Effect of Soluble Soybean Polysaccharides (SSPS) concentration and SSPS /PVA ratio on characteristics of biodegradable plastic

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Abstract. This study aims to determine the effect of Polyvinyl alcohol (PVA) and Soluble soybean polysaccharides (SSPS) and to characterize it (water resistance and biodegradation test). This research was done by blending (mixing) PVA, SSPS, acetic acid, and maleic anhydride. From the results of infrared spectrum analysis on plastic films showed peaks in the area 1000-1100 cm⁻¹ which indicates the absorption of polysaccharides. This plastic has an optimum water resistance in the ratio between 1:1 w/w (SSPS: PVA). Optimum biodegradation test results in the ratio of 1:1 w/w (SSPS: PVA). Based on the result of the research, it can be concluded that water resistance and biodegradation reach optimal on composition 1:1 w/w (SSPS: PVA).

1. Introduction
At present, the use of polymers has become an integral part of human life. As an example that we often encounter every day is plastic. Most of the items used by humans in daily life cannot be separated from this plastic material. Ranging from children's toys, household appliances, medical equipment, and electrical equipment components, and packaging in various types of food made of plastic [1]. The use of plastic will increase along with the increase in population and technological advancements. This is due to the use of plastic materials which have many advantages, including much lighter than glass or metal, transparent, not corrosive and not easily broken. The increasing plastic material, the greater the amount of waste produced which can cause environmental problems. The problem caused by plastic waste is the plastic which is difficult to be degraded by microorganisms or plastic non-biodegradation properties. In Indonesia, there are recorded 175,000 tons/day of plastic waste, equivalent to 64 million tons/year.

Various efforts have been made in handling plastic waste such as recycling plastics, storing plastic in the soil and burning it. The use of recycled plastic is considered inefficient because the process is
more difficult and requires more time than buying new plastic raw materials. When plastic waste originating from the polyolefin material is piled up in the soil. The plastic cannot be degraded by the soil and causes the water quality to decrease and the soil becomes infertile. The plastic material has high barrier properties to the permeability of O2 and CO2 [2]. So that it can interfere with the air circulation in the ground. While the processing of plastic waste by combustion produces toxic gases for humans and increases global warming. Biodegradable plastics utilize natural materials such as polysaccharides (cellulose, starch, chitin), proteins (casein, whey, collagen), and fats derived from plants and animals. Thereby reducing the consumption of the main raw material from plastic, which comes from petroleum, where at present the amount of petroleum in nature is depleting and cannot be renewed.

Biopolymers derived from natural materials have attracted attention because they have the potential to substitute for making non-biodegradable plastic materials. They are environmentally friendly, resources that are always renewable and affordable. Polysaccharides are one example of natural polymers that can be used to produce biodegradable materials [3]. However, polysaccharide-based films are relatively rigid, easily broken and strong hydrophilic when compared to films from synthetic packaging [4]. To overcome the fragility of the film, increase workability and flexibility, a plasticizer which usually a polyalcohol group is added. The plasticizer will form a composite with a polysaccharide. According to Tudorachi et al., the use of plasticizers and polysaccharides can be used to make biodegradable plastics [5]. Therefore, in this study a comparison of polyvinyl alcohol (PVA) as plasticizer and soybeans was treated to become Soluble Soybean Polysaccharides (SSPS) on the characteristics of the plastic produced, then characterized using FTIR (Fourier Transform Infrared), DSC (Differential Scanning Calorimetry), tested for water resistance and biodegradability.

2. Method
Biodegradable plastic was synthesized using soybeans, demineralization water, glacial acetic acid, PVA (polyvinyl alcohol) p. a maleic anhydrous p.a. Soybeans are mashed, demineralization water 2 times the weight is added and acidified to pH 5.0 with 0.5 M acetic acid, then heated to 120 °C for 1.5 hours and cooled to room temperature. The suspension is centrifuged for 30 minutes to remove residue and filter. The precipitate is rinsed with distilled water and dried at room temperature. Then the precipitate is smoothed to a size of 35 mesh. Plastic production is carried out by mixing polyvinyl alcohol (PVA) and SSPS with variations in mass (g/g) of 1: 0.25, 1: 0.5, 1: 0.75, 1: 1. The addition of PVA is expected to provide a high tensile strength value.

The method of plastic filming is the blending method. The comparison between PVA and demineralization water is 1:10 w/v, where 1 gram of PVA is dissolved in 10 ml of demineralization water. SSPS was dissolved in 10 ml of 0.5 M acetic acid heated at a temperature of ± 120oC and stirred at a speed of 500 rpm. After that, the mixture is molded and left at room temperature to dry. The obtained plastic, which had been dried was characterized by a spectrophotometer Fourier transform infrared (FTIR) to identify the formation of plastic, water resistance test, and biodegradation test.

3. Results and discussion
Isolation of soluble soybean polysaccharides (SSPS). After the process is done, the results of SSPS in the form of soybean flour are smooth and yellow. SSPS flour obtained as many as 153 grams of 350 grams of soybeans and produced a yield of 43.7%. From the variation of comparison produced plastic that has a flatness and a different level of homogeneity. The plastic obtained is in the form of thin sheets with different yellow levels according to variations in the composition of SSPS. Film results can be seen in Figure 1. The addition of SSPS variations in making plastic causes the product of plastic to become increasingly homogeneous. Plastics without the addition of SSPS is transparent and colorless. Whereas the increase of the addition of SSPS variation produces plastic with high yellow intensity.

The PVA and SSPS functional groups are analyzed by FTIR. The results of the functional group analysis using FTIR obtained spectrum as shown in Figure 2. Based on the FTIR spectrum (Figure 2.a) it was found that there was a typical PVA band which was the wide band at 3311.70 cm⁻¹ which showed stretching OH and in the regional band 2854.65 - 2924.09 cm⁻¹ which is the CH aliphatic
band. This has similarities with Mansur et al., who reported the characteristics of PVA in the area of 3300 cm\(^{-1}\) and area 2940 cm\(^{-1}\) [6]. Based on the spectrum, it can be concluded that the spectrum shows peaks in accordance with the PVA literature. Based on the FTIR spectrum (Figure 2.b) it was found that there was a typical SSPS band, namely wide band at 1026 cm\(^{-1}\) which is a typical peak of the polysaccharide group and 1625.99 which is C = O, aldehyde, ketone, and carboxylic bands. This has similarities with, Yang et al. reported the characteristics of SSPS with peaks appearing in the region of 1000 - 1100 cm\(^{-1}\) as the peak of the polysaccharide (arabinose, galactose, arabinogalactan) [7].

![Figure 1. Plastic film Variation of PVA and SSPS w/w (a) 1: 0 (b) 1: 0.25 (c) 1: 0.5(d) 1: 0.75 (e) 1:1.](image)

![Figure 2. Comparison of the FTIR spectrum overlay (a) SSPS,(b) Plastic film (0.5g SSPS: 1g PVA), (c) PVA.](image)

The peaks that appear in the 1600-1630 cm\(^{-1}\) region are derivatives of stretching carboxylic ions. Based on the spectrum, it can be concluded that the spectrum shows peaks according to the literature
Comparison of SSPS: PVA was chosen because of the homogeneous plastic results obtained by the spectrum as shown in Figure 2. The effect of adding SSPS and PVA to plastics in the FTIR spectrum such as Figure 2. The SSPS addition gives effect to the emergence of wave band absorption bands in 1000 - 1100 cm$^{-1}$ which identify the presence of a typical group of polysaccharide compounds found in SSPS such as arabinose, galactose, and arabinogalactan. This is influenced by the existence of a composite interaction between SSPS and PVA [8].

The results of the swelling test for one hour showed that the sample dissolved in demineralization water before one hour. This can be observed from changes in the shape and color of the sample since the beginning of immersion, observations of the 20th minute, the 40th minute and the 60th minute. In the 20th minute, the sample begins to expand and the color fades. These changes are increasingly clear at 40 minutes of immersion. Samples that were initially square and yellow began to change increasingly formless, destroyed and decomposed because they were degraded by water. The addition of SSPS affects the resistance of the plastic film to water. The plastic film without SSPS has relatively low water resistance because the nature of PVA as the SSPS matrix has hydrophilic properties, so plastic films without SSPS can dissolve in demineralized water [9-10]. The plastic film has a relatively higher water resistance when mixing PVA and SSPS with variations of 1: 1 (w/w %).

From Figure 3, we can see the pattern of weight loss monitored every other day. In all samples, it was seen that the sample began to degrade on day 2 since the sample was planted. In SSPS: PVA 0: 1-gram sample of the degraded period is 9.16% of initial weight. In SSPS samples: PVA 0.25: 1 gram of degraded mass by 11.02% of initial weight. Samples with SSPS: PVA 0.5: 1 gram degraded with a percent mass loss of 14.27% by initial weight. In SSPS: PVA 0.75: 1-gram sample degraded with a lost mass percentage of 14.37% of its initial weight. Whereas in the SSPS: PVA 1: 1-gram sample was degraded mass with a lost mass percentage of up to 26.77% of the initial mass. From the data obtained (Figure 3), it can be concluded that the percentage of mass loss up to the 10th day, the percent weight loss of each sample increases with the large variation of SSPS in the composition of the sample making significantly. It is suspected that microorganisms prefer to spend plastic which has more SSPS composition. From the graph, it can be seen that the mass loss for 10 days.

Based on Figure 4. SSPS: PVA variation used affects plastic biodegradation. In plastics containing SSPS 1: PVA 1g is more easily degraded than plastic that does not contain SSPS or which has a composition of SSPS with a smaller concentration. This is due to the greater variation of SSPS, the more degraded. While plastics containing smaller SSPS variations are less degraded due to the increasing variety of PVA, the less plastic is degraded by the soil. It can be concluded from the graph, the more SSPS is used, and the more degraded plastic will be. From the biodegradation test results, it can be concluded that the optimum condition is in the variation of SSPS 1: 1 gram PVA with degradation reaches 72.92% and reviewed from the water resistance test graph. The biodegradable plastic has constituent components that are naturally easily degraded, there is assistance from microorganisms and microorganisms in the soil so that it will accelerate the rate of degradation of plastic. The number of constituent components
also affects the length of the plastic to be degraded, the smaller the constituent period, the faster the plastic to be degraded. The biodegradable plastic has constituent components that are naturally easily degraded, there is assistance from microorganisms and microorganisms in the soil so that it will accelerate the rate of degradation of plastic. The number of constituent components also affects the length of the plastic to be degraded, the smaller the constituent period, the faster the plastic to be degraded.

4. Conclusion
Based on the discussion of the results, it can be concluded that biodegradable plastic films can be synthesized from soluble soybean polysaccharide, PVA and maleic anhydrous using a blending method to produce a transparent plastic film with excellent biodegradation potential. The plastic film produced based on the biodegradation test has the optimum results on the addition of SSPS of 1 gram with the amount of degradation reaching 72.82%. Based on the water resistance test, it can be seen from the plastic structure that it has optimum results on the addition of 1 gram SSPS.

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References
[1] Geyer J R, Jambeck and K L Law 2017 Sci. Adv. 3 7 1700782
[2] Tulio I S O, Morsyleide F R, Michael J R, Kathryn C, Edy S B, Lorena M A S, Selma E M, Keith W W, Henriette M C A 2017 Int. J. Biol. Macromol. 101 1–8
[3] Dominik S, Feuilloley P, Gratraud J, Morel M H and Guilbert S 2004 Chemosphere 54(4) 551–559
[4] Janjarasskul T and Krohta J M 2010 Edible Packaging Materials Annu. Rev. Food Sci. Technol. 1(1) 415–448
[5] Tudorachi N, Cascaval C N, Rusu M and Pruteanu M 2000 Testing of polyvinyl alcohol and starch mixtures as biodegradable polymeric materials Polym. Test. 19(7) 785–799
[6] Mansur H S, Sadahira C M, Souza A N and Mansur A A P 2008 Mater. Sci. Eng. C 128 4
[7] Yang Y, Cui S W, Gong J, Guo Q, Wang Q and Hua Y 2015 Food Hydrocoll. 48 (4)
[8] Davoud S, Mohsen T, Bibi S, Fazly B and Behrouz J 2018 Int. J. Bio. Macro. 112(852)
[9] Nakamura A, Furuta H, Maeda H, Takao T and Nagamatsu Y 2003 Biosci. Biotechnol. Biochem 66(6)
[10] Salarbashi D, Tajik S, Ghasemlou M, Shojaei-Aliabadi S, Noghabi M S and Khaksar R 2013 Carbohydr. Polym. 98(1)