The concentration of sorbitol on bioplastic cellulose based carrageenan waste on biodegradability and mechanical properties bioplastic

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Abstract. Synthetic plastic waste is the cause of environmental pollution. Therefore, innovation is needed in the manufacture of plastics using renewable raw materials, namely bioplastics. Bioplastics can be made from carrageenan industrial waste because they have high cellulose content. Bioplastics need to add sorbitol plasticizer to affect the biodegradability and mechanical properties. This study aimed to determine the effect of sorbitol concentration in synthesis bioplastics cellulose-based from carrageenan waste on biodegradability and to determine the best sorbitol concentration in the bioplastics cellulose to get biodegradation standards and mechanical properties. This research is experimental in biodegradability testing by adding sorbitol (0, 3, 6, 9, 12 mL) to bioplastics and Article study on the mechanical properties of bioplastics. The experimental study used ANOVA data analysis and continued with DMRT. The results of this study indicated that the effect of sorbitol concentration affected the biodegradability of bioplastics (P <0.05) with the highest value of 58.68 ± 0.90% for seven days at a concentration of 12 mL. Based on the Article review, the optimum sorbitol concentration in production bioplastics cellulose that get biodegradation standards and the mechanical properties of bioplastics was 3 mL.

1. Introduction
Synthetic plastic or non-degradable plastic is a cause of waste and triggers for environmental pollution [1]. Therefore, there needs to be innovation in making plastics using renewable raw materials, by making bioplastics. Bioplastic is a type of plastic that is almost entirely made of materials that are easily renewable and can be decomposed by microorganisms. The materials that can be used for making bioplastics is cellulose, it derived from carrageenan waste. In the process of carrageenan production, waste produced (65-70% of the weight of seaweed) still contains 71.38% cellulose [2]. The high cellulose content in carrageenan waste can be used as a raw material for making bioplastics.

Bioplastics based cellulose have weak hydrogen bonds due to the distance between the tenuous molecules so it is easily degraded. The weak hydrogen bonds also cause bioplastics to be less strong and flexible. Therefore, it is necessary to add chitosan for increasing a cellulose adhesive. Chitosan has a role to reduce the distance between cellulose molecules due to weak hydrogen bonds. The addition of chitosan causes bioplastics to be fragile, rigid and inelastic, therefore in the process of making bioplastics it is necessary to have an additional material namely sorbitol.
Sorbitol can reduce internal hydrogen bonds in intermolecular bonds [3]. The addition of sorbitol is directly proportional to the percentage of elongation or strain. The greater the concentration of addition of sorbitol, the greater the value of the percentage of elongation or strain. High sorbitol concentration also causes a decrease in tensile strength in bioplastics [4]. Sorbitol concentration can also affect the degradation ability of bioplastics. Increasing the sorbitol concentration will accelerate the process of bioplastic degradation [5]. Degradation is the ability of biodegradable films to decompose dependent on availability microbes, moisture and chemical factors present in the soil [5] so that the addition of sorbitol will affect the on the bioplastic is degraded.

This study aimed was to determine the effect of sorbitol concentration in synthesis bioplastic cellulose-based from carrageenan waste on biodegradability and too determined the best sorbitol concentration in the bioplastics cellulose to geet biodegradation standards and mechanical properties based on article review.

2. Materials and methods
The method used in this research was experimental, and article review. Experimental research was conducted at the Chemical Analysis Laboratory of the Faculty of Fisheries and Maritime, Universitas Airlangga, Surabaya in February-March 2020 and article review in March-April 2020.

2.1 Bioplastic manufacturing
The process of bioplastics production beginning with the process of separating cellulose in the carrageenan waste. the waste sample powder was immersed in a 6% H$_2$O$_2$ solution at a ratio of 1:3 (w / v), then it was heated for 1 hour at 70°C in a water bath shaker. Then the waste sample washing with water to neutral pH and dried for 2-5 days The cellulose obtained from this process was weighed 50 grams and added 1 gram of chitosan, then given the treatment of the addition of glycerol (0; 3; 6; 9; and 12 mL) and 2.5 grams CMC for each treatment. The mixture was heated and stirred in 100 mL of distilled water for 30 minutes at 70°C. Then printed on a petri dish with a diameter of 9 cm and dried in an oven at 60°C for 1 hour. The formulation for making bioplastics is in Table 1.

| No. | Materials               | Unit | Treatment |
|-----|-------------------------|------|-----------|
| 1.  | Aquades                 | mL   | P0        |
| 2.  | Carrageenan Waste       | Gram | P1        |
| 3.  | Sorbitol               | mL   | P2        |
| 4.  | CMC                     | Gram | P3        |
| 5.  | Chitosan               | Gram | P4        |

Table 1. Bioplastic Formulation from cellulose-based from carrageenan waste

2.2 Biodegradation test
The biodegradation test was indicated by the degree of damage to bioplastics. The biodegradation test is chosen by using the soil as an aid to the degradation process or so-called soil burial test technique [6]. The sample was placed and planted in a soil-filled pot, the sample was left exposed to air. formerly, the initial mass of the sample was weighed first as (m0). Following with burial the sample in the soil for seven days. After seven days buried, the Bioplastic samples t dried and weighed. Then the re-weighing process is carried out as the value of mL [7]. The percentage average mass reduction from buried bioplastics is obtained through the following equation:

$$m(\%) = \frac{m_1 - m_0}{m_0} \times 100\%$$

2.3 Data analysis
The data of biodegradation was tested using a Completely Randomized Design (CRD) and continued by Duncan’s Multiple Range Test if treatment significantly affected biodegradation of the sample. The
statistical analysis using the IBM SPSS statistics version 23.0 software. The parameters mechanical properties other that were not possible to obtain due to the existence of a pandemic were conducted an article review using qualitative descriptive analysis.

3. Results and discussion

3.1 Results

This research produced bioplastics from carrageenan waste cellulose with a diameter of 9 cm (Figure 1). The Analyze of Variance (ANOVA) test showed that the addition of sorbitol concentration (0, 3, 6, 9, 12 mL) significantly affected the biodegradability of bioplastics. Meanwhile, in the DMRT follow-up test, it was found that bioplastics with the addition of 12 mL sorbitol has the best bioplastic biodegradation capability, the value is 58.68 ± 0.90% for seven days (Figure 2).

![Figure 1](image1)

**Figure 1.** Bioplastic Carrageenan Waste Cellulose with Addition of Sorbitol in different concentration

Note: Letter notation (a) sorbitol concentration 0 mL; (b) sorbitol concentration of 3 mL; (c) sorbitol concentration of 6 mL; (d) sorbitol concentration of 9 mL; (e) sorbitol concentration of 12 mL

![Figure 2](image2)

**Figure 2.** Comparison Graph of Bioplastic Percentage of Biodegradation with Different Sorbitol Concentrations. Note: Different superscript letter notations in the same column show comparisons between treatments are very significant differences (P <0.05).

3.2 Discussion

The results of the analysis show that the concentration of sorbitol on cellulose-based bioplastics from carrageenan waste significantly affects on biodegradation ability in the bioplastic, so increasing the sorbitol concentration will greater speed up the process of bioplastic degradation. Based on the results of this study the degradation of cellulose-based bioplastics from carrageenan waste with the addition of 12 mL sorbitol obtained the highest value of 58.68 ± 0.90% for seven days. These results of this research indicate that the degradation time of carrageenan waste cellulose bioplastic with the addition of sorbitol was faster than the ASTM D-6002 standard, which that the time required to degrade 100% bioplastics is 60 days [8]. Furthermore, when compared to LDPE and HDPE packets whose degradation ability in 120 days only reached 75.3% [9]. The carrageenan waste cellulose bioplastic
with the addition of sorbitol has a much higher degradation ability because of the fast degradation time. The addition of plasticizer to cellulose bioplastics can reduce the degree of crystallinity in cellulose which will result in decreased bioplastic density [10] so that the addition of sorbitol to bioplastics can accelerate the process of biodegradation [11].

Sorbitol is a hydrophilic material that can bind water. Water is a growing medium for most bacteria and microbes, so the high water content causes bioplastics to be more easily degraded [12]. Plastic surfaces that are hydrophilic will make it easier for decomposing bacteria to colonize [13]. The bacterial colony will stick to the surface of the plastic and form a biofilm, then the bacteria breakdown complex polymers into simple ones thus accelerating the degradation process [3]. Furthermore, according to Sumartono et al. [10], the length of time a material's biodegradation is affected by the polymer structure contained in a material.

Bioplastics cellulose is easily degraded because they contain hydroxyl (OH) and carbonyl (CO) groups [14]. According to Pratomo and Rohaeti [15], the process of biodegradation occurs because of the bond breaking reaction in the β-1,4-glycosidic bond so that the cellulose molecule decomposes back into glucose molecules gradually. Chemical degradation reactions in linear polymers give arise a decrease in molecular weight or make shorter of chain length [16]. The addition of sorbitol to bioplastic manufacturing can also affect the mechanical properties of bioplastics such as per cent elongation, tensile strength, and water resistance.

Tensile Strength is the maximum tensile strength that a plastic sheet can withstand during measurement. Tensile strength values indicate the tensile strength of plastics produced when under load [17]. The resulting bioplastics are not fragile, this is because the addition of sorbitol as a plasticizer serves to reduce intermolecular forces and increase film flexibility and weaken the polymer chain hydrogen bonds [18] so that it can affect the tensile strength of bioplastics.

Research on the effect of sorbitol on bioplastic manufacturing has been carried out several times. In the research of Hidayati et al. [5] using nata de cassava and sorbitol showed tensile strength values on the addition of 0 mL sorbitol that was 62.22 MPa, 3 mL sorbitol was 35.28 MPa, 6 mL sorbitol was 16.66 MPa, 9 mL sorbitol was 11, 76 MPa, the results of the study indicate that the addition of sorbitol 3 mL in bioplastic manufacturing has produced tensile strength under SNI standards of packaging materials which range from 24.7-302 MPa [19].

According to Putra et al. [20] the higher the concentration of sorbitol used in making bioplastics, the lower the tensile strength value of bioplastics produced. Sorbitol can reduce the molecular internal hydrogen bonds and cause the intermolecular pull of adjacent polymer chains to reduce the tensile strength [21]. Sorbitol is a hydrophilic material (capable of binding water) and can make the bioplastic surface-soft which causes a reduction in strength between adjacent molecules so that the tensile strength is lower [22].

The addition of sorbitol to bioplastic manufacturing also influences cellulose will reduce intermolecular interactions and increase polymer mobility [23]. Increasing the concentration of plasticizer in this case sorbitol will reduce hydrogen bonds to increase flexibility so that the tensile strength decreases [24]. According to research Hidayati et al. [25], the addition of chitosan and CMC in bioplastic production also affects the tensile strength value, CMC concentration > 3.5% and chitosan > 3.5% can reduce the tensile strength of biodegradable films, this is caused by the formation of intermolecular hydrogen bonds between NH4+ from chitosan and OH- from CMC. The addition of sorbitol to bioplastic manufacturing can also affect the per cent elongation in bioplastics.

Percent of elongation is the amount of length increase caused by the load pulling at the time of breaking up. The addition of plasticizers can affect the percentage of elongation because plasticizers can cause bonds to be reduced so that the plastic is more elastic [26]. Cellulose in seaweed itself has high flexibility so that it affects the per cent elongation because the addition of plasticizer gives more elastic properties to the plastic [27].

The effect of sorbitol addition on bioplastics in several studies has been conducted to determine on per cent elongation. The results of Sitompul et al. [28] in making bioplastics with the addition of 3 mL sorbitol, bioplastics have an elongation per cent of 44.65%. The elongation of bioplastic with sorbitol
additional in this study is in under SNI standard packaging materials with an elongation per cent value of 21-220% [20]. According to Afif et al. [12], sorbitol will disrupt hydrogen bonds between adjacent polymer molecules so that the tensile strength of polymer chain intermolecular is reduced, causing bioplastics to become more elastic. The mechanism of sorbitol insertion between amylose-amylopectin-chitosan molecules is presented in Figure 3.

![Figure 3. The hydrogen Interaction between Starch-Chitosan-Sorbitol [12]](image)

The increased sorbitol concentration in bioplastics also affects the water resistance. The bioplastic's resistance to water is determined by the swelling test that is the percentage of plastic condensation by the presence of water [29]. In the study of Afif et al. [12], the addition of sorbitol 1 mL, 2 mL, 3 mL, and 4 mL in the making of bioplastics resulted in a bloating result of 71.04%; 73.78%; 87.39%; and 88.03%, this shows that the addition of sorbitol influences on the per cent of distension so that the greater the sorbitol added, the greater the per cent of distension in bioplastics. The increase in per cent distension is due to the increased concentration of sorbitol because sorbitol has hydrophilic properties [5]. Sorbitol has many -OH groups so that it can attach to water by hydrogen interactions which created an increase in water absorption in bioplastics.

Based on the results of the study, the degradation of cellulose bioplastics from waste making carrageenan with the addition of 12 mL sorbitol gets the highest value of 58.68 ± 0.90% for seven days. Based on the previous studies used the Article review on the mechanical properties of bioplastic based cellulose with the addition of sorbitol, it is well known that the concentration of 3 mL sorbitol can meet the SNI mechanical properties standards especially the elongation per cent 21-220%, tensile strength value of 24.7-302 MPa, and 99% hydrophobicity [19].

4. Conclusion

The concentration of sorbitol on cellulose-based bioplastics from carrageenan waste effects on biodegradation ability in the bioplastic. The highest degradation rates of bioplastic were at addition sorbitol concentrations of 12 mL with degradation rates 58.68 ± 0.90% for seven days. Based on the article review, sorbitol concentration 3 mL has resulted in higher of the ability of biodegradation and mechanical properties.

5. References

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