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Original Paper

Variations in Size of Sugarcane Bagasse Fiber as Raw Material for Making Environmentally Friendly Plates

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***Abstract* — Plastic is a material that is often used as a storage medium, equipment and also furniture to support human activities, but plastic is not easily broken down by the environment. Bioplastic technology is one of the efforts made to address the problem of plastic packaging which can pollute the environment. Environmentally friendly plates, bioplastic products made from tapioca, glycerol and sugar cane bagasse. This research aims to determine the effect of variations in the size of bagasse on tensile strength, elongation at break, water resistance and biodegradability of environmentally friendly plates and to obtain the best formulation of varying sizes of bagasse as raw material for making environmentally friendly plates. This research used a Completely Randomized Design (CRD) with one factor, namely variation in the size of the bagasse. The results of this research show that there is a real influence between tensile strength, water resistance and biodegradability, however, in the elongation test, variations in bagasse did not have a significant effect. Tensile strength values range from 20.00 N/mm2 to 47.72 N/mm2. The largest elongation value is 4.08%. The highest water resistance is at room temperature, namely 88.86% with a degree of curvature of 16º and in water with a temperature of 60ºC, namely 85.02% with a degree of curvature of 18.75º. Variations in the size of bagasse also affect the biodegradability of environmentally friendly plates which ranges from 11.77% to 14.65%. The best treatment is a sample with a variety of bagasse sizes of 60 mesh, because it has high strength compared to other samples.**

Keywords— plastic, bioplastic, environmentally friendly plates, sugar cane bagasse.

I. INTRODUCTION

Plastic is a material that is often used as a storage medium, equipment and also furniture to support human activities. The existence of plastic is really needed by humans, because many products are made from plastic and are often found in everyday life. Plastic is a synthetic polymer that is widely used in everyday life because it is stable, waterproof, light, transparent, flexible and strong, but materials made from this plastic are not easily broken down by microorganisms. Plastic waste is not easily decomposed by decomposing organisms, because the process of decomposing plastic takes 300 - 500 years to decompose completely [1]. Bioplastic technology is one of the efforts made to address the problem of plastic packaging which can pollute the environment. Bioplastics are plastics or polymers that can naturally be degraded through attack by microorganisms or weather [2]. Materials that can be used to make bioplastics are starch and cellulose. Environmentally friendly plates are a bioplastic product that is expected to reduce the use of plastic plates, so that the presence of environmentally friendly plates is expected to reduce the accumulation of plastic waste. Environmentally friendly plates can replace the function of plastic plates or Styrofoam plates which are often used by people.

Cassava starch is one of the ingredients that can be used in making environmentally friendly plates. The characteristics of starch-based bioplastics are generally brittle and hydrophilic, so other materials are needed to increase the strength, flexibility and water resistance of the polymer when used as food packaging [3]. Therefore, a plasticizer is added to produce a suitable product and can improve its mechanical properties, namely the addition of glycerol. Glycerol is a starch plasticizer that can produce homogeneous and elastic bioplastics [4]. Another material used is sugar cane bagasse. Cellulose found in sugar cane bagasse can improve the structure and strength of bioplastics . Cellulose has good mechanical properties and can be used directly as a filling or reinforcement in bioplastic products [5]. It is hoped that the cellulose content in sugar cane bagasse can be used as an additional ingredient for making ideal environmentally friendly plates. Apart from the cellulose content in bagasse, there is lignin content which can increase the water resistance value of bioplastics.

II. METHOD

A. Tools and materials

The tools used in this research are: The tools used in this research include oven, blender, 60 mesh sieve, stopwatch, cement plate mold, digital scales, *universal testing machine* (UTM), plastic bucket, knife, scissors, jar. , ruler, bow ruler, spoon, pan.

The materials used in this research are: The materials used in this research include bagasse waste (Street ice cane vendors along Jalan Losari, Ploso District), cassava starch (rose brand), glycerol, distilled water, compost soil.

B. Research design

Observations carried out included dimensional analysis, water content analysis, water solubility analysis, biodegradation analysis. This research was conducted using a Completely Randomized Design (CRD) with 1 factor. Each treatment was repeated 3 times. The treatment factors are the addition of bagasse in powder form (A1), bagasse with a size of 1mm (A2), bagasse with a size of 3mm (A3) with a weight of 10% of the weight of cassava starch .

C. Research procedure

a. Making sugarcane bagasse flour

The bagasse is cut into ± 1 mm, 3 mm and 1 cm pieces, then washed with water until clean. Drying process in an oven at 90 ^{o}C for 3.5 hours. Then grind the bagasse with a blender little by little until completely smooth. Finally, sift the dregs of flour with a 60 mesh sieve to obtain fine flour.

b. Making bioplastic plates

Biodegradable plates begins with weighing 50 g of cassava starch, 5 g of sugarcane bagasse, 10 ml of glycerol and 50 ml of distilled water using a digital balance. After that, mix all the ingredients and stir manually until homogeneous, then heat the mixture over low heat for 10 minutes, stirring the sample until it thickens (gelatinization). The dough that has become smooth is molded using a plate mold made of cement to produce the desired plate shape. Next, drying was carried out using an oven at a temperature of 120°C for 2.50 hours, then oven again for 10 minutes at a temperature of 230°C. The finished dish is cooled by placing it on a baking sheet at room temperature.

D. Analysis Procedure

a. Tensile Strength Test

Tensile strength test is the maximum tensile force (N) that a bioplastic sample can withstand before breaking per sample area (mm^2) [6]. Tensile strength testing uses the ASTM D638-94 standard, this test is to determine the optimum concentration of the mechanical properties of bioplastics in the form of tensile strength and percent elongation of the material (elongation). The biodegradable plate sample was cut into an l shape with a length of 60 mm and a width of 20 mm, after which the sample was tested using a *Universal Testing Machine.*

b. Elongation Test at Break (Elongation)

Percent elongation at break (elongation %) is the ratio of the increase in length of bioplastic before breaking [7]. Tensile strength testing uses ASTM D638-94 standards. Biodegradable plate samples were cut into l shapes with a length of 60 mm and a width of 20 mm, after which they were tested using a *Universal Testing Machine.*

c. Water Resistance Test

The water resistance test is used to predict the stability of *biodegradable plates* against the effects of water. This test is with modified treatment [8]. This test is carried out by taking a test sample that has been cut to a width of 2 cm and a length of 6 cm and then placing it in a plastic cup containing 50 ml of water each at room temperature and 60^{o}C. The sample is immersed in half or only 3 cm. Observe the increase in sample weight and degree of curvature for up to 60 minutes, where the sample will be measured every 15 minutes. Calculation of Water Resistance as follows:

$$\text{Water Resistance} = 100\% - \text{Water absorbed } (\%)$$

$$\text{Water absorption capacity } (\%) = \frac{W1-W0}{w0} \text{x } 100\%$$

Information:
W0 = Initial mass of sample (g)
W1 = Final mass of sample (g)

d. Biodegradability Test

Biodegradability testing is carried out using the *soil burial test method* , namely burying bioplastic samples in the ground. *Soil Burial Test Method* is a measurement method where a plastic sample that has been weighed is buried in soil for a certain period of time and then the plastic is weighed again to find out what percentage of the sample has been degraded [9]. The soil used is a mixture of soil and compost in a 1:1 ratio. This test was carried out by burying a *biodegradable* plate sample that had been cut to a length of 6 cm and a width of 2 cm in tin wool containing soil until the sample was not visible on the surface. The time needed to analyze biodegradation capacity is 15 days. The results of the observations are the mass of bioplastic samples before and after experiencing degradation. The calculation of the percentage of mass loss is as follows:

$$\text{Mass loss percentage} = \frac{Wi-wf}{wi} x100\%$$

Information:
Wi = Sample mass before biodegradation (g)
Wf = Mass of sample after biodegradation (g)

E. Data analysis

The data obtained from this research will then be analyzed using *Microsoft Excel* 2016 and SPSS version 16 using the variance method (ANOVA) to determine the effect of each treatment on the characteristics of bioplastic plates. at the level α=0.05. If there is a real difference, a further *Duncan's Multiple Range Test* (DMRT) test will be carried out at a significance level of 5%.

III. RESULTS AND DISCUSSION

A. Tensile Strength Test

The tensile strength test is a mechanical test on bioplastics, where this test is carried out to determine the extent to which the product can withstand the tensile force before the sample breaks. The *tensile* strength test is the value of the maximum tensile force (N) that a bioplastic sample can withstand before breaking per sample area (mm^2) [6]. The tensile strength test was carried out using a *Universal Testing Machine* (UTM). The tensile strength test results of environmentally friendly plates can be seen in Figure 1.

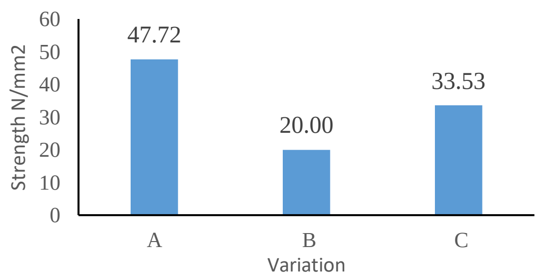

Figure 1Tensile Strength Test

Based on the table above, it can be seen that the sample that has the highest tensile strength value is sample A (a variation of adding bagasse with a size of 60 mesh) with a value of 47.72 N/mm ^{2} . Meanwhile, the sample that has the smallest tensile strength value is sample B (variation of adding 1 mm bagasse) with a value of 20.00 N/mm ^{2} . Based on the ANOVA test, variations in bagasse have a significant effect on tensile strength, this is proven by the sig value < 0.05. Based on the Duncan test, the tensile strength values for each treatment variation of bagasse were significantly different. The tensile strength of samples A and C meets the specified SNI standards, but sample B does not meet the tensile strength standards. namely the SNI tensile strength for plastic is 24.7 – 302 MPa.

Biodegradable products that have a high density can withstand effective tensile forces, where smaller or finer fiber sizes have a higher density. Apart from that, the thickness of the sample can also affect the tensile strength value. This is in accordance with the opinion of [10], who stated that thicker bioplastics will increase the tensile strength value, but this can cause the elongation to decrease. This research is in line with research conducted by Panjaitan [11]. Where the increase in tensile strength values is influenced by the size of the cellulose fibers, the smaller the fiber size, the greater the surface area, so the interaction between the filler and the matrix will be stronger. Tensile strength measurements are used to determine the amount of force achieved to achieve maximum tensile strength for each unit area of the film to stretch or elongate [12].

B. Elongation Test at Break (Elongation)

Elongation at break (elongation) is the increase in the maximum length *of the film* due to changes in tensile strength which is measured from the initial length to break. The quality of plastic can be said to be good if the elongation percentage is greater [13]. The elongation test was carried out using a *Universal Testing Machine* (UTM). The results of the elongation test at break of environmentally friendly plates can be seen in Figure 2.

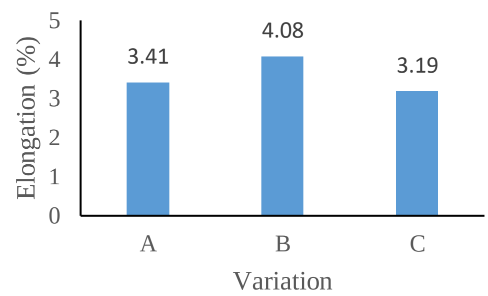

Figure 2Elongation Test at Break (Elongation)

Based on the table above, it can be seen that the greatest elongation at break test value is sample B (1mm bagasse variation) with a value of 4.08%. Meanwhile, the smallest value is sample C (3 mm bagasse variation) with a value of 3.19%. Based on the ANOVA test, variations in bagasse size did not have a significant effect on elongation at break, this was proven by the sig value >0.05. Meanwhile, in the Duncan test, the elongation at break for each variation of bagasse was not significantly different. The elongation test in this study did not meet the specified standards, which based on SNI for the elongation value was 21-220%.

A small elongation value can be influenced by the density of the sample itself, where a sample with fine particles will be denser and a sample with long fibers can also withstand the applied tensile load, this can cause the sample to become stiffer and less elastic. Stated that the denser bioplastics will increase the tensile strength value, but this can cause the elongation to decrease [10]. This is in accordance with research by Panjaitan [11], which states that the addition of cellulose is inversely proportional to the percent elongation value produced, the more cellulose content in plastic, the more the percent elongation value will be reduced. The decrease in percent elongation occurs due to the bond between the hydroxyl group (OH) from starch and the hydroxyl group (OH) from cellulose, these two groups will bond with each other and form strong hydrogen bonds, the more hydrogen bonds in the sample the lower the bond distance between the molecules. Apart from that, this bond can reduce the freedom of movement of starch molecules to move and shift, thereby increasing the stiffness and reducing the elastic properties of the plastic.

C. Water Resistance Test

The water resistance test is a test carried out to determine how much water absorption a material has. In biodegradable products, it is hoped that the percentage of water absorption will have a small value, which means that the quality of the bioplastic is getting better, and vice versa, products that have a large water absorption capacity will affect the function of the bioplastic. Water content testing was carried out using water at 2 different temperatures, namely room temperature and 60ºC. The average values for the percentage of weight gain and water resistance can be seen in Table 1.

TABLE 1. AVERAGE PERCENTAGE OF WEIGHT GAIN AND WATER RESISTANCE

Treatment	Weight Gain		Water Resistance	
	Room temperature (%)	Temperature 60ºC (%)	Room temperature (%)	Temperature 60ºC (%)
A	11.14	14.98	88.86%	85.02%
B	13.86	20.60	86.14%	79.40%
C	15.32	15.01	84.68%	84.99%

Source: Processed Data (2024)

Table 1 shows the results that sample A (60 mesh bagasse variation) has better water resistance compared to samples B and C. The water resistance of sample A at room temperature is 88.86% while at 60ºC it is 85.02% . The results of testing the degree of curvature can be seen in table 2.

TABLE 2. AVERAGE INCREASE IN DEGREE OF CURVATURE

Treatment	Room Temperature (º)	Temperature 60ºC (º)
A	16.00	18.75
B	17.5	26.67
C	20	20.25

Source: Processed data (2024)

Table 2 shows the results that sample A (60 mesh bagasse variety) has the least degree of curvature, namely with a value of 16 º at normal temperature and 18.75 at 60 º C. Meanwhile, the largest value is found in sample C at room temperature with value 20 º and at a temperature of 60 º C the sample with the highest degree of curvature is sample B with a value of 26.67 º . The smallest degree of curvature indicates that the sample has high water resistance, because the sample does not bend easily when immersed in water.

The sample experiences an increase in weight and degree of curvature because when soaked in water it will experience swelling and the sample will become more flexible, due to the water seeping into the sample plate. The lower the water absorption in the plastic, the higher the water resistance, while the high water absorption will result in the water resistance decreasing which results in swelling *in* the sample. Stated that increasing temperatures can cause the water absorption value of bioplastics to increase and can cause water resistance to decrease.

Bioplastics made from starch are very susceptible to water resistance, this is because starch has hydrophilic properties, where water molecules will attack the hydrogen bonds in starch. However, there are other factors that influence the water absorption results, namely the thickness of the different samples which is caused by the sample molding process being less even, it can also be caused by the process of stirring the sample solution being not homogeneous causing the solution not to dissolve completely causing the resulting plastic to not perfect. Cellulose had unequal mesh sizes so during the mixing process the plastic dough was not homogeneous. The application of cellulose with different mesh sizes was thought to create cavities in the bonds formed. This caused the plastic to absorb water more easily [14]. Plate products with a variety of bagasse sizes of 60 mesh have the smallest increase in weight and degree of curvature, this is because bagasse which has a small size will produce a denser or tighter product. This is in accordance with the opinion of [15], which states that thick and dense plastic products will reduce the rate of water transmission. Stated that the level of density between fibers in samples with small diameters is higher than those with large diameters, so that the voids between fibers that occur in small diameters are lower than those with large diameters [16].

D. Biodegradability Test

This biodegradation test uses the *soil burial test method*, which in this test This was done with the aim of knowing the decomposition time of bioplastics by microorganisms in the soil. The biodegradation test was carried out using the *soil burial test method*, namely burying the sample in the ground [17]. Starch and glycerol are hydrophilic components that have a hydroxyl group – OH that can initiate hydrolysis reactions after absorption of water from the soil. Starch will be decomposed into small pieces and will disappear in the soil because high water absorption can provide conducive space for the development of decomposition microorganisms [18]. In this test, the sample is cut to a length of 6 cm and a width of 2 cm, then buried in soil mixed with compost, in a ratio of 1:1. The results of the biodegradability test can be seen in Figure 3.

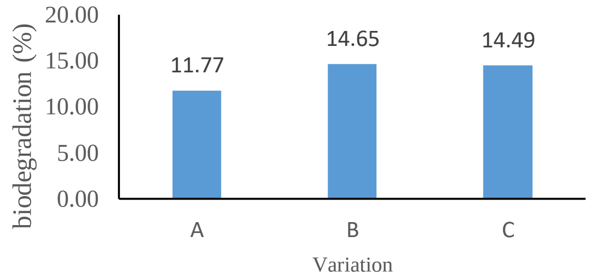

Figure 3. Biodegradability test

Based on Figure 3, it can be seen that the plate sample that has the highest biodegradation value is sample B (1mm bagasse variation) with a value of 14.65%. Meanwhile, the sample that had the lowest biodegradation value was sample A (60 mesh bagasse variety) with a value of 11.77%. Based on the ANOVA test, sugarcane bagasse variations have a significant effect on biodegradability, this is proven by a sig value <0.05. Based on the Duncan test, the biodegradability of bagasse variation A is significantly different from bagasse variations B and C, this is proven by different notations. The plate can be seen at Figure 4.

Figure 4. The Plate

This irregular damage shows that soil microorganisms also influence the degradation of the resulting bioplastic samples [19]. The results of this research are in line with research by Panjaitan [11] which shows that the smaller the size of cellulose, the lower the biodegradation rate. This biodegradation rate is due to the smaller size of cellulose resulting in a decrease in the level of water absorption, because with the smaller fiber size the sample will be denser, water provides space for microorganisms to enter the sample and accelerates the rate of degradation.

Bioplastics with a structure that is not too dense and dense are better, because they can speed up the rate of degradation, this is because water can absorb the sample pores well. The balance of water content influences the biodegradation process in the sample. Equilibrium water content is the water content of a material after being in certain environmental conditions for a long period of time. The water absorption process occurs when the relative humidity in the environment is higher than the humidity in the material, and vice versa. Water absorbed by the material can produce ideal conditions for the growth of decomposing microorganisms, so that the degradation process can proceed more quickly. Water content can cause plastic samples to degrade more easily [20].

IV. CONCLUSION

The addition of cellulose and the smaller the fiber size result in increased tensile strength and water resistance values. The largest tensile strength value produced was 47.72 N/mm ^{2} , the smallest weight addition value was 11.14% at room temperature and 14.98% at 60ºC and the smallest degree of curvature value was 16º at normal temperature and 18.75º at temperature 60ºC. However, this reduces the elongation and biodegradation values of the plate samples, this is because the smaller the fiber size, the denser the resulting plate structure. The greatest elongation value was 4.08% and the greatest degradation value was 14.65 on the plate with the addition of 1mm bagasse.

The best formulation obtained is an environmentally friendly plate with the addition of 60 mesh bagasse, because this variation has a high tensile strength value, has low elongation, has the highest water resistance, and can be degraded. Because the desired plate product is a plate that has a strong structure.

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