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The effect of alginate extract on the properties of brown rice (*Oryza nivara*) ice cream

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Abstract

The production of ice cream with the basic ingredients of brown rice milk is carried out to increase the consumption of antioxidants derived from brown rice (*Oryza nivara*). This is because the plant is less consumed due to its rough texture. The recent development of brown rice ice cream (BRICE) is intended to expand the use of the plant into a common commodity. Previous investigations have established that stabilizers are required in ice cream production, although only a few used natural stabilizers such as alginate. Therefore, this study aimed to determine the effect of adding the different concentrations of alginate from brown seaweed *Laminaria* sp. on the physical characteristic, namely melting power, viscosity, overrun, total dissolved solids, chemical properties, which include protein, fat, as well as antioxidant activity and hedonic level of BRICE. The concentration of alginate used was at 0.025%, 0.05%, 0.075%, and 0.1%, while the data collected were analyzed using analysis of variance (ANOVA) and Duncan's test. The result showed that the addition of different alginate concentrations had a significant effect on the value of the parameters observed.

1. Introduction

Currently, investigations are more focused on product innovation in terms of functional food. This is due to the rapid growth in global demand for these commodities and the increase in public awareness about the impact of food on health (Saputri *et al*., 2015). Functional foods are foodstuffs with bioactive components that provide multifunctional physiological effects for the body, including strengthening the immune system, regulating the rhythm of physical conditions, delaying aging, and preventing disease. The types that are widely developed include those with antioxidant activities (Azis *et al*., 2015). This is because antioxidants are substances that protect the body from radical attack. They are easily obtained from food and can stop the process of cell destruction by donating electrons to free radicals. Due to their roles as a deterrent to the emergence of various diseases, much attention is given to discovering material containing antioxidant compounds (Azis *et al*., 2015).

There is a need to consider raw materials that have good nutritional content for human health to produce functional food. This is because various kinds of food products can serve as functional foods to increase the healthy food source for humans. Ice cream is a well-known product that is liked by many people and has good potential to be developed as a functional food. Generally, it is a kind of semi-solid food made by freezing a mixture of milk, animal or vegetable fat, sugar and other permitted ingredients. According to Mulyani *et al*. (2018), ice cream is a processed product of milk and mixtures of ingredients such as cream, skim, stabilizers, emulsifiers, sweeteners and flavors. During the experiment, brown rice (*Oryza nivara*) was selected as a functional food conducted in ice cream innovation.

Brown rice is broken from the ground, while the husk is still attached to the endosperm, which is approximately 80% rich in mineral and protein content (Nuryani, 2013). It also has a low glycemic index (low starch and high complex carbohydrates) that can reduce the risk of diabetes type-2 (Latifah and Warganegara, 2018). The vitamin and mineral content are 2-3 times higher than white rice. Azis *et al*. (2015) reported that brown rice can be used as raw material because of several advantages such as higher phenolic compounds and antioxidants, which can be maintained when stored at cold temperatures (Wulansari *et al*., 2020). The phenolic compounds were concentrated higher in the

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pericarp and aleurone layers (Ekowati and Purwestri, 2016). A previous study has discovered that the red color of brown rice is formed from anthocyanin pigments, therefore, the darker the color, the higher the antioxidant content. Currently, this product is less consumed due to its rough texture and little bitter taste (Nurhidajah and Nurrahman, 2016). However, it is commonly consumed directly or as brown rice milk that is produced on a large scale in Japan and Australia (Anggraeni *et al*., 2018). One of the innovations of brown rice is the production of ice cream. This is to increase the consumption of brown rice as well as diversify ice cream products, which collaborate to be developed into functional foods.

Another aspect that needs to be considered when producing ice cream is the use of stabilizers. Without the addition of a stabilizer, larger ice crystals might appear because the texture is not soft and the melting speed is relatively fast. A previous report has identified several problems among the public in the manufacture of food products, especially ice cream. Although the use of animal stabilizers is doubtful of halal, there is limited information on the application of vegetables (Mulyani *et al*., 2018). Therefore, this study was carried out using an alginate vegetable stabilizer extracted from brown seaweed *Laminaria sp*. Alginate is a type of hydrocolloid and a colloid system by organic polymers in water (Subaryono, 2010).

The advantages of alginate include antioxidant bioactivity due to the presence of hydroxyl groups, which will donate hydrogen atoms when reacting with free radical compounds, leading to the inhibition of the oxidation process (Kamisyah *et al*., 2020). In the food sector, alginates are widely used as emulsion stabilizers, suspenders, and viscosity regulators (Subaryono, 2010). Therefore, this study aimed to determine the physical, chemical, and organoleptic characteristics of BRICE with the addition of alginate.

2. Materials and methods

2.1 Sample preparation

This study begins with the preparation of brown rice puree and the raw materials used were brown rice and water. The production process was carried out based on the procedures by Boonterm *et al*. (2012) and Lee *et al*. (2019) with slight modifications. The brown rice was washed 3 times, mixed with water in a ratio of 1:6 (w/v), and refined using a blender for 7 s. The refined brown rice milk was pasteurized at a temperature of 70-75°C for 20 mins. The last stage was the filtering process.

2.2 Brown rice ice cream formulation

The ingredients used in making BRICE are brown rice puree, milk, gelatin, whipping cream, sugar, salt, CMC, and alginate extract from chocolate seaweed *Laminaria* sp. These ingredients have the same amount but a different ratio of alginate extract. A dough was formed by mixing the ingredients presented in Table 1.

2.3 Physical analysis of brown rice ice cream

2.3.1 Melting power

The principle of the melting time test is based on the duration for the sample to melt completely at room temperature. The melting time is calculated using a stopwatch on a 5 g sample that has been frozen for 24 hours and allowed to melt at room temperature. Subsequently, the melting power test was carried out using the melting resistance method, which is the time required to melt ice cream at a certain volume (Pramono and Hintono, 2019).

2.3.2 Viscosity

The viscosity of the BRICE was measured using a rotational viscometer digital (LVDVE230, Brookfield, USA). During measuring, all samples were in cold water to prevent the change in temperature (Al Hajar *et al*., 2019).

2.3.3 Overrun

Overrun was carried out by measuring the volume of

Table 1. Brown rice ice cream formulation with different levels of alginate extract.

Ingredients	Formula									
	Control		1		2		3		4	
	g	%	g	%	g	%	g	%	g	%
Milk	200	59.3	200	59.27	200	59.23	200	59.2	200	59.2
Brown rice puree	50	14.8	50	14.8	50	14.8	50	14.8	50	14.8
Sugar	50	14.8	50	14.8	50	14.8	50	14.8	50	14.8
Cream	35	10.4	35	10.4	35	10.4	35	10.4	35	10.4
CMC	1	0.3	1	0.3	1	0.3	1	0.3	1	0.3
Gelatin	1	0.3	1	0.3	1	0.3	1	0.3	1	0.3
Salt	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1
Laminaria sp. alginate extract	-	-	0.08	0.025	0.17	0.05	0.25	0.075	0.33	0.1
Total	337.5	100	337.6	100	337.7	100	337.8	100	337.8	100

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ice cream dough before and after being processed in an ice cream maker. It was calculated using the equation expressed by Achmad *et al*. (2012):

$$Overrun\ (\%) = \frac{V2 - V1}{V1} \times 100\%$$

Where V1 = volume of ice cream dough before processing and V2 = volume of ice cream dough after processing.

2.4 Nutritional analysis of brown rice ice cream

2.4.1 Antioxidant activity analysis

The antioxidant activity was determined using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method (Yen and Chen, 1995). A total of 0.1 mM DPPH reagent was prepared in methanol, 2.9 mL of the reagent was added to 100 µl of the sample, and vortexed in the test tube at 500 g for 2 mins. This was followed by the incubation of tubes in the dark for 30 min at 25°C and the color reduction was measured at 517 nm using a spectrophotometer (Shimadzu) (Sami *et al*., 2019).

2.4.2 Chemical composition analysis

The products were subjected to chemical composition analysis for fat and protein content. The fat analysis was carried out using the soxhlet method (Apriyantono *et al*., 1989), while the protein content was calculated by Kjedahl procedures (Apriyantono *et al*., 1989).

2.5 Sensory evaluation of brown rice ice cream

Sensory evaluation was performed using 7 points scale and randomly coded samples were offered to thirty panels. The BRICE with different levels of alginate extract were evaluated for their sensory attributes which are smell, texture, taste, color, and overall acceptability (Abilgos-Ramos *et al*., 2019)

2.6 Statistical analysis

The experimental design was completely randomized. The statistical analysis was carried out using Analysis of Variance (ANOVA) and the data were expressed as mean ± standard deviation (SD). Subsequently, Duncan's Multiple Range Test was used to identify significant differences between the mean values at $p<0.05$.

3. Results and discussion

3.1 Physical characteristic of brown rice ice cream

Ko *et al*. (2014) reported that the melting time of ice cream is related to air content, fat size, ice crystal size and others. Based on the results shown in Table 2, the melting time of BRICE ranged from 16.9 to 41.2 mins. Formulations using 0.025%, 0.05%, 0.075%, and 0.1% of alginate extract maintained their appearance longer than the control at room temperature. Mulyani *et al*. (2018) mentioned that alginate can regulate the emulsion balance of water holding capacity and colloid protection. This has a relationship with the alginate extract to increase the solid ability of ice cream at room temperature. Alginate functions as a stabilizer that forms a gel or mixes with water to inhibit melting quickly. According to Muse and Hartel (2004), the fat network plays a key role in determining the melting time of ice cream. Hidayah *et al*. (2017) have discovered that several factors affecting the melting rate other than stabilizers include the accumulation of fat (fat destabilization/agglomeration), viscosity, and size of ice crystals. The fat destabilization forms a clump of globules that coat and surround the air. According to Hidayah *et al*. (2017), high-fat globules will increase the resistance to the flow of serum (water-soluble material) when melted and decrease the rate of melting because the chain of fat globules formed builds tissue. Prapasuwannakul *et al*. (2014) reported that melting time may be related to viscosity, hardness, and overrun. In this study, the value of the statistical analysis using One Way ANOVA with a confidence level of 0.05 was significant. Therefore, it can be concluded that the addition of alginate extracts significantly affected the melting time of BRICE.

Table 2 shows that the values of the calculated viscosity ranged from 2.095-2.805 cP. Formula 1, which was without addition has the lowest, while formula 5 with the 0.1% alginate addition has the highest viscosity, compared to the overrun value. The higher additive of alginate extract led to more viscosity with less overrun value than the control. This is because when the viscosity of the dough is high, less air enters the ice cream during the manufacturing process (Prapasuwannakul *et al*., 2014). Yeon *et al*. (2017) reported that the higher viscosity has lower overrun ice cream. However, a high

Table 2. Physical characteristics of BRICE with different levels of alginate extract.

Formula	Control	1	2	3	4
Melting power (mins)	16.9±0.9^{a}	25±0.8^{b}	29.4±0.8^{c}	34.9±0.8^{d}	41.2±0.8^{e}
Viscosity (cP)	2095±6.1^{a}	2204±5.7^{b}	2212±4.7^{b}	2505±4.8^{c}	2805±6.8^{d}
Overrun (%)	41.2±0.9^{d}	38.5±0.8^{c}	35.2±0.9^{b}	33.9±0.9^{ab}	32.7±0.6^{a}
Dissolved solid (°Brix)	27.1±0.3^{a}	28.1±0.4^{b}	28.6±0.4^{b}	29.5±0.5^{c}	30.1±0.1^{c}

Values are presented as mean±SD of triplicates. Values with different superscripts within the same row are statistically significantly different ($p<0.05$).

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value produces a soft texture and small ice crystals, which reduces the overrun value (Violisa *et al*., 2013). Goraya *et al*. (2021) reported that an appropriate viscosity can hold enough amount of air. The low values of both parameters may be responsible for their longer form appearance at room temperature. Overrun is the expansion of the ice cream volume to the initial dough volume due to the air trapped in the ice cream (Hasanuddin *et al*., 2011). It is an increase in the volume of the ice cream dough due to the presence of a retaining wall that traps air to freeze and prevents the air from breaking into the cream during storage (Hidayah *et al*., 2017). It is suggested that ice cream overrun for household production scale is 30-50% and industrial scale is 70-80% (Chodijah *et al*., 2019).

The total solids will also affect the viscosity (Simanullang *et al*., 2019), this is related to the higher protein content, leading to a larger number of particles that can bind to water. Therefore, the total solids bind to water and increase the viscosity (Bayu *et al*., 2017).

3.2 Nutritional compound of brown rice ice cream

3.2.1 Antioxidant activity of brown rice ice cream

The antioxidant compounds in BRICE, with values 19.65 to 27.59% reacted with DPPH radicals and decolorized the original deep purple. Verma *et al*. (2009) reported that the scavenging potential was indicated by the degree of decolorization due to the donation of hydrogen protons to terminate the free radical mechanism. In this study, the antioxidant activities of the control were 19.65±0.5, while formulae 1, 2, 3, and 4 of BRICE samples were 21.49±0.7, 25.93±0.6, 26.70±0.7 and 27.59±0.6%, respectively. A linear correlation was observed between the concentration of alginate extract and the antioxidant activity. Alginate concentration significantly affected the antioxidant activity of BRICE. This showed that the antioxidant activity is strongly connected with the alginate extract concentration.

3.2.2 Chemical composition of brown rice ice cream

The chemical composition of BRICE samples prepared using different levels of alginate is shown in Table 3. For different treatments, fat content in the BRICE ranged from 5.73±0.1% to 6.07±0.2%, and protein content from 1.92±0.1% to 2.44±0.1%. Fat content for all treatments had a statistically non-significant compositional difference ($p \geq 0.05$). According to SNI 01-3713-1995, the minimum value of the fat content of ice cream is 5.0%. In this study, the addition of alginate extract to BRICE did not induce any observable effect on fat attributes, which are related to that of milk. Meanwhile, the average fat content of alginate seaweed is only 1-3% of the dry weight. This low value is due to their food reserves in form of carbohydrates, especially polysaccharides (Handayani *et al*., 2004). However, the addition of alginate *Laminaria* sp. extract containing up to 0.05% has a significant effect on the protein content of BRICE. The protein value of formulae 2, 3, and 4 samples were significantly ($p<0.05$) and higher than the control. This is due to the high protein content of seaweed *Laminaria* sp., which is 6.7% in units of g/ 100 g dry weight (Erniati *et al*., 2016). In the production of ice cream, the protein element stabilizes the fat emulsion after homogenization, adds flavor, assists foaming, increases and regulates the water -holding capacity, which affects the viscosity and texture of soft ice cream (Mulyani *et al*., 2018).

3.3 Sensory evaluation of brown rice ice cream

A total of 30 participants evaluated the BRICE samples made with different concentrations of alginate extract. The sensory evaluation results listed in Table 4 showed that the addition of *Laminaria* sp. alginate extract has a significant ($p<0.05$) effect on the texture, taste and overall acceptability of BRICE treatment samples. The texture parameter ranged from 4.43 to 6.13, which implies the panelists gave a neutral-to-like assessment. The taste parameters value ranged from 5.10 to 6.33, while the overall sensory value varied from 5.03 to 6.27. The high addition of alginate extract obtains a greater score of texture, taste, and overall acceptability. The smell and color have no significant effect on the addition of different concentrations of *Laminaria* sp. alginate extract. Although formula 1 BRICE has a similar rate to the control, participants liked the sample better than the control. This is indicated by the overall acceptability value, which was higher than the control.

Ice cream is a partially complex frozen food consisting of ice crystals, air cells, emulsified fat, colloidal sugars, salts, proteins and stabilizers (Goraya and Bajwa, 2017). Its textural properties are the key aspects that determine market success (Goff and Hartel, 2013). Ice cream manufacturers are constantly seeking solutions to improve quality. During the manufacturing process, ingredients such as hydrocolloids, including alginate, and cellulose are used to augment the serum-

Table 3. Chemical composition of BRICE with different levels of alginate extract.

Formula	Control	1	2	3	4
Fat (%)	5.73±0.1^{a}	5.82±0.2^{a}	5.93±0.3^{a}	5.97±0.2^{a}	6.07±0.2^{a}
Protein (%)	1.92±0.1^{a}	2.05±0.1^{a}	2.23±0.2^{b}	2.31±0.1^{bc}	2.44±0.1^{c}

Values are presented as mean±SD of triplicates. Values with different superscripts within the same row are statistically significantly different ($p<0.05$).

Table 4. Sensory evaluation of BRICE with different levels of alginate extract.

Formula	Control	1	2	3	4
Smell	5.73±0.9[a]	5.50±0.7[a]	5.47±0.8[a]	5.37±0.9[a]	5.20±0.9[a]
Color	5.87±0.9[b]	5.73±0.7[ab]	5.70±0.9[ab]	5.57±0.8[ab]	5.30±0.9 [a]
Texture	4.43±0.9[a]	4.83±0.9[ab]	5.17±0.7[b]	5.60±0.8[c]	6.13±0.7[d]
Taste	5 .10±0.9[a]	5.43±0.9[ab]	5.73±0.8[bc]	5.90±0.8[c]	6.33±0.8[d]
Overall acceptability	5.03±0.9[a]	5.37±0.8[ab]	5.77±0.7[bc]	5.93±0.9[cd]	6.27±0.7[d]

Values are presented as mean±SD of triplicates. Values with different superscripts within the same row are statistically significantly different ($p<0.05$).

phase micro-viscosity and resist air cells from shrinking during storage. This is because hydrocolloids have an inequitable impact on ice cream structure, even at low concentrations, due to their different properties (Goraya and Bajwa, 2018). Since hydrocolloids exhibit their functionality at lower concentrations, the addition of ingredients and mixing techniques can impact the mix's consistency. Due to the solubility and gel-setting conditions during freezing and hardness, alginates are preferred for ice creams.

Alginate is one of the polysaccharide groups that is a major component of brown algae sap and is an important compound in cell walls (Kloareg and Quatrano, 1988; Belitz *et al*., 2008). In the cell wall and the intracellular environment, alginate is found as a mixture of alginic acid salts such as calcium, sodium, or potassium. Chemically, alginate is a pure polymer of uronic acid composed of long linear alginic acid (Stephen and Phillips, 2016). This pure polymer is unbranched and contains 1.4 β D-mannuronic and 1.4 α L-guluronic acid bonds. As a stabilizer, alginate serves as a thickening agent that provides a broad variety of flow behavioral properties, namely gel firmness which correlates with crystal growth inhibition and changes the morphology (Goraya *et al*., 2021). The product form is generally sodium alginate which is soluble in water. In the presence of calcium ions, it sets a strong gel structure on cooling that lowers the recrystallization rate than gelling stabilizers (Regand and Goff, 2003). It was also reported that sodium alginate can control ice recrystallization, regardless of the storage time, and improve frozen texture when compared to other gums (Soukoulis *et al*., 2008).

Other water-soluble alginate forms are potassium or ammonium alginate, while water-insoluble is sodium. To form a gel, it needs divalent ions such as calcium (Ca^{2+}) for crosslinking polymers to attain better sensory attributes (Goraya *et al*., 2021). A previous study reported that sodium alginate has colloidal, gel-forming, and hydrophilic properties, leading to its wide use as an emulsifier and stabilizer in the industry (Subaryono, 2010). Meanwhile, the hydrophilic nature of alginate is used to bind water and stabilize the food during the freezing process. The addition of alginate to ice cream might cause the increasing mix viscosity, prevent serum separation, enhance melting rate, produce stable foam, retard ice crystal growth, delay the moisture migration from the product, and prevent shrinkage during storage (Goff and Sahagian, 2019).

4. Conclusion

The addition of different levels of alginate extract in BRICE affects physical characteristics with parameters such as melting time, viscosity, overrun and total dissolved solids. The highest melting time, viscosity, and total dissolved solids of 41.16 mins, 2.805 cP, and 30.05°Brix, respectively, were obtained in the BRICE sample with 0.1% concentration of alginate. Meanwhile, the highest value of fat, protein content, and antioxidant activity was produced by the addition of alginate with a concentration of 0.1% which was 6.07%, 2.44% and 27.59%, respectively. The addition of alginate in various concentrations in the manufacture of BRICE did not affect the sensory characteristics of aroma and color but affected the texture, taste, and overall. Based on these results, the best formulation for making BRICE is the addition of 0.1% alginate.

Conflict of interest

The authors declare no conflict of interest.

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