensis* [5].

The flavor value showed no significant difference ($p>0.05$) among all treatments, that indicates that the addition of sodium alginate and κ-carrageenan does not affect the flavor of *Spirulina* ice cream. Flavor value of *Spirulina* ice cream in this study is lower than flavor value of *Spirulina* ice cream according to Listyowati (2017), which was 3.7 [5]. *Spirulina* ice cream has a specific flavor mixture of milk and cinnamon in all treatments. The ice cream flavor comes from the ingredients, so the flavor deviation is not allowed. Based on the hedonic test, sodium alginate and κ-carrageenan did not affect taste and flavor of *Spirulina* ice cream [21].

3.2 pH

Spirulina ice cream pH was determined before and after the aging process (Fig. 2). *Spirulina* ice cream pH before the aging process ranged from 6.1-6.2 which was not have a significant difference ($p>0.05$) among all treatments. *Spirulina* ice cream pH after the aging process had increased, ranged from 6.3 to 6.7. pH of *Spirulina* ice cream ranged from 6.1-6.7 is normal, pH of fresh milk generally ranges from 6.3-6.75, fresh milk is the main ingredient of ice cream [22].
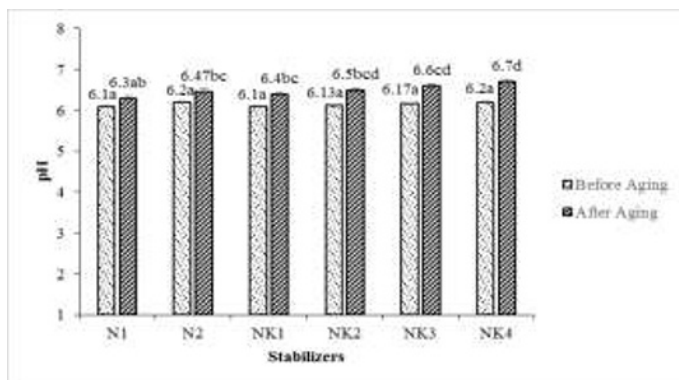

Fig. 2. pH of *Spirulina* ice cream

   Spirulina ice cream contained κ-carrageenan had a higher pH compared to *Spirulina* ice cream without κ-carrageenan. According to Derkach *et al*. (2019), compared with gelatin solution, κ-carrageenan which was left in distilled water for one hour at 20°C, then dissolved by stirring at 80°C, the pH increased from 6.7 to 8.9, while pH of the gelatin solution ranged at 4.9 [23]. The increased of κ-carrageenan solution pH due to higher polysaccharide content. κ-carrageenan is one of polysaccharide type that has been widely applied to food products [24]. pH of *Spirulina* ice cream had increased after the aging process for 24 hours in all treatments. Derkach *et al*. (2019) stated that pH of κ-carrageenan solution had increased after being left for one hour [23]. The aging process of ICM is carried out for 24 hours at a temperature of less than 4°C which aims to improve protein development and crystallization of fat so that prevent fat melting and make the ICM freeze faster and produce a better ice cream texture [20].

3.3 Viscosity

Viscosity is a measure of the resistance of a liquid when it flows. High viscosity value of ice cream mixture indicates an increasingly thick ice cream mixture [15]. The viscosity value of *Spirulina* ice cream can be seen in Fig. 3.
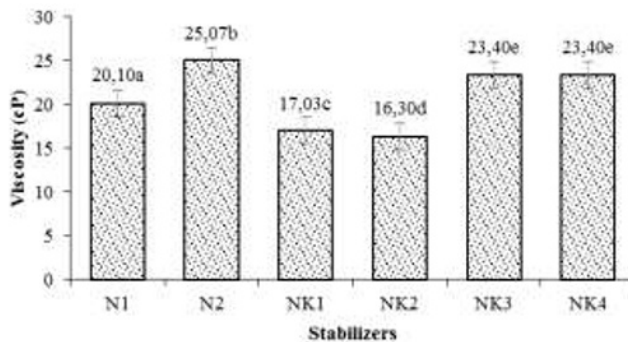
Fig. 3. Viscosity of *Spirulina* ice cream

Based on statistical analysis (Fig. 3), the viscosity of *Spirulina* ice cream showed a significant difference ($p<0.05$) among all treatments. This indicates that sodium alginate and κ-carrageenan on different concentrations affect the viscosity of *Spirulina* ice cream. NK2 had the lowest viscosity compared to the other which is 16.3 cP, while N2 had the highest viscosity among all treatments which is 25.06 cP. *Spirulina* ice cream contained 0.2% stabilizer had a higher viscosity than *Spirulina* ice cream contained 0.1% stabilizer. *Spirulina* ice cream contained 0.2% sodium alginate and κ-carrageenan had a higher hydrocolloid content, stabilizers which are hydrocolloid compounds play a role in increasing the viscosity of ice cream mix (ICM) [15]. *Spirulina* ice cream contained higher percentage of sodium alginate also showed a higher viscosity. N1 had a higher viscosity than NK1 and NK2, while N2 had a higher viscosity than N1, NK1, NK2, NK3 and NK4. Alginate is easily soluble in cold water and can absorb water to form viscosity in ice cream mix [16].

3.4 Overrun

Overrun is volume increase of ice cream from ICM volume due to the presence of air trapped in the ice cream [25]. Overrun can affect the stability of the foam and the texture that affects the sensory reception of ice cream [6]. Overrun of *Spirulina* ice cream contained sodium alginate and κ-carrageenan can be seen in Fig. 4.
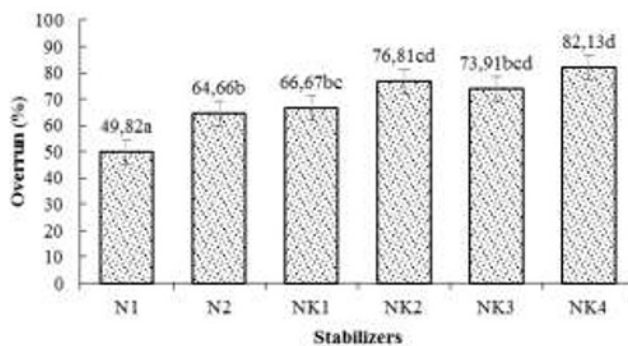

Fig. 4. Overrun of *Spirulina* ice cream

Overrun of *Spirulina* ice cream contained sodium alginate and κ-carrageenan ranged from 49.82-82.13%. High overrun of ice cream contained sodium alginate can be attributed to its ability to form rigid polymers in closed and stable air cells [6]. N1 (0,1% sodium alginate) had the lowest overrun compared to other treatments. The low overrun of N1 can be attributed to the total content of solids in ice cream. The low total solid can increase the amount of freezing water, the air trapped in the ice cream will be limited, resulting ice cream overrun decreased [26]. This study also showed *Spirulina* ice cream contained κ-carrageenan stabilizer had a higher overrun compared to *Spirulina* ice cream without κ-carrageenan. Soukoulis *et al*. (2008) mentioned that κ-carrageenan interaction with casein has been shown to be an important factor for overrun increasing [6]. Overrun of *Spirulina* ice cream contained 0.02% κ-carrageenan is higher than overrun of *Spirulina* ice cream contained 0.01% κ-carrageenan. This shows that 0.02% κ-carrageenan can increase the overrun of *Spirulina* ice cream. High overrun indicates soft texture of ice cream [14].

Overrun obtained in this study is higher than household scale ice cream according to SNI 01-3713-1995 which ranges 30-50%, also higher than vanilla ice cream according to Masykuri *et al*. (2012), which ranged from 36.60-38.45% [27]. Overrun of *Spirulina* ice cream obtained in this study is lower than the standard according to SNI 01-3713-1995 which is 70-80% and lower than vanilla ice cream contained sodium alginate and κ-carrageenan according to Soukoulis *et al*. (2008) which ranged from 70-120% [6].

3.5 Melting characterization

Melting ice cream is related to heat transfer, heat penetrates ice cream causing melting ice crystals then spread to the serum phase causing unstable fat globules and trapped air cells leaving ice crystals so that the ice cream melts [28]. Melting rate is influenced by various factors such as composition of the ingredients, the consistency of the ICM, the water content in the product, the nature of ice crystals and the fat globules formed during freezing process. Stabilizer increases melting resistance due to its ability to bind water and increase viscosity [7, 28]. Melting characteristics were reviewed through two parameters, first dripping time (the time needed for the first droplet ice cream) and melting rate (the average melting time), which can be seen in Table 3.

Table 3. Melting characteristics of *Spirulina* ice cream

Attribute	Sample					
	N1	N2	NK1	NK2	NK3	NK4
Melting rate (g/s)	0.98	0.53	0.93	0.60	0.53	0.51
First dripping time (s)	395	620	416	571	631	694

3.5.1 First dripping time

First dripping time of N1, NK1 and NK2 is lower than N2, NK3 and NK4. *Spirulina* ice cream contained lower stabilizer (0.1% stabilizer) had a lower first dripping time compared to *Spirulina* ice cream contained 0.2% stabilizer. Low first dripping time means ice cream requires faster time to melt at room temperature. This study proved 0.2% sodium alginate and κ-carrageenan can slow down the first dripping time of *Spirulina* ice cream. High hydrocolloid content can lower heat transfer, also cause higher microviscosity of the serum phase so that more time is needed for water to penetrate the serum phase before exiting the ice cream body [6] which will be seen as melting ice cream.

This study proved that κ-carrageenan can slow down the first dripping time of *Spirulina* ice cream. *Spirulina* ice cream contained 0.02% κ-carrageenan had a higher first dripping

time than *Spirulina* ice cream contained 0.01% κ-carrageenan. First dripping time is influenced by the ice crystal content related to ice recrystallization, while κ-carrageenan is a gelation agent to inhibit ice crystal growth caused by decreased water mobility due to water retention and steric resistance [29].

3.5.2 Melting rate

Melting rate of ice cream is determined by the physical structure of ice cream [28]. Melting rate of ice cream describes as volume of melt ice cream over a period of time at room temperature [14]. Melting rate of *Spirulina* ice cream contained sodium alginate and κ-carrageenan can be seen in Table 3. N1, NK1 and NK2 had a higher melting rate compared to N2, NK3 and NK4. High hydrocolloid content showed the lower melting rate. Hydrocolloids with their ability to bind water and increase viscosity can influence the quality of melting rate [30]. The increasing of ice crystal size can increase melting rate of ice cream [28].

3.6 Texture analysis

3.6.1 Texture analysis with texture analyzer

Based on texture analysis with texture analyzer (Table 4), NK4 showed the lowest hardness compared to other treatments. *Spirulina* ice cream contained 0.2% double stabilizers showed the highest hardness and cohesiveness. Hardness is the body strength of ice cream when getting external pressure [6]. Hardness can be associated with ice crystal activity in structural elements of ice cream, large ice crystals will cause higher hardness [28]. Cohesiveness shows coherence between ingredients in ice cream formulations.

Table 4. Texture attributes of *Spirulina* ice cream by texture analyzer

Atribute	Sample					
	N1	N2	NK1	NK2	NK3	NK4
Hardness (g)	688	622	631	683	593	301
Adhesive force (g)	153	184	185	173	185	186
Cohesiveness	0.26	0.27	0.25	0.32	0.37	0.41

3.6.1 Texture analysis with trained panelists

Texture analysis with trained panelists examined through sensory attributes. Based on texture analysis with trained panelists (Table 5), NK4 showed the lowest hardness in scoop, coarseness in scoop, brittleness, iciness and sandiness, while it had the highest gumminess and smoothness compared to other treatments. *Spirulina* ice cream contained 0.2% double stabilizers showed higher sensory value compared to other treatments. High stabilizer in ice cream can increase serum microviscosity phase, the higher serum microviscosity phase will be more efficient in controlling free water between ice crystals to prevent the incorporation of larger ice crystals and inhibits ice recrystallization [6, 18, 19].

Table 5. Sensory attributes of *Spirulina* ice cream by trained panelists

Attribute	Sample					
	N1	N2	NK1	NK2	NK3	NK4
Hardness in scoop	5.14	4.57	4.86	4.71	3.86	3.71
Coarseness in scoop	4.86	3.71	4.57	4.00	3.29	2.57
Brittleness	5.86	4.57	5.86	5.71	4.14	3.43
Gumminess	5.14	6.29	5.43	6.14	6.71	7.14
Iciness	5.57	4.43	4.57	4.71	3.57	2.43
Smoothness	5.14	7.00	6.00	6.29	7.00	7.57
Sandiness	4.71	3.57	4.29	4.29	3.71	3.43

4 Conclusion

The use of 0.2% double stabilizer was able to increase ($p<0.05$) the level of consumer acceptance in the texture attribute and first dripping time of *Spirulina* ice cream, but not affected ($p>0.05$) overrun. NK4 (sodium alginate 0.18% + κ-carrageenan 0.02%) showed the lowest brittleness and sandiness attribute, and the highest smoothness attribute. Therefore, the use of double stabilizer of 0.18% sodium alginate and 0.02% κ-carrageenan can be applied in the production of ice cream fortified with *Spirulina platensis*.

Acknowledgement

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