Effect of addition of semi refined carrageenan on mechanical characteristics of gum arabic edible film

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Abstract. Currently the seaweed is processed flour and Semi Refined Carrageenan (SRC). However, total production is small, but both of these products have a high value and are used in a wide variety of products such as cosmetics, processed foods, medicines, and edible film. The aim of this study were (1) to determine the effect of SRC on mechanical characteristics of edible film, (2) to determine the best edible film which added by SRC with different concentration. The edible film added by SRC flour which divided into three concentrations of SRC. There are 1.5%; 3%; and 4.5% of SRC, then added 3% glycerol and 0.6% arabic gum. The mechanical properties of the film measured by a universal testing machine Orientec Co. Ltd., while the water vapor permeability measured by the gravimetric method dessicant modified. The experimental design used was completely randomized design with a further test of Duncan. The result show SRC concentration differences affect the elongation breaking point and tensile strength. But not significant effect on the thickness, yield strength and the modulus of elasticity. The best edible film is edible film with the addition of SRC 4.5%.

1. Introduction

Indonesia has become the largest producer of seaweed in the world, particularly Eucheuma cottonii. Statistical data while the UN Food and Agriculture Organization (FAO) published in March 2015 mentioned the production of Indonesian seaweed species Eucheuma cottonii in 2013 ranks first in the world that is as much as 8.3 million tones. As for the seaweed Gracilaria sp. in the same year, Indonesia ranks second after China, with a production of 975 000 tones [11]. Indonesia ministry of industry supports the cessation of exports of seaweed gradually.

Eucheuma cottonii seaweed has been used as a source of iodine to prevent goiter on the thyroid, fertilizer to the energy source of bioethanol [6]. Because of its function as a source of iodine, it was an opportunity using algae as a mixture of dodol [13]. A development of algae as an edible film carrageenan was reviewed [4]. Edible film may be made of hydrocolloids, lipids, and composites [8]. When this was developed on the basis of hydrocolloids edible film, including the use of polysaccharides [16, 17, 18]. Films made of composite materials with k-carrageenan and locust bean gum [10]. A mixture of two polysaccharides enables better mechanical properties and water vapor permeability. Gum arabic is one of main material base for edible film [9]. Edible films gum arabic can be combined with chitosan [15]. But the packaging must remain flexible so that the packaging is not
easily torn. In addition, the packaging must be able to withstand the vapor permeability of water the material is packed. Therefore, it takes a lipid as a plasticiser to increase the flexibility of the package based on polysaccharides [14]. To improve the mechanical properties of the film of gum arabic can be added Semi Refined Carrageenan (SRC) and glycerol.

SRC is a product derived from seaweed *Eucheuma cottonii* that alkalized. Carrageenan alkalization process decrease a part of sulphate content. This can improve the strength of the carrageenan gel better than carrageenan. The aim of this study were (1) Knowing the mechanical characteristics of the SRC edible film, (2) Determine the best treatment of SRC edible film. SRC flour divided into three concentrations of 1.5%; 3%; and 4.5% with the addition of glycerol 3% and 0.6% arabic gum.

2. Materials and methods

SRC used in this study were made from seaweed powder. Each edible film added by SRC flour with different concentrations, and then carried out a mechanical characteristics and the water vapor permeability measurement.

2.1. Materials used.
The main material used is seaweed of *Eucheuma cottonii* which bought from traditional market in Bandung, West Java. The chemicals used are Potassium Hydroxide (Merck), Gum arabic (Bratachem), glycerol (Bratachem) and distilled water. The glasswares used are glass beaker, hot plate stirrer, thermometer, measuring cup, Erlenmeyer, aluminum foil, pan and the oven fan.

2.2. SRC flour preparation.
SRC made from *Eucheuma cottonii* extract powder with a size of 60 meshes. SRC flour preparation process is modified from [3]. Algae washed to remove impurities such as sand and gravel. Then algae dipped in 3% of Potassium Hydroxide solution for 30 minutes to remove salts and impurities. Then algae boiled in 8% of Potassium Hydroxide solution with a ratio of dry seaweed and solution of 1:8 (w/v) at 75° C ± 2 °C for 3 hours. Wash algae until the wash water has a neutral pH. Then slice algae with a size of 0.5 – 1 cm. Then algae should be dried at 37°C for 1-2 days. Dried algae grinded and filtered with a 60 mesh screen.

2.3. Edible film preparation.
Edible films made from 0.6% gum Arabic, 3% glycerol and SRC with concentration of 1.5%; 3% and 4.5% respectively. A method of preparation an edible film refers to [12] with modifications. The first step in edible film preparation is dissolution of flour SRC into 80 ml of distilled water (mixture A). Once uniformly mixed, heating the mixture A on a hot plate stirrer for 15 minutes at a temperature of 50°C. Then add the mixture B (3% glycerol and 0.6% gums Arabic was dissolved in 20 ml distilled water) and heat to 60 °C for 15 minutes. Then the air needs to reduce with a vacuum pump (degassing) for 10 minutes. Films printed on glass mold as edible film A (SRC 1.5%), edible film B (SRC 3%), and edible film C (SRC 4.5%). Each edible film put in a drying oven for 10-12 hours.

2.4. Characterization and Measurements.

2.4.1. Measurement of the mechanical characteristics of edible film
The samples that were printed then tested the straining until the film broken. This test used a universal testing machine Oriented Models Co. Ltd. UCT-5T.

2.4.2. Measurement of the speed of water vapour transmissions
The test is performed using Standard Test Methods for Water Vapor Transmissions of Materials [1] modified. SRC edible film to be tested is placed in a porcelain dish containing 10 g of silica gel. The edge of the cup covered with insulation. The cup and edible film were weighed, put into a plastic jar containing 100 ml of 40% sodium chloride solution, and then the jar is sealed. Each time the cup is
weighed. This observations for 8 hours. Vapor permeability of water is expressed as the slope of the cup-weight gain (g / h) divided by the area of the test sheet (m²). The water vapor transmission is calculated by the formula:

\[
WVT = \frac{\Delta W}{t \times A}
\]

Where, W is weight changes edible film after 8 hours, t is time (hours), A is area of the surface area of the film (m²).

3. Experimental design
This study used a completely randomized design (CRD), which is arranged with one factor, namely the concentration of the SRC. SRC concentration composed of three levels, namely 1.5%; 3%; and 4.5%. On mechanical examination five repetitions while the transmission permeability of water vapor carried with two repetitions long test times for eight hours. Data were initially evaluated by analysis of variance (ANOVA), and significant results were further analyzed using Duncan’s multiple range tests (p < 0.05) to compare the mean values of films’ properties.

4. Result and Discussion
4.1. The thickness of edible film
Based on the average results can be described an increase of the thickness of the added edible film SRC. The higher concentration of SRC added to the edible film, the thickness of the edible film will be even greater. The average result of edible film thickness has shown on Figure 1.

![Figure 1. The average value of edible film thickness which SRC added.](image)

Solution of edible film A molded more easily than edible film B and C. It shows the concentration of SRC affects the texture of the solution. The more liquid of solution make easier to print uniformly, but if the solution more viscous and have jeladal properties, it should use a tool to flatten the surface of the film. Jendal properties in edible film solution are influenced by the concentration of the gum arabic and SRC. Gum arabic absorbs the free water contained in the solution of the edible film SRC. The fluid which trapped in the gum solution is then formed a gel [5].

Gum arabic contains a protein consisting of amino acid and hydroxyl groups which are hydrophilic. This is the hydrophilic group which can form hydrogen bonds with one or more molecules of water, so that it can absorb water and keep it in a molecule. Then, a liquid form a viscous colloidal with gel structure. The addition of less concentration of gum and SRC could form a viscous solution. The polysaccharide gum group and its derivatives (including carrageenan) are characterized by its ability to produce highly viscous solutions at low concentrations [7]. The result of thickness test obtained
there is not significantly different between edible film B and C. But the best thickness is edible film A, its about 0.082 mm.

4.2. Tensile strength of the edible Film
The higher concentration of SRC increased the tensile strength of the film. The results of variance calculations show that the F-results > F-table (28.52) > F (3.89) in 5% and 1% level (6.93). There is a significantly different treatment. Edible film A and B have SRC concentrations lower than edible film C, so the film has a tensile strength value less than C. The less solids content in the solution is lower tensile strength values. The average of SRC tensile value shown in Figure 2.

![Figure 2. The average tensile strength value of SRC edible film.](image1)

4.3. Elongation of the edible film
Elongation of an edible film is provided by the number of force which makes an edible film broken. Then measured a number of edible film lengthening before separating, then we calculate the average of the results. The higher concentration of SRC added make the edible film texture becomes more rigid. The higher concentration of SRC, elongation or lengthening becomes lower. The addition of the gum arabic in edible film compositions also affect to the texture of the edible film. The average elongation value of edible film shown in Figure 3.

![Figure 3. The average elongation value of SRC edible film.](image2)

Indeed, both SRC and gum arabic is a substance which can bind the water such that the higher concentration of the SRC edible film solution is more viscous. Once dry, edible film with the higher
concentration of SRC made the edible film become harder. The best results edible film elongation values are edible film C. The solid film that is formed, it is increasingly difficult for the elongated film so that it reduces the percentage of the value of the extension. Powerful edible film should pack the food.

4.4. Yield stress of SRC edible film.
Yield is the edible film indicated value before changes when pressurized and forced. In the case of linear polymers, the yield point is often defined as the expected maximum stress. Indeed, the measurement of the yield expected maximum elasticity, very sensitive to how the load applied during the tensile test [2].

![Figure 4. The average yield stress value of SRC edible film.](image)

The results of tests shown the addition of SRC on different concentrations of edible film does not provide a real effect on the yield of edible film. It is assumed lack of accuracy when testing the yield strength during the test. The yield stress value must be measured accurately before edible film changes due to the force on the edible film. The average yield stress value of SRC edible film shown in Figure 4.

4.5. Modulus of elasticity of edible film.
Modulus of elasticity is a linear elasticity which uses a comparison between the strain and the stress. The test results showed that higher addition of SRC concentration causes higher the modulus of elasticity. The elasticity differences suggest that the differences in the concentration of edible SRC to provide a different modulus of elasticity of the film. The average modulus elasticity value of edible film shown in Figure 5.

![Figure 5. The average modulus elasticity value of SRC edible film.](image)
4.6. Water vapor permeability of edible film.
The results of the vapor permeability of water from the edible film for 8 hours showed that the higher concentration of the added SRC causes decreasing of vapor permeability of water. The results of analyzing of variance show that there was no significant difference, either at the 5% and 1%. However, a good edible film is edible film with the lowest vapor permeability of water. Test results showed that the edible film to the value of the lower water vapor permeability is an edible film of C, with an average of 0.975 g-water / m$^2$.8h. Water vapor permeability of SRC edible film shown in Figure 6.

![Water vapor permeability of SRC edible film](image)

Figure 6. Water vapor transmission of SRC edible film.

5. Analysis of variance the mechanical characteristics of the edible film variance
Table 1 shows the variance analysis results of the mechanical characteristics of edible film SRC. Other tests have shown that the addition of SRC Duncan 3% and 4.5% on the same influence edible film thickness statistically. With regard to the modulus of elasticity characteristics known to increase by 4.5% SRC differ significantly from 1.5% to 3%. Meanwhile, further SRC 1.5% and 4.5% did not differ significantly, but significantly over the addition of 3% SRC. But adding CBC with different concentrations had a significant effect on the elongation point of the parameters at break.

| Mechanical characteristics | Concentration of SRC |
|----------------------------|----------------------|
|                            | 1.5% (A)            | 3% (B)            | 4.5% (C)          |
| Thickness (mm)             | 0.0838$^a$          | 0.1660$^b$        | 0.1620$^b$        |
| Tensile strength (MPa)     | 1.6615$^a$          | 2.6564$^b$        | 7.6352$^c$        |
| Break point elongation (mm)| 30.2750$^a$         | 22.1342$^b$       | 13.2522$^c$       |
| Yield stress (Mpa)         | 1.6586$^a$          | 2.6634$^b$        | 1.9796$^c$        |
| Modulus of elasticity (MPa)| 3.9907$^a$          | 3.5460$^a$        | 162.8544$^b$      |

**Table 1.** The variance analysis results and duncan test results.

**Conclusion**
The result show SRC concentration differences affect the elongation breaking point and tensile strength. But not significant effect on the thickness, yield strength and the modulus of elasticity. The best edible film is edible film with the addition of SRC 4.5%.

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