Development and Characterization of Bioplastic Film from Salacca zalacca Seed Starch

S Ma’mun, D N Alamsyah, and A S Pribadi
Department of Chemical Engineering, Universitas Islam Indonesia
Jl. Kaliurang Km. 14.5, Yogyakarta 55501, Indonesia
E-mail: sholeh.mamun@uii.ac.id

Abstract. The world community has given a particular concern to environmental issues such as pollution of the marine environment due to petroleum-based plastic materials. Since petro-based plastics cannot easily be degraded in nature, bioplastics’ development is a must. Bioplastics can be made from various renewable feedstocks such as polysaccharides, protein, and fat. Salacca zalacca is one of the starch sources that can be used to manufacture bioplastics. The purpose of this study was to develop and characterize the bioplastic by use of Salacca zalacca starch. The bioplastic films were made by mixing all the raw materials at 70 °C for 40 minutes. The sample was then put into a mold and heating it in the oven at 50 °C for 24 hours. The results show that an optimum condition with 4 wt% of PVA occurs at the starch concentration of 1.8 wt% with the tensile strength and the elongation of 20 N and 53%. Moreover, the optimum condition with 15 wt% of PVAc gives the tensile strength of 20 N with lower elongation (15%).

1. Introduction
One of the recent environmental problems facing the world community is the marine environment's pollution due to petroleum-based plastic materials in which about 70 – 80% of plastic waste is found in the oceans that originates from land [1]. The petroleum-based plastics cannot be degraded both in the landfills and aquatic environments. Since petroleum-based polymers are very durable materials, they will remain intact as polymers for a long time [2].

Policies to reduce plastic use have been implemented in many countries worldwide to minimize plastic waste. However, these policies have proven insufficient to solve the problem; therefore, the substitution of petroleum-based polymers with biodegradable ones is necessary. Various renewable feedstocks, which are environmentally friendly, such as polysaccharides (starch, cellulose, chitin), protein, and fat, can be used as raw materials for biodegradable plastics manufacture [3-12]. Moreover, biodegradable synthetic materials such as polyvinyl alcohol (PVA), polyhydroxyalkanoate (PHA), polylactic acid (PLA) have also been used as materials for biodegradable plastics. PVA is a synthetic polymer that is soluble in water and easily degraded. PVA has widely been used as a promising alternative packaging material because of its excellent properties in packaging formation, resistance to oil and grease, high tensile strength as well as high flexibility [12]. Besides, plasticizers such as glycerol will improve the material performance because it reduces the inter-and intra-molecular strength but increases the film's mobility and flexibility.

Salacca zalacca, known as snake fruit, is a native Indonesian plant. The fruit can be made into several derivative products such as chips, syrup, sweets, and pudding. Salacca zalacca derivative products' production has resulted in a large amount of seed waste that needs to be utilized. Since Salacca zalacca
seed contains about 81 wt% of starch [13], the Salacca zalacca seed waste can then be used as a raw material in manufacturing bioplastics. The purpose of this study is to develop and characterize the bioplastic film by use of Salacca zalacca seed starch as a matrix in addition to PVA and polyvinyl acetate (PVAc).

2. Materials and Method

2.1. Materials
The materials used were Salacca zalacca seeds obtained from a domestic industry in Sleman Yogyakarta, Indonesia, polyvinyl alcohol, polyvinyl acetate, chitosan, glycerol, acetic acid, and deionized water.

2.2. Apparatus and Procedure
Salacca zalacca seed starch was prepared by cutting the seeds into small pieces and dried them in the sun. The dried samples were then ground and sieved using a 100-mesh screening. A certain weight of seed flour was mixed with deionized water and left the mixture for about 24 hours until the starch was formed; the water was then removed while the sediment was taken and dried.
The bioplastic film was made by mixing 100 mL of deionized water, 10 mL of 5 wt% chitosan, and 2 mL of glycerol with a certain amount of the Salacca zalacca seed starch and a certain amount of either PVA or PVAc for about 40 mins at 200 rpm and 70 °C. The mixture was then poured into a mold and dried in an oven at 50 °C for 24 hrs. The bioplastic film was then taken from the mold to be further characterized.

3. Results and Discussion
The bioplastic films were made from Salacca zalacca seed starch (0.7 – 8.3 wt%) in the mix together with either PVAc (4 – 15 wt%) or PVA (4 wt%) by use of glycerol (2 wt%) as plasticizer and chitosan (0.4 wt%) as filler. The Salacca zalacca seed starch was used as the matrix to provide the desired plastic properties. Glycerol was used as the plasticizer because of its hydrophilic properties, which are readily soluble in water and hygroscopic, absorbing water in the soil to affect the film's degradation process. The bioplastic films produced were then characterized by measuring the tensile strengths $\sigma$, elongation $\varepsilon$, and degradability factors.

Figure 1. Effect of starch variation on the tensile strength $\sigma$ dan elongation $\varepsilon$ with 4 wt% of PVA

Figure 1 shows Salacca zalacca seed starch's effect on the tensile strength $\sigma$ and elongation $\varepsilon$ with 4 wt% of PVA. It can be seen that starch concentration positively affects the tensile strength in which the matrix becomes more compact and more robust. It requires more force to make it break up. Besides, as
the starch concentration increases, the film thickness slightly increases; this leads to a shorten elongation factor. An optimum condition was observed at the starch concentration of 1.8 wt% with the tensile strength and the elongation of 20 N and 53%, respectively.

Figure 2. Effect of PVAc variation on the tensile strength $\sigma$ dan elongation $\varepsilon$ with 2 wt% of starch

In addition to PVA, PVAc was also used as another matrix with concentrations ranging from 4 – 15 wt%. Figure 2 shows PVAc concentration’s effect on the tensile strength and the elongation with 2 wt% of starch. It is shown that as the PVAc concentration increases, both the tensile strength and the elongation factor also increase. This is due to PVAc's nature as white glue that could have similar properties as those of cassava starch. Using PVAc 15 wt%, the effect of the Salacca zalacca seed starch concentration on the tensile strength and the elongation was also evaluated. As seen in Figure 3, the higher the starch's concentration, the higher the tensile strength. Similar to the PVA matrix, PVAc also provides a compact matrix structure leading to higher force to break it up. This condition also affects shortening the elongation factor. The optimum condition is slightly better than the one of the PVA matrix, which gives the tensile strength of 22 N and the elongation factor of 15% with the starch concentration of 2.7 wt%.

Figure 3. Effect of starch variation on the tensile strength $\sigma$ dan elongation $\varepsilon$ with 15 wt% of PVAc
Anaerobic degradation test was conducted to evaluate a change in the biofilm's morphological structure consisting of 12 wt% of PVAc and 2.2 wt% of the *Salacca zalacca* seed starch. Starch is mainly degraded by glycoside hydrolases, a large group of enzymes that catalyze glycosidic bonds' hydrolysis [14]. The biofilm was buried in the soil for 20 days. Figure 4 shows the morphological structure change before and after the degradation test. It can be seen from Figures 4a and 4b, the biofilm was physically changing in which the biofilm structure was significantly damaged. Moreover, based on the Scanning Electron Microscope (SEM) results, as shown in figures 4c and 4d, the biofilm was damaged due to starch's hydrophilic property.

![Figure 4](image)

**Figure 4.** Effect of starch variation on the tensile strength $\sigma$ dan elongation $\varepsilon$ with 15 wt% of PVAc: 4a and 4b, sample before and after degradation test; 4c and 4d, SEM results before and after degradation test.

### 4. Conclusion

Bioplastic films from *Salacca zalacca* seed starch were developed with PVA and PVAc as the matrices and chitosan as filler. The biofilms made were then characterized toward the tensile strength, the elongation, and degradation process in the soil. The experimental results show that as the starch concentration increases, the tensile strength also increases while the elongation decreases. This occurs due to the compactness of the matrix, which makes it stronger. A degradation test was also conducted to evaluate the degradability factor when the biofilm was buried in the soil for a particular time. The result shows that the biofilm was damaged due to the hydrophilic property of starch.
Acknowledgment
This work was financially supported by the Department of Chemical Engineering, Universitas Islam Indonesia through Research Grant No. 086/Kaprodi/70/TK/VII/2020.

References
[1] Calabrò PS and Grosso M 2018 Bioplastics and waste management Waste Management 78 800-01.
[2] Honhenblum P, Bettina L and Marcel L 2015 Plastic and microplastic in the environment Report REF-0551 Vienna, Austria: Umweltbundesamt.
[3] Luckachan GE and Pillai CKS 2011 Biodegradable polymers - a review on recent trends and emerging perspectives Journal of Polymers and the Environment 19 637–76.
[4] Amin MR, Chowdhury MA and Kowser MA 2019 Characterization and performance analysis of composite bioplastics synthesized using titanium dioxide nanoparticles with corn starch Heliyon 5 e02009.
[5] Jimenez-Rosado M, Zarate-Ramirez LS, Romero A, Bengoechea C, Partal P and Guerrero A 2019 Bioplastics based on wheat gluten processed by extrusion Journal of Cleaner Production 239 117994.
[6] Azmin SNHM, Hayat NAbM and Nor MSM 2020 Development and characterization of food packaging bioplastic film from cocoa pod husk cellulose incorporated with sugarcane bagasse fibre Journal of Bioresources and Bioproducts 5 248–55.
[7] Rocha CJL, Alvarez-Castillo E, Yanez MRE, Bengoechea C, Guerrero A and Ledesma MTO 2020 Development of bioplastics from a microalgae consortium from wastewater Journal of Environmental Management 263 110353.
[8] Thiruchelvi R, Das A and Sikdar E 2020 Bioplastics as better alternative to petro plastic, Materials Today: Proceedings (In press: https://doi.org/10.1016/j.matpr.2020.07.176).
[9] Yamada M, Morimitsu S, Hosono E and Yamada T 2020 Preparation of bioplastic using soy protein International Journal of Biological Macromolecules 149 1077–83.
[10] Emadian SM, Onay TT and Demirel B 2017 Biodegradation of bioplastics in natural environments Waste Management 59 526–36.
[11] Zimmermann L, Dombrowski A, Volker C and Wagner M 2020 Are bioplastics and plant-based materials safer than conventional plastics? In vitro toxicity and chemical composition Environment International 145 106066.
[12] Maryam, Rahmad D and Yunizurwan 2019 Micro synthesis of bacterial cellulose as a reinforcement in bioplastic composite with PVA matrix (polivinyl alcohol) Journal of Chemical and Packaging 41 110–18.
[13] Karta IW, Susila LANKE, Mastra IN and Dikta PGA 2015 Nutrition content in snake fruit (Salacca zalacca) seed coffee produced by Abian Salak farmers of Sibetan village which has the potential as a competitive local food product containing antioxidant Virgin Journal 1 123–33.
[14] Warren RAJ 1996 Microbial hydrolysis of polysaccharides Annual Review of Microbiology 50 183–212.