The effect of increasing chitosan on the characteristics of bioplastic from starch talas (Colocasia esculenta) using plasticizer sorbitol

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Abstract. The aims of this research to determine the profile of starch gelatinization, bioplastic and the effect of increasing chitosan and sorbitol to the properties of tensile strength and elongation of break bioplastic. Preparation of bioplastics was used by casting method, that is 30% w/v solution of starch mixed with chitosan solution (0.5 w/v; 1 w/v; 1.5 w/v; 2 w/v; and 2.5 w/v) and plasticizer sorbitol (10 % w/w; 20 % w/w; 30 % w/w; 40 % w/w and 50 % w/w) were heated using a hotplate magnetic stirrer at 75°C. The results of Rapid Visco Analyzer (RVA) obtained by starch and bioplastic gelatinization temperature of 72.94°C; 77.72°C with peak viscosity 6632 cP and 3476 cP. Analysis of Fourier Transform Infrared (FTIR) and Scanning Electron Microscopy (SEM) obtained the change a functional group of bioplastic O-H at wave number 3765 cm⁻¹ and uneven chitosan distribution, and there is still an empty fraction. The addition of chitosan and sorbitol had an effect on tensile strength and elongation at break, tensile strength and elongation at break the highest of 8.36 MPa and 22.06% in starch composition 30%, 2.5 w/v chitosan and sorbitol 30% w/w.

1. Introduction

Bioplastic is plastics made from renewable resources (starch) and biodegradable [1]. Starch is a form of energy storage produced by all green plants. Starch-based bioplastic research has done, using potato starch, sago, maize, taro, cassava stem starch, avocado seeds and durian seeds [2, 3, 4, 5, 6, 7, 8]. The taro starch to be material bioplastic because it contains high starch [9]. Starch bioplastics have weaknesses, among others like hydrophilic, less hydrophobic and low mechanical properties, so it’s necessary to add cellulose filler, chitosan (0.37-1.45%) [7, 10], to fixed the elasticity properties must added glycerol plasticizer (10%-40%) or sorbitol 30% [3, 11]. The purpose of this research was to determine the profile of starch gelatinization, the effect of adding chitosan and sorbitol to the properties of tensile strength, elongation at break, functional groups and surface morphology of bioplastics.

2. Material and Method

2.1 Materials

Talas Banten is obtained from the Traditional Market Padang Bulan, North Sumatera Province, Chitosan was obtained from PT. Sanjaya Bandung, Sorbitol from UD. Rudang Jaya Sumatera Utara, glacial acetic acid from Merck.
2.2 Isolation Taro Starch Procedure
Taro is cut thin [12] with a thickness of ± 2 mm [13], repeatedly rinsed with water until clean and dried under the sun for 6 hours. Dry taro is blended by adding 1: 5 (w / v) water to form a slurry. The slurry of taro starch is taken by the filtrate (starch suspension). Suspension of starch is precipitated for 24-48 hours. The wet starch was dried in an oven at 50°C [8] for ± 24 hours until dry [14]. The dried starch is milled and sieved to be a size of 100 mesh [11].

2.3 Manufacture Bioplastic
Into the beaker glass is inserted 0.5% w chitosan and 100 ml of 2% acetic acid stirred until homogeneous. The taro starch 20% w/ml, acetic acid 2 ml and sorbitol solution 20% w and heated using hotplate magnetic stirrer at 75°C for 30 minutes at 375 rpm to homogeneous. The bioplastic solution poured onto acrylic plate mold 25 cm x 25 cm x 1cm and dried the oven at 45°C for 24 hours. After drying into the desiccator for 24 hours [7].

2.4 Characteristics of Bioplastic
2.4.1 Analysis of Mechanical Characteristics.
Measurement test of tensile strength and elongation at break is done based on the ASTM D882.

2.4.2 Analysis of gelatinization profile
Analysis of gelatinization profile is done using Rapid Visco Analyzer (RVA) and carried out in Laboratory of Industrial Technology of Agriculture Faculty, University of Padjadjaran, Bandung.

2.4.3 Analysis of Fourier Transform Infra Red (FTIR)
Fourier Transform Infra Red (FTIR) analysis was doing at Laboratory of the Faculty of Pharmacy University of Sumatera Utara, Medan.

2.4.4 Analysis of Scanning Electron Microscopy (SEM)
Scanning Electron Microscopy (SEM) analysis was doing at Laboratory Faculty of Mathematics and Natural Sciences Institute Teknologi of Bandung (ITB).

3. Results and Discussion
3.1 Tensile Strength
The effect of adding chitosan and sorbitol to the properties of tensile strength is presented by figure 1.

![Figure 1](Image)

**Figure 1.** The effect of increasing chitosan and sorbitol to the properties of tensile strength

Figure 1 showed of addition chitosan variations, increase the value of tensile strength. The largest tensile strength bioplastic at composition: chitosan 2.5% and plasticizer sorbitol 10% was 30. 91 MPa. The adding of chitosan at starch solution being a thickener so affecting the bioplastic chemical bond and increasing tensile strength. Chitosan has amine functional groups, primary and secondary hydroxyl groups, it causes high chemical reactivity in starch suspension. The addition of chitosan is
result from a physical interaction of hydrogen bonds between the starch and chitosan solution, so the resulting bioplastic had good tensile strength [7,11]. Figure 1 also showed added plasticizer sorbitol being decreasing the tensile strength. The smallest tensile strength 3.14 MPa in bioplastic with sorbitol plasticizer 50% composition and chitosan 0.5%. The decreasing of tensile strength disturbing compactness of bioplastic structure, thereby reducing the hydrogen bonding interaction (internal molecules) which causes the weakening of intermolecular forces of adjacent polymer chains. This decrease in tensile strength was in by Ginting et al. (2016) bioplastic research of durian seed starch with sorbitol plasticiser, The greater the sorbitol concentration will decrease the tensile strength [16].

3.2 Elongation at Break.
The effect of increasing chitosan and sorbitol to the elongation at break is presented by Figure 2.

Figure 2. The effect of increasing chitosan and sorbitol to the elongation properties at break

Figure 2 showed the addition of plasticizer sorbitol increase the elongation at break. The highest elongation at break of 42.42% at composition plasticizer sorbitol 50% and chitosan 0.5%. The plasticiser sorbitol molecule will disturb compactness of starch, decrease intermolecular interactions and improve polymer mobility [17]. The starch bond disturbed by plasticizers sorbitol causes film (bioplastic) to be more flexible to reduced stiffness. Increasing Elongation at break by Ginting et al. (2017) bioplastic research of durian seed starch with plasticiser sorbitol [7]. The variation of a heating starch solution and plasticiser sorbitol will decrease the Elongation at break. The lowest elongation at break was 1.23% at chitosan 2.5% and plasticiser sorbitol 10%. Adding of chitosan make the elongation at break decrease. Tensile strength increases, bioplastic flexibility, decreases then the Elongation at break is low.
3.3 Fourier Transform Infrared (FTIR)
Characterization FTIR of taro starch, chitosan, bioplastic without/with chitosan filler with sorbitol plasticizer is presented by figure 3.

![Figure 3. Fourier Transform Infrared (FTIR)](image)

The FTIR of taro starch obtained by O-H, C-H, C = O, C-O-H, C-O and C-O-C groups. The resulting functional groups have represented taro starch groups such as amylose, amylopectin and reducing glucose \((C_{6}H_{10}O_{5})_n\) [54]. Chitosan, \((C_{6}H_{9}NO_{3})_n\) is also called poly β (1,4) -2 amino-2-Deoxy-D-Glucopyranose composed of amino and hydroxy groups [23]. FTIR analysis showed that chitosan had the functional group of N-H, C-H, O-H, C=O, C-O-H, C-O and C-O-C. The group has representatives of the chitosan functional group and chemical structure similar to cellulose and lignin [20]. FTIR analysis showed wave number 3765.05 cm\(^{-1}\) showing OH group from strain of alcohol, at wave number 2935 cm\(^{-1}\) showing CH group of strain alkane, at Wave number 2056.17 cm\(^{-1}\) showing OH group of hydrogen bond strain, at wave number 1338.60 cm\(^{-1}\) showing COH group of strain CH\(_3\), and at wave number 929.69 cm\(^{-1}\) showing OH group of strain starch molecule ring.

3.4 Gelatinization Profile Analysis
The result of gelatinization of taro starch, bioplastic without/with chitosan filler with plasticizer sorbitol is presented by figure 4.
The temperature of gelatinization is the temperature at which the starch granules expand rapidly and irreversible [18]. From the analysis, the temperature of gelatinization of taro starch, bioplastic without/with chitosan filler and sorbitol plasticizer was in the temperature range of starch gelatinization, which is stated by Yamin, et al. (1997), it was 68-85°C [19] each of 72.94; 74.88; and 77.72°C. From the analysis result showed that taro starch processing into bioplastic by using plasticizer sorbitol increase the temperature of bioplastic gelatinization that is from 72.94°C to 74.88°C, while addition of chitosan filler in bioplastic process also increase gelatinization temperature from 72.94°C to 77.72°C. This is by the research of Spies and Hoseney (1982) that the addition of organic compounds will increase the temperature of gelatinization [20]. The addition of organic compounds such as chitosan and sorbitol will lead the addition of hydrogen bonds so that the space between molecules of starch is limited, and decrease the enthalpy of the system so that more heat is required to reach the gelatinization temperature of starch [21].

From the analysis, taro starch, bioplastic without/with an addition of sorbitol plasticiser and chitosan addition will decrease the peak viscosity of the bioplastic produced with the peak viscosity value of 6632; 4290; and 3476 CP. This is the increase of gelatinization temperature which causes decreased bioplastic viscosity because the viscosity of the liquid is inversely proportional to the temperature. This is also by the statement of Hirashima et al. (2005) which states that the addition of acid to the starch gelatinization process will decrease the viscosity of the liquid because the acid will first hydrolyze the starch molecule before gelatinization takes place [22]. From the analysis it was found that taro starch, bioplastic without/with filler and plasticizer sorbitol had a hold viscosity value of 2122 each; 1509; 1645 cP. Chitosan bioplastic (1645 cP) has a higher hold viscosity than bioplastic without chitosan (1509 cP). This is because acetic acid dissolves chitosan first and makes starch molecules hydrolyzed slightly so that the hold viscosity is higher.

From the analysis, taro starch, bioplastic without/with an addition of sorbitol plasticizer and chitosan addition had the value of breakdown viscosity of 4510 each; 2781; 1831 CP. The addition of sorbitol plasticiser reduces the viscosity breakdown of 1729 CP, and the addition of chitosan filler will reduce the viscosity breakdown of 2679 CP in the resulting bioplastic product. From the analysis result, it’s found that taro starch, bioplastic without/with an addition of sorbitol plasticiser and an addition of chitosan had a final viscosity of 2910 CP each; 2082.5 CP; And 2439 CP. Bioplastic with chitosan filler (2439 CP) has higher final viscosity value than non-chitosan bioplastic (2082.5 CP). Similarly, with the hold viscosity parameter, this is an increase of gelatinization temperature resulting and causes the decrease the viscosity mixture [23]. From the analysis result, it’s found by taro starch, bioplastic without/with addition of sorbitol plasticiser and chitosan addition had 1024 CP viscosity setback value; 799.5 CP and 830 CP

3.5 Scanning Microscopy Electron analysis (SEM)

Characterization of surface morphology analysis (SEM) in fault region of tensile strength analysis with 5000x enlargement is presented by figure 5
The characterization of SEM morphological analysis results in the fracture area of tensile strength analysis with 5000x enlargement. From the picture is seen fracture analysis has a rigid structure and brittle structure which shows that the spread of chitosan particles is uneven and there is an empty fraction therein. The emergence of chitosan particles on the results of morphology analysis, caused chitosan is not dissolved by the solvent acetic acid 2%, while the appearance of voids on the morphology of bioplastics due to the air trapped when pouring process and alignment of bioplastics solution into a molding acrylic. The voids in bioplastics forming a gap or space that is affecting the bond between filler and matrix. The gap or space causes the middle to move to the void area so as to reduce the tensile strength value when the bioplastic is load. Insoluble chitosan particles will reduce of bioplastics tensile strength. Based on pasting analysis obtained the chitosan insoluble particles will reduce the hydroxyl that is interacting with amylose and amylopectin thus increasing the value of the elongation at break of bioplastics produced.

4. Conclusion
Based on this research gelatinization temperature of 72.94°C with peak viscosity of 6632 cP, best bioplastics obtained is on the composition of starch 30%, sorbitol 40% and chitosan 2% with a tensile strength of 7.05 MPa and elongation at break of 21.05%.

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