The Effect of Sorbitol Addition on the Characteristic of Carrageenan Edible Film

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Abstract. Edible film is a thin layer functioning for packaging or coating of food ingredients. Edible films can be made up from basic ingredients such as carrageenan as it is cost efficient and environmentally friendly. Carrageenan edible film is fragile and therefore it is important to add sorbitol as a plasticizer to produce a more elastic and stronger edible and meet the standard. This study aims to determine the effect of sorbitol concentration addition on a characteristics of edible film carrageenan, and to determine the optimal addition of sorbitol concentration in producing carrageenan edible film with the best characteristics. This study used a completely randomized design (CRD) with four types of treatment of different sorbitol concentrations, namely 0%, 2%, 4%, 6%. Each treatment was conducted five times. The results and analysis of the data showed that the addition of sorbitol concentration could affect the characteristics of edible film carrageenan, including its thickness, tensile strength, and elongation at break. On the other hand, the transmission rate of edible film carrageenan vapor was not affected by the addition of sorbitol concentration. The addition of 6% sorbitol concentration resulted in carrageenan edible film with thickness of 0.222 mm, tensile strength of 7.136 kgf/cm², broken extension of 20.46%, and water vapor transmission rate of 6.83 g/m²/day.

Keywords. Edible film, carrageenan, sorbitol, thickness, tensile strength, elongation, water vapor transmission rate.

1. Introduction
The development of packaging in the packaging industrial is expanding and diversified as technology advances. Packaging is a treatment of safeguarding or preservation of a product so it remains in good condition and safe for consumption (Firman, 2012). Plastic packaging is widely used because it has superior properties, e.g. light, transparent, waterproof, elastic, and affordable. However, plastic packaging waste also poses the biggest environmental problem for the environment. Plastic commonly used packaging are polyethylene, polyvinyl, and polystyrene which have negative impact on the environment, cannot be degraded, and is expensive (Saputra, 2015). Plastic waste takes 200-400 years to decompose (Hasannudin, 2015).

Based on its statistics on domestic solid waste, Indonesia occupies the second largest plastic waste producing country in the world after China. Its produces plastic waste 5.4 million tons per year (Bebassari, 2014). This underlies the need for this research into synthetic plastic substitute packaging materials that can be broken down by microorganisms in the soil (Kusumawati and Putri, 2013). Edible film is food packaging that does not pollute the environment (Murdianto, 2005).
The advantages of edible film compared to plastic packaging commonly used are: act as a barrier against oxygen, reduce water evaporation, and improve the appearance of the products packed (Harmely et al., 2014). One of the natural resources of biopolymers that can be used as a base for edible film is carrageenan (Herliany et al., 2013). Carrageenan is one of polysaccharide polymers. The use of polysaccharides as the base material for making edible films is based on the relatively low cost compared to other materials, material abundance, and its thermoplastic nature (Brody, 2005). Edible films can be made from the basic ingredients of carrageenan because it is affordable and environmentally friendly (Fardhyanti and Julianur, 2015).

Edible film made from pure polymers is fragile therefore plasticizer is required to increase its flexibility (Yoshida et al., 2009). One type of plasticizer that can be used in making edible films is sorbitol (Vieira et al., 2011). Baldwin et al., (2012) stated that sorbitol could reduce bonding internal hydrogen in intramolecular bonds. This can produce better mechanical strength. The right concentration of sorbitol influences the characteristics of edible film. Several previous studies have used sorbitol as plasticizer in manufacturing edible films including pectin-based (Wirawan et al., 2012), tapioca (Paradita, 2013) and banana peel starch (Widyaningish et al., 2012). This study was conducted to determine the effect of adding sorbitol to the characteristics of carrageenan edible film.

2. Material and method
2.1. Time and place
The study was conducted in December 2016 in Education Laboratory of Faculty of Fisheries and Marine, Airlangga University Surabaya, and Laboratory of Faculty of Pharmacy, Airlangga University.

2.2. Research material
The tools used in making edible films were beaker glass, measuring cup, spinbar, hot plate stirrer, thermometer, analytical scale, spatula, stirring rods, saucer, 15x15 cm2 glass plate, oven, scissors, plastic spoon. The tools used in testing the characteristics of edible films were desiccator, plastic sample container, silica gel, tensile strength and elongation tester, and digital thickness. The materials used in this study were carrageenan, sorbitol, and aquades.

2.3. Research method
This is an experimental research. The research design used was completely randomized design (CRD). There were four types of treatment of different sorbitol concentrations, namely 0%, 2%, 4%, 6% and each treatment was repeated five times.

3. Work procedure
3.1. Making the edible film
The procedure for creating an edible film was as follows: we made carrageenan solution with a concentration of 1.5% (b/v) each. Next, each of them was poured into a measuring cup of 100 ml then mixed with 100 ml distilled water. We stirred the mix with a magnetic stirrer, then heated it using a hot plate until it reached 50°C. Next, sorbitol (0; 2; 4; 6%) was added as plasticizer while continued stirring and heated until it reached 60°C and maintained for 5 minutes.

We poured the edible film solution into a glass plate and dried it in an oven 50°C for 6 hours to create an edible film. The carrageenan edible film was cooled down to room temperature (25°C). Afterwards, it was separated from the glass plate. Next, we conducted a characteristics testing on the edible film which included thickness, tensile strength, elongation, and water vapor transmission rate (Fardhyanti and Julianur, 2015).

3.2. Characteristic testing of edible film
Testing of edible film characteristics produced included thickness, tensile strength, elongation, and the water vapor transmission rate of the edible film (Nurindra et al., 2017).
3.2.1. **Thickness testing**
Thickness testing was done with a digital thickness with an accuracy of 0.01 mm and placing a sample of edible film between the jaw micrometers. Measurements were carried out in five different places. Next, we took an average of the results to get the thickness that represented the sample (Nugroho et al., 2013).

3.2.2. **Tensile testing**
Testing of tensile strength was done by clamping the sample on the tensile strength and elongation tester. Next, we recorded of cross-sectional area and the initial length of the edible film sample was carried out. The start button on the computer is pressed and the tool will pull the sample at a speed of 100 mm/minute until the sample breaks. After the sample is broken, the maximum voltage will appear on the computer and then calculated (Setiani et al., 2013).

3.2.3. **Elongation testing**
The measurement of the breakout extension was done by clamping of each tip of the sample to the tensile strength and elongation tester. Next, we recorded the initial length of edible film samples. The start button on the computer was pressed and the tool pulled the sample at a speed of 100 mm/minute until the sample broke off. After the sample broke off, the final length of the sample appeared on the computer and then we measured it (Setiani et al., 2013).

3.2.4. **Water vapor transmission rate testing**
Edible film samples for water vapor transmission rate testing were cut to size of 5x5 mm, then the sample pieces were glued to a plastic container of 10 ml of distilled water. We then placed them in a desiccator with silica gel in it to control the moisture. Prior to this, the silica gel was dried at 180°C for 3 hours. Samples that have been attached to a plastic container were put into the desiccator at 25°C for 1 day. After 1 day, the sample was removed from the plastic container and we measured the water vapor transmission rate.

3.2.5 **Research parameter**
The parameters observed used in the study were thickness, tensile strength, elongation, and the rate of edible film water vapor transmission.

3.3. **Data analysis**
Data from this study were analyzed using Analysis of Variants (ANOVA) and Duncan's multiple distance test (Duncan's multiple range test) as a follow-up test to determine the difference between treatments.

4. **Result and discussion**
The results of this study indicate that edible carrageenan films with the addition of different sorbitol had different characteristics. Edible carrageenan film with sorbitol had a smooth, supple and flexible texture while the edible carrageenan film without sorbitol had a rather rough and easily broken texture.

The results of testing the thickness of edible carrageenan film with sorbitol in each treatment E1 (0% sorbitol), E2 (2% sorbitol), E3 (4% sorbitol), E4 (6% sorbitol) i.e. 0.060 mm, 0.170 mm, 0.192 mm, and 0.222 mm. The results of variance analysis showed that the addition of sorbitol had a significant effect on the value of the carrageenan edible film thickness produced (p <0.05). Figure 1 shows that the highest thickness value was with treatment E4 (6% sorbitol) which is 0.222 mm, while the lowest value was with treatment E1 (0% sorbitol) which is 0.060 mm. As sorbitol increased, so did the thickness of the edible film.
The thickness of edible film is an important parameter that influences the use of edible film in product packaging. Variance analysis showed that the addition of sorbitol had a significant effect (p < 0.05) on the thickness of carrageenan edible film. Rachmawati and Suryani (2011) stated that factors that influence the thickness of edible film are edible film characteristics and composition of constituent materials. As sorbitol increased, so did the thickness of the edible film. This is because when the total solids found in the edible film solution was increased, the edible film produced became thicker.

The test results of tensile strength of edible film carrageenan in each treatment of addition of sorbitol were 0%, 2%, 4% and 6% were 9,126 kgf/cm², 8,140 kgf/cm², 7,329 kgf/cm², and 7,136 kgf/cm². Analysis of variance showed that the addition of sorbitol significantly affected the value of edible film carrageenan tensile strength produced (p < 0.05).

Figure 2 shows that the highest tensile strength was with treatment E1 (0% sorbitol) which is 9,126 kgf/cm², while the lowest tensile strength was with treatment E4 (6% sorbitol) which is 7,136 kgf/cm². As sorbitol increased, so did the tensile strength of edible films.

Tensile strength shows the resistance of edible film, i.e. the maximum strain a sample can endure before it breaks off (Suryaningrum et al., 2005). There was a decrease in the value of tensile strength as the addition of sorbitol increased. The results of the variance analysis also showed that the addition of sorbitol had a significant effect (p < 0.05) on the tensile strength of edible film carrageenan. The reason was that sorbitol given to edible film worked in decreasing the bonding between polymeric materials so the distance between molecules increased which resulted in a decreased tensile strength of edible film.

The testing results on the value of edible film carrageenan breakdown in each treatment of sorbitol addition 0%, 2%, 4% and 6% are respectively 8.61%, 11.56%, 15.68% and 20.46%. The results of variance
analysis showed that the addition of sorbitol had an effect on the extension of edible film carrageenan (p <0.05). Figure 3 shows that the highest breakout extension value was found in treatment E4 (6% sorbitol) i.e. 20.46%, while the lowest breakdown value is found with treatment E1 (0% sorbitol) i.e. 8.61%. As sorbitol increased, so did the elongated value of edible film.

Figure 3. The elongation of edible carrageenan films with the addition of different sorbitol concentrations

Elongation is percentage change in the length of edible film when an edible film is pulled until the edible film breaks off. A variance analysis showed that the addition of sorbitol had an effect (p <0.05) on the elongation of carrageenan edible film produced. Figure 3 also shows that as sorbitol increased, so did the value of the elongation of edible film. The elongation parameter was inversely proportional to the tensile strength value of edible film. The value of tensile strength and elongation depends on the addition of plasticizer. This is in line with the opinion of Widyaningsih et al. (2012) that sorbitol was capable of reducing intermolecular forces in polymer chains thereby increasing the flexibility of edible films and widening the distance between molecules.

The test result on the value of edible film carrageenan vapor transmission rate with each treatment on sorbitol addition 0%, 2%, 4% and 6% are respectively 15.76 ml/m2/day, 13.99 ml/m2/day, 8.064 ml/m2/day, and 6.83 ml/m2/day. The variance analysis results showed that the addition of sorbitol had no significant effect on the value of carrageenan edible film steam transmission rate (p> 0.05). Figure 4. shows that the highest water vapor transmission rate was found in treatment E1 (0% sorbitol) i.e. 15.76 ml/m2/day, while the lowest value of water vapor transmission rate was found in treatment E4 (6% sorbitol) i.e. 6.83 ml/m2/day. As sorbitol increased, the value of the edible film's water vapor transmission rate decreased.

Figure 4. The transmission rate of edible water film carrageenan with the addition of different sorbitol concentrations.
The rate of water vapor transmission is a measure of the passage of water vapor through a substance in a certain unit of time at a certain temperature of humidity. There was a decrease in the value of water vapor transmission rate along with the increase in sorbitol. The addition of sorbitol will lower the value of water vapor transmission rate. This is in line with McHugh and Krochta (1994) statement that the transmission rate of water vapor of a material is influenced by the chemical properties and structure of the constituent material, the concentration of plasticizers and environmental conditions such as humidity and temperature.

The characteristics assessment of carrageenan edible film from the research results was compared to the standard of food packaging industry (JIS 2-1707) and the results are illustrated in Table 1.

**Table 1.** Comparison on characteristics of edible film carrageenan with standard JIS 2-1707.

| Parameter                        | Treatment          | Standard JIS 2-1707 (1946) |
|----------------------------------|--------------------|-----------------------------|
| Thickness (mm)                   | 0% | 2% | 4% | 6% | Maximum 0.25 mm |
| Tensile Strength (kgf/cm²)       | 9.126 | 8.140 | 7.329 | 7.136 | Minimum 4 kgf/cm² |
| Extension break (%)              | 8.61 | 11.65 | 15.68 | 20.46 | Minimum 70% |
| Water vapor transmission rate (g/m²/day) | 15.76 | 13.99 | 8.06 | 6.83 | Maximum 7 g/m²/day |

Thickness values (Figure 1) and elongation (Figure 2) carrageenan edible film are in contrast to the tensile strength value (Figure 3) and water vapor transmission rate (Figure 4) edible film. The thickness value will affect the value of the edible film's water vapor transmission rate. When we increased the thickness value, the pores in the film matrix shrank, and the transmission of water vapor into the edible film network decreased so the value of water vapor transmission rate decreased. The value of tensile strength decreased and the elongation increased along with the increase of sorbitol addition. This is because sorbitol is a plasticizer that can reduce the bonds of internal hydrogen so that it increases intermolecular distances and increases the elasticity of edible films (Widyaningsih et al., 2012).

There are several factors that influence the relationship between the four edible film parameters, i.e. the amount of dissolved solid, the size of the printing plate, the composition of material (sorbitol), the process of making edible film carrageenan, and the characteristics of its constituent materials. The increase in dissolved solids and material composition (sorbitol) will tend to increase the thickness of edible film and the value of elongation and tend to decrease the value of tensile strength and the rate of transmission of water vapor. As we added sorbitol, the edible film solution became thicker so the thickness of carrageenan edible film tended to increase. Sorbitol is also able to reduce intermolecular forces in polymer chains by reducing hydrogen bond in polymer chains and widening the inter-molecular distance to increase the flexibility of carrageenan edible films and the increase in the elongation value of carrageenan edible film.

The thicker the edible film of carrageenan is, the lower the tensile strength because sorbitol can be to influence the tensile strength of carrageenan edible film which is capable to enter between polymer chains and reduce hydrogen bonds.

In reference to the JIS (Japanese Industrial Standard) standard, plastic for food packaging categorized as edible film has a maximum thickness of 0.25 mm so the results of this study is thus categorized under edible film because the average thickness of carrageenan edible film added with sorbitol concentration is between 0.170-0.222 mm. The value of water vapor transmission rate suggested by JIS is ≤7 g/m2/day. The carrageenan edible film produced in this study is thus categorized as edible film, namely in the treatment with the addition of 6% sorbitol with water vapor transmission rate of 6.83 g/m2/day.

The value of tensile strength suggested by JIS is ≥4 kgf/cm². The carrageenan edible film produced in this study is thus categorized as edible film with a tensile strength value of around 7.136-9.126 kgf/cm². The value of the elongation listed in JIS is ≥70%. The standard values set by JIS has not been met by the carrageenan edible film produced in this study. The maximum value of breaking extension produced was only 20.46% (with the addition of 6% sorbitol).
5. Conclusion
The addition of 6% sorbitol resulted in carrageenan edible film with thickness 0.222 mm, a tensile strength 7.136 kgf/cm², elongation 20.46%, and water vapor transmission rate 6.83 g/m²/day.

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