

Production of Starch-Based Bioplastic from *Durio zibethinus* Murr Seed Using Glycerol as Plasticizer

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Abstract

Bioplastics are bio-based plastics from natural resources, made to replace conventional plastics. The utilization of biopolymers in bioplastics provide a faster degradation compared to petroleum-based plastics. Starch-based bioplastic from mixing *Durio zibethinus* Murr starch and glycerol as plasticizer have been conducted. In this research, the concentration of glycerol has been varied to study the effect on starch-based bioplastics mechanical properties. The tensile strength for *Durio zibethinus* Murr starch-based bioplastic with 20% glycerol was 50.28 MPa with 13.3% elongation. The functional group found on the Fourier transform infrared spectroscopy (FTIR) spectra indicated the presence of O-H stretch, C-H stretch, C=O stretch, and C-O stretch which stated the formation of bioplastic. The image results gained from scanning electron microscope (SEM) showed that the morphology surface of bioplastic was less homogenous and rough. The soil burial test for biodegradability showed *Durio zibethinus* Murr starch-based bioplastic achieved 38.9% weight loss in a 5-day observation.

Keywords: *bioplastics, Durio zibethinus* Murr starch, glycerol, tensile strength

Introduction

Plastic is widely used as packaging material and other applications due to its several advantages such as being light, durable, cheap, and has thermoplastic characteristics. As the human population increases, the plastic demand will also increase. Conventional plastics can not be degraded and leads to environmental issues such as global warming, climate change, etc^[1]. This problem raises an idea for producing plastics from other sources that are environmentally friendly. One of the solutions is the utilization the use of natural sources as an

alternative ingredient to produce bioplastics or biodegradable plastics. The biodegradability of bioplastics will decrease the pollution caused by petroleum-based plastics and reduce the amount of plastic waste^[2].

Starch-based bioplastics can be produced by using starch of a plants such as cassava^[3], potatoes and yam^[4], corn and rice^[5] and Durian (*Durio zibethinus* Murr) seed^[6]. The advantages of using starch as raw materials are cheap and renewable. However, the use of starch from food sources causes competition with basic needs, especially cassava, potatoes and corn. Therefore,

utilizing the starch from food waste can be a viable option. Starch-based bioplastics from *Durio zibethinus* Murr seed have a lower cost than other sources, so it can be an applicable choice to use food waste to produce useful products.

Durian (*Durio zibethinus* Murr) is a seasonal fruit that is found in the tropics in Indonesia. During this time, part of the commonly consumed Durian is the fruit, while the bark and seeds have not been fully utilized and more turn into waste. Ripe of durian seeds containing 51.1% water, 46.2% carbohydrate, 2.5% protein and 0.2% lipid^[7]. High carbohydrate contains in *Durio zibethinus* Murr seed make it capable to be the source of making bioplastics^[8].

Starch-based materials have attracted the researcher's attention due to their advantages, especially their biodegradable properties, low-cost production, and renewable^[4]. The mechanical properties of plastics are influenced by the composition of the constituent components. Plastic films based on starch alone have low tensile strength and elongation, so it is necessary to add a plasticizer to improve their mechanical properties. However, the moisture content and plasticity of starch are highly dependent on the temperature and humidity of plastic storage, making it less efficient to apply^[9].

Many efforts have been exerted to develop starch-based bioplastic by combining it with plasticizers, such as glycerol. Hydrophilic and hygroscopic properties of glycerol are expected to increase the stability of the plastic film^[3]. The plasticizer could form the hydrogen bonds with starch, take the place of the strong interaction between intra- and intermolecular hydrogen bonds in starch, and make starch display the plasticization and gives the elastic properties to the bioplastics^[10].

In this study, the ability to use *Durio zibethinus* Murr starch to produce bioplastic with the addition of various concentration of glycerol as plasticizer was determined. The mechanical properties, the functional group that exist, and biodegradable properties of the product were also characterized to evaluate the potential of

bioplastic as a suitable alternative to reduce the existing conventional plastics.

Experimental

Materials

The materials used for production starch-based bioplastic were *Durio zibethinus* Murr seed, was collected from Payakumbuh. Glycerol and lime water ($\text{Ca}(\text{OH})_2$) were purchased from Andeska Laboratory, Padang. Distilled water was obtained from Material Chemistry Laboratory, Department of Chemistry, Universitas Andalas.

Instruments

The testing equipment used were Fourier transform infrared spectroscopy (FTIR Perkin Elmer 1600 series), scanning electron microscope (SEM Hitachi S-3400N) and tensile strength test with COM-TEN Testing Machine 95T Series.

Methods

Extraction of Durio zibethinus Murr starch

To extract the starch, 20 kg of *Durio zibethinus* Murr seed were weighed and washed. The seeds were peeled and cut into small pieces. Then it soaked in 10 L of lime water for 12 h to remove the sap. The durian seeds are then drained and washed with clean water and after that dried under sunlight. Dried durian seeds were blended and added with water in a ratio of 1:2, then squeezed and the filtrate was taken. The filtrate was allowed for 12 h to obtain a precipitate. The precipitate was taken and dried under sunlight for 48 h, and obtained durian seed starch. The Durian seed starch is sieved to get a smaller and same size.

Production of starch-based bioplastic

Table 1 shows the composition of prepared bioplastics. Starch-Based Bioplastic was made by dissolved 10 g of starch in the water while stirring for 5 min at 90 °C^[8]. Then, glycerol with a variation concentration of 10%, 15%, 20%, 25%, 30% was added to the mixing solution. The mixture was poured into a mould with size 19.5 cm x 19.5 cm and dried in an oven at 45 °C for 30 min and then cooled at room temperature for 24-

48 h. Finally, the starch-based bioplastic in sheet form was obtained^[3].

Tensile strength test

The tensile strength test was performed using the COM-TEN testing Machine 95T Series. Five samples with variation concentration of glycerol were tested according to ASTM D638 for plastic polymers.

SEM analysis

Bioplastic samples with high tensile test values were followed by examination of morphological characteristics using scanning electron microscopy (SEM). Plastic film size 1 cm² was observed using an accelerating voltage of 10 kV.

FTIR analysis

FTIR characterization was used to determine the functional groups in bioplastic, compared with functional groups in *Durio zibethinus* Murr starch to estimate the types of interactions that occur in the bioplastics product.

Biodegradability test

The biodegradability test was carried out using the soil burial test technique^[5]. Bioplastics were cut into 2 x 1 cm² size and buried in the soil and exposed to open air without being covered with glass. Observations of the sample were carried out for 5 days.

Biodegradability calculation:

$$\% \text{Biodegradability} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100\%$$

Results and Discussion

Durio zibethinus Murr starch-based bioplastic

Table 2 below presents the content of amylose and amylopectin in *Durio zibethinus* Murr starch. The ratio of amylose and amylopectin causes the gelatinization temperature used during the bioplastic formation process. Amylopectin has a larger molecule than amylose. This causes the amylopectin granules to take a long time to begin to gelatinize^[11].

Table 1. Composition of prepared bioplastics

Sample	Durian Starch (g)	Glycerol (mL)	Water (mL)
Sample 1	10	1	100
Sample 2	10	1.5	100
Sample 3	10	2	100
Sample 4	10	2.5	100
Sample 5	10	3	100

Table 2. Characteristic of *Durio zibethinus* Murr starch

No.	Components	Percentage %
1.	Amylose	3.21%
2.	Amylopectin	96.79%
Total		100%



Figure 1. *Durio zibethinus* Murr starch-based bioplastic.

Figure 1 shows the starch-based bioplastic *Durio zibethinus* Murr. The color of the bioplastic is slightly brown and smells of durian fruit.

Mechanical properties of bioplastic

Figure 2 shows the tensile strength and elongation of *Durio zibethinus* Murr starch-based bioplastic with various concentrations of glycerol. The graph of tensile strength and elongation increases due to the addition of glycerol until 20%. Increasing more glycerol decrease the tensile strength and elongation value. In the presence of water and glycerol as plasticizer, the strong intramolecular and intermolecular hydrogen bonds in starch can be weakened^[12]. It is called "anti-plasticization" properties that make a material become stiff and brittle^[3]. On the other hand, decreasing glycerol addition in bioplastic causes lower tensile strength due to the interaction between starch and glycerol has not been achieved. It would

also affect the flexibility of bioplastic. The maximum tensile strength and elongation values were achieved at 20% glycerol with a tensile strength value of 50.28 MPa and 13.3% elongation. This result occupies SNI standards (24.7-302 MPa) as plastic packaging while the elongation value does not meet the standard (21-220%) yet^[13].

FTIR analysis

The FTIR spectra of *Durio zibethinus* Murr starch and bioplastic product are shown in Figure 3. The spectra of figure 3a and b, shows the specific hydroxyl (O-H) at 3200-330 cm^{-1} , C-O stretch at 1000-1150 cm^{-1} , C-H stretch at 2700-2900 cm^{-1} , and C=O stretch at 1600-1820 cm^{-1} . FTIR results show that there were no new functional groups found in the bioplastic spectra compared to the starch. The presence of C-O and C=O functional groups in bioplastics indicates that the product had the ability to be degraded.

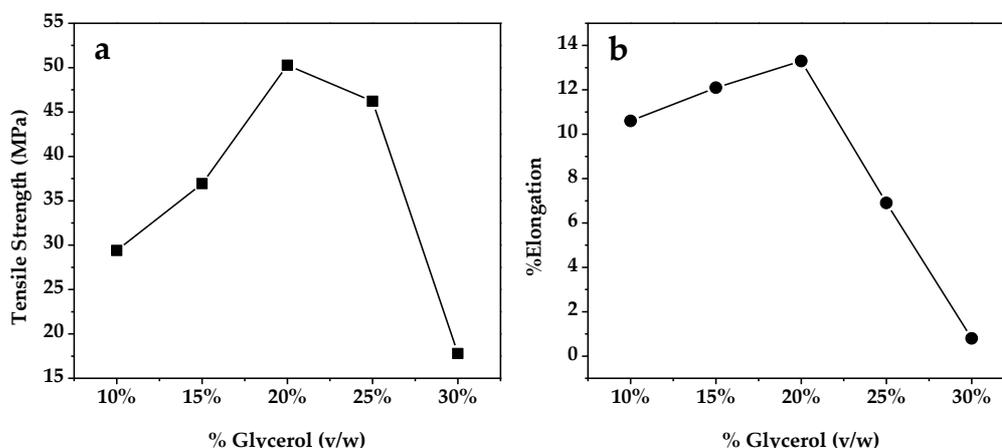


Figure 2. Mechanical properties of *Durio zibethinus* Murr starch-based bioplastic a) tensile strength and b) elongation, with various concentration of glycerol.

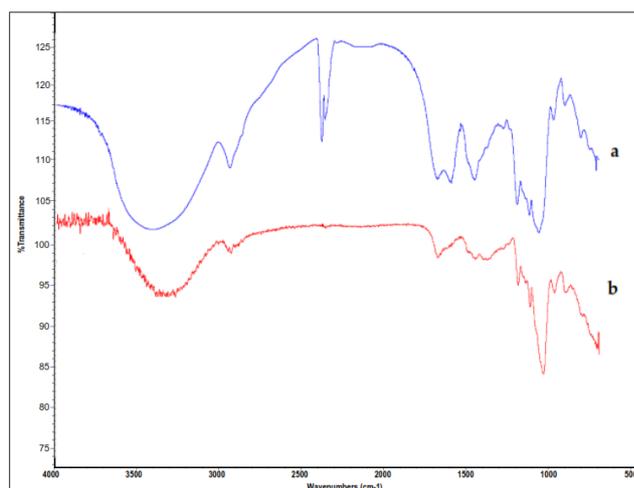


Figure 3. FTIR spectrum of a) *Durio zibethinus* Murr starch and b) *Durio zibethinus* Murr starch-based bioplastic with 20% glycerol.

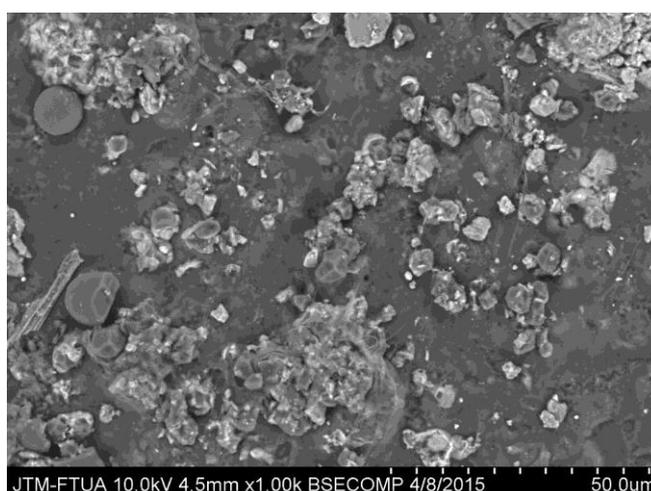


Figure 4. *Durio zibethinus* Murr starch-based bioplastic with 20% glycerol (1000 x).

Bioplastic component such as starch and glycerol have hydrophilic properties which bind water molecules from around the environment and facilitate degradation^[14].

SEM analysis

Figure 4 shows the surface morphology of the *Durio zibethinus* Murr starch-based bioplastic. It can be seen that the bioplastic surface is less homogeneous and rough. On heating starch with water, a phase transition of the starch called gelatinization occurs. Swelling power and solubility provide evidence of interactions

between water molecules and starch chains in amorphous and crystalline domains of the starch granules^[8]. Thus, the insoluble remnants of the starch granule swelling process are clearly visible on SEM^[15]. These results could also affect the elongation properties of the bioplastics.

Biodegradability test

The following Table 3 gives the weight loss conducted by *Durio zibethinus* Murr starch-based bioplastic with 20% glycerol in 5 days of soil burial test.

Table 3. Biodegradability test of *Durio zibethinus* Murr starch-based bioplastic

Sample	W ₀ (gram)	W ₅ (gram)	%Biodegradability
<i>Durio zibethinus</i> Murr starch- based bioplastic with 20% glycerol	0.2840	0.1734	$\% \text{Biodegradability} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100\%$ $= \frac{0.2840 - 0.1734 \text{ g}}{0.2840 \text{ g}} \times 100\% = 38.9\%$

W₀ = initial weight and W₅ = final weight of bioplastic

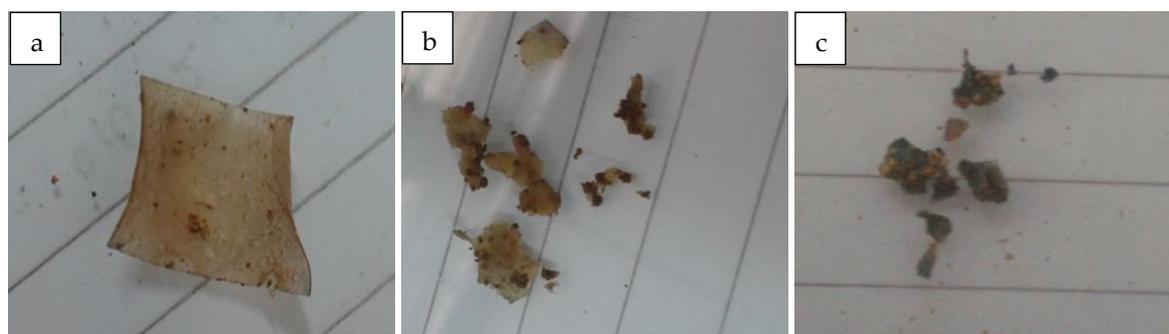


Figure 5. *Durio zibethinus* Murr starch-based bioplastic biodegradation test on soil a) day-0, b) day-5, c) day-7.

No soil preparation was used in the biodegradability test. This aims to see the biodegradability process of bioplastics if buried in open ground which in this study uses soil taken outside the laboratory.

The presence of glycerol in plastic will bind moisture in the air. This causes bioplastics to easily absorb water in the soil so that the swelling of plastic films becomes greater which causes the plastic to be more easily broken into fragments that will be easily degraded by bacteria or fungi in the soil^[10]. The weight loss of bioplastic was calculated to examine bioplastics biodegradability. The hydroxyl, O-H groups contain in starch-based bioplastic lead the hydrolysis after absorbing water from compost and increased the decomposition process^[3]. The polymer chains in starch are broken and cause the weight loss of bioplastic film during burial in soil indicates the amount of degradation by microorganisms^[10].

According to the calculation, *Durio zibethinus* Murr starch-based bioplastic has 38.9% biodegradation for 5 days soil burial test. Figure 5 show the plastic film damage after being buried in the soil from day-0 until day-5, on day-7 the plastic film was broken down and blend with the soil, so it can not weigh precisely. Thus, it is required longer times to be completely degraded.

Conclusions

Starch-based bioplastics are renewable use for making bioplastics to replace conventional plastics. The addition of various glycerol concentrations affected the tensile strength and elongation values of bioplastics. The optimum conditions for making *Durio zibethinus* Murr starch-based bioplastics were obtained in a mixture of 20% glycerol as a plasticizer with a tensile strength value of 50.28 MPa and 13.3% of elongation. FTIR results showed that the

presence of C-O ester and C=O carbonyl groups in bioplastics indicates that the starch-based bioplastic had the ability to degraded and it showed in the biodegradability test which revealed 38.9% of bioplastics broke down in 5th day. The SEM image of bioplastic indicated that the gelatinization of starch is not complete so that the morphology is less homogeneous and rough. It is necessary to vary the plasticizer used and also the addition of filler to improve the mechanical properties of the bioplastic.

Acknowledgments

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