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Original Paper

Biodegradable Spoon Based on Glycerol and Cassava Starch with The Addition of Sugar Cane Pulp

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***Abstract*—Biodegradable Spoon is an environmentally friendly spoon-based product made from cassava starch, glycerol, and sugarcane. The research aims to determine the influence of the addition of sugar cane to biodegradable spoon characteristics. This research uses a completely randomized design (RAL) with 1 factor that is the variation of the addition of sugarcane. Each treatment is 3 times repeated and 2 observations. The results showed that the addition of sugarcane affects the value of water content, solubility as well as biodegradability of the spoon. The moisture content of ingredients ranges between 3.78-2.16%. The time of solubility in biodegradable spoon water is increasing with the highest time being 79 hours 50 minutes. The value of biodegradability of the highest spoon in the treatment of adding a 0% cane pulp with a value of weight loss of 52.92%, but on the other hand the increase of sugarcane is added the value of biodegradation increased.**

Keywords*—Biodegradable, Spoon, Cassava starch, Sugarcane pulp

I. INTRODUCTION

Based on data obtained from [1] plastic waste in Indonesia reaches 64 million tons/year where as much as 3.2 million tons is plastic waste dumped into the sea dominated by disposable packaging. Plastic Packaging in food products is a disposable packaging that raises environmental pollution problems. A plastic spoon is one complement of packaging on food products, especially instant food. Its massive use (large) makes the disposable plastic spoon waste contribute to the amount of plastic waste dumped into the environment. Therefore, there is a need for alternative plastic materials obtained from materials that are easily acquired and available in large quantities of nature and cheap but able to produce products with the same strength. Bioplastic Technology is one of the efforts to get out of the problem of conventional plastic packaging that can pollute the environment. Bioplastics are plastics or polymers that can naturally be degraded either through the attack of microorganisms or by the weather (moisture and sunlight radiation) [2]. Materials that can be used as bioplastics such as starch, cellulose, and other microorganisms.

Cassava starch can be used as raw material for bioplastics manufacture. Cassava starch content is quite high which is about 85%. The characteristics of the plastics produced from starch are less elastic and hydrophilic so it will be less resistant to water [3, 16, 17]. Additional plasticizers need to be given to obtain suitable plastic and improve its mechanical properties, namely glycerol. Glycerol is one of the starch plasticizers that produce homogeneous and elastic biodegradable plastics [4]. Cellulose in sugarcane pulp is expected to improve the structure and strength of biodegradable plastics. The content of cellulose in sugar cane is 37.65%, so the sugar cane can be used as additional material for the ideal biodegradable plastic.

II. MATERIAL AND METHODS

A. Materials

The materials used in this research include sugarcane pulp waste, cassava starch, glycerol, aquades, soil compost, blue silica gel. The tools used are magnetic stirrer hot plate, oven, blender, 80 mesh, stopwatch, thickness gauge, Vernier, plastic spoon, digital scales, glassware, 16 oz. plastic cup, plastic bucket, knife, jar, ruler, spatula, desiccator, baking sheet.

B. Methods

This research was conducted using a completely randomized design (CRD) with 1 factor. Each treatment was repeated 3 times and 2 times observation. The treatment factor is the addition of sugarcane pulp (A) consisting of 4 values, namely 0% (A0), 5% (A1), 10% (A2) and 15% (A3) of the weight of cassava starch.

i. Making Sugarcane Flour

The pulp is cut into ± 1 cm, then the washing process with water until clean and rinsed with distilled water. The drying process with an oven at a temperature of 60 oC for 72 hours. Then the smoothing of the sugar cane with the blender bit by bit until smooth completely. Lastly, sieve the pulp with a sieve size of 60 mesh to get the flour result with the same size and smooth [5].

ii. Biodegradable Spoon Making

The biodegradable spoon is produced through the process of mixing cassava starch with a solvent aquades with a ratio of 1:1 in this case, using 20g cassava starch and

20ml aquades. Cassava starch first dissolved until homogeneous manually. Cassava starch solution is further added as much as 20% glycerol from the starch weight. The mixing process is done by heating with a temperature of 100oC accompanied by stirring for 30 minutes. While stirring, sugarcane flour is added with the appropriate amount of treatment little by little. Make sure all the ingredients are perfectly mixed, marked by the absence of lumps in the solution. Stirring is done until the solution becomes smooth. The mixture of plastic film was then printed and warming in the oven with a temperature of 60oC for 72 hours. The resulting plastic is then cooled in the Desiccator for 24 hours [6].

C. Analysis Procedure

i. Dimension Test

Measuring spoon dimensions include length, width, weight, and thickness. Measurements of length, width, and thickness are performed based on measuring points. Data from the measurement of biodegradable spoons will be compared with measurement data of molded plastic spoons as a reference. Measuring points can be seen in Fig. 1.

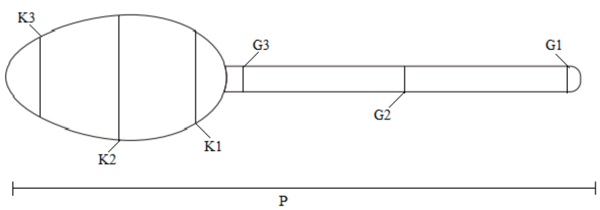

Fig. 1. Dimension measurement scheme

Explanation: K1 = base of spoon head; K2 = Middle head spoon; K3 = Spoon head tip; G1 = Tip of the handle of the spoon; G2 = Middle handle of spoon; G3 = base of spoon handle; Gtot = Spoon handle.

ii. Moisture Test

Each sample is weighed on a digital balance to determine the initial weight of the sample (W). Place the samples on the baking pan, then heat in the oven with a temperature of 105oC for 4 hours. Then put in a desiccator for 15 minutes to lower the temperature. Weigh the samples after drying using the digital balance to figure out the final weight of the sample (W1). This treatment is repeated until the constant weight is reached. Moisture content is obtained using the following calculations:

$$\text{Water content } (\%) = \frac{w - w1}{w}\, x\, 100\% \qquad (1)$$

Where, W = initial weight of the material (g); W1 = final weight of material after heating (g).

iii. Solubility Test

This test is done by taking a test sample and then put in a 16 Oz plastic cup containing 250 ml of water. The water used is water at room temperature. Make sure the spoon has been completely submerged in water. Do the stirring regularly, every 6 hours. Next, calculate the time of dissolution in water. Time measurement is stopped when the spoon is completely dissolved in water and sediment is formed.

iv. Biodegradability Test

Biodegradability testing is done by using the soil burial test method, which is to bury bioplastic samples in the soil. The soil used is a mixture of soil and compost with a ratio of 1: 1. This test is carried out by keeping the biodegradable spoon sample in a 16 Oz plastic cup containing soil. The time needed to analyze is 21 days. Calculation of percent loss of mass using the formula below:

$$\text{Percentage of mass loss} = \frac{\text{Wi} - \text{Wf}}{\text{Wi}}\text{ x } 100\% \qquad (2)$$

Where, Wi = Mass of sample before biodegradation (g); Wf= Mass of sample after biodegradation (g)

D. Data analysis

The data obtained were analyzed using SPSS version 16 using the analysis of variance (ANOVA) method to determine the effect of each treatment on the characteristics of biodegradable plastic spoons at a level of $\alpha = 0.05$. If there is a real difference, Duncan's Multiple Range Test (DMRT) will be tested at a significant level of 5%.

III. RESULT AND DISCUSSION

A. Dimension Test

TABLE I. DIMENSION TEST SPOON

No	Parameter	Plastic spoon	Biodegradable Spoon
1	Long (mm)	110,00	107,84 ± 1,79
2	Width(mm):		
	K1	17,52	17,67 ± 0,27
	K2	21,15	21,40 ± 0,61
	K3	13,11	13,28 ± 0,50
	Gtot	6,39	6,43 ± 0,24
3	Weight (g)	1,32	4,58 ± 0,26
4	Thickness (mm) :		
	K1	1,9	4,04 ± 0,47
	K2	1,9	4,45 ± 0,37
	K3	1,7	3,37 ± 0,29
	G1	2,1	4,51 ± 0,23
	G2	2,1	4,49 ± 0,22
	G3	2,1	4,36 ± 0,22

Based on the data in Table I it can be seen that the control plastic spoon is longer than the biodegradable spoon while the biodegradable spoon width is greater than the control spoon. The biodegradable spoon is thicker than the control spoon. The biodegradable spoon weight is greater than the control spoon with a difference of 3.26 g. This is influenced by the density of the basic ingredients making the spoon itself. Conventional plastic spoons are usually made of polystyrene (PS) or polypropylene (PP) type plastic. The density of the two types of plastic is 1.06 g / cm3 and 0.895-0.92 g / cm3. The basic ingredients of making biodegradable spoons are cassava starch, glycerol and sugarcane pulp which have densities of 1.5 g / cm3, 1.26 g / cm3 and 0.8 g / cm3, respectively. The more additives that have a higher density added in a polymer matrix, the higher the weight and density of the polymer [7]. Comparison of biodegradable spoons with control plastic spoons can be seen in Fig. 2.

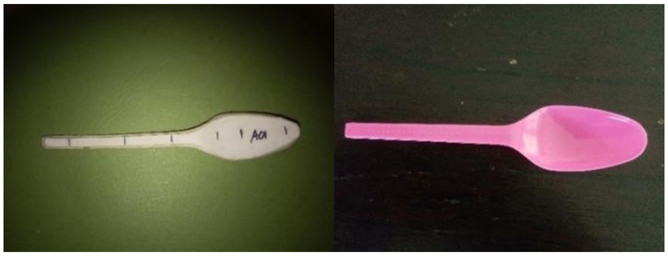

Fig. 2. Biodegradable spoon and control plastic spoon

B. *Moisture Test*

The decrease in water content occurs as an increase in the amount of sugar cane. Sugar cane is a hydrophobic component. The addition of sugarcane is aimed at reducing the hydrophilic starch properties, due to the hard-soluble cellulose characteristics in water. Cellulose has strong hydrogen bonds making it difficult to mix with the water [8]. The less water is tied, the water content in the material will be less. Drying causes the spacing of cellulose fibers to be more tightly, resulting in a more compact and cohesive increased hardness of the membrane. Water content value is very closely related to the resilience of a substance on the influence of microorganism'2 activity. Low water content makes the ingredients more durable in the storage process with a relatively long period time so the possibility of damage to the fungus at the time of storage is very small [9].

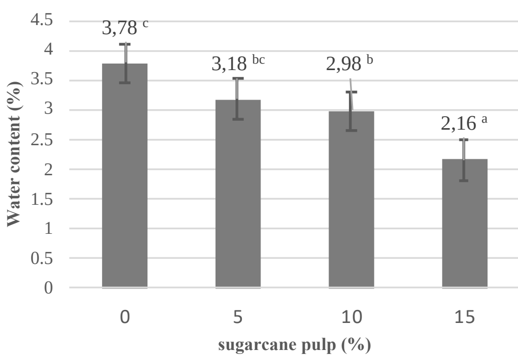

Fig. 3. The value of the moisture content of the biodegradable spoon

C. *Test solubility*

The increase in the number of hydrophilic components is thought to cause increased film solubility. With the addition of cellulose treatment as a hydrophobic component on the composition of cassava and glycerol starch as a hydrophilic component created remains to be expected to improve biodegradable plastic durability. The combination of cassava starch with cellulose from sugar cane makes the biodegradable spoon's resistance to water increased. The addition of cellulose can reduce the hydrophilic properties of starch because cellulose has the hard-soluble characteristics of water [10]. Cellulose is a homopolysaccharide that has a linear molecular form. Cellulose has a strong hydrogen bonding structure so it is difficult to mix with the water. Cellulose with a formula $(C_6H_{10}O_5)n$ is a natural polymer with a long chain formed from small interlinked molecules. The structure causes cellulose to be crystalline and not easily soluble in water (hydrophobic) [6]. That trait is used in the making of this biodegradable spoon. It is in accordance with the data obtained that the spoon with a percentage of the increase in the sugar cane pulp (cellulose) by 15% has the longest durability when immersed in the water.

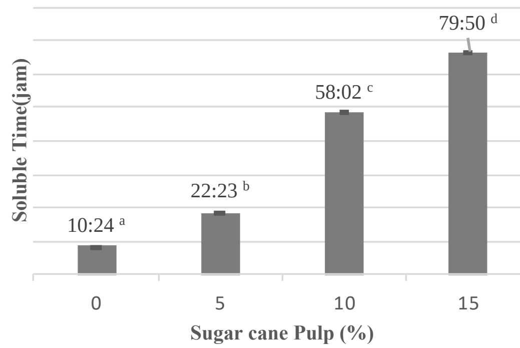

Fig. 4. Biodegradable solubility of spoon test

D. *Biodegradability test*

The more hydrophilic of a bioplastic is the easier it unravels in the soil [11]. 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. The biodegradable test process can be seen in Fig. 6.

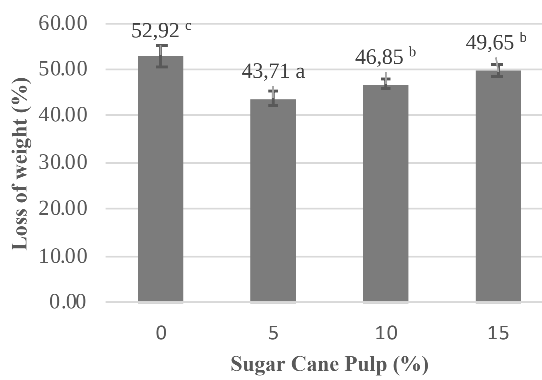

Fig. 5. Biodegradability value of biodegradable spoon

The additional treatment of the pulp of 5%, 10%, and 15% have a lower biodegradability value compared to the treatment of 0% sugar cane pulp. Sugar cane is causing decreased degradation power of the sample. It is because of the sugar cane contains cellulose. Cellulose is a hydrophobic component that can inhibit the rate of diffusion of water in a polymer. However, increasing the volume of sugarcane is added increasing the value of biodegradability of the spoon. According to [12], the more cellulose contained by plastic, the faster the plastic is to be degraded. The increase in cellulose content in the biodegradable spoon composition without being followed by an increase in the volume of glycerol and starch causes the mixture to become less homogeneous. A bond between glycerol, cellulose, and starch will be formed if there is still a free -OH group. If there is no free -OH group, then the compound added will remain independent as a molecule without bonds with other molecules [13]. Chemical degradation reactions that occur in linear polymers cause a decrease in molecular weight or shortening of chain length catalyzed by microorganisms. Degradation will occur due to the process of damage or quality degradation due to the breaking of the chain bonds in the polymer [14].

Fig. 6. Biodegradable test process

Water content equilibrium also influences the spoon biodegradation process. Water content equilibrium is the water content of material after being in certain environmental conditions for a long period of time. Water vapor displacement occurs due to differences in the relative humidity (RH) of the environment and the sample. Conditions for achieving equilibrium in the sample water content and environment are characterized by a constant sample weight. The lower the water content of the material, the higher the absorption. This happens because the addition of excess cellulose causes hydrogen bonds in cellulose molecules to tend to form intramolecular hydrogen bonds including water molecules. The process of water absorption (adsorption) occurs when the relative humidity (RH) the environment is higher compared to the realistic moisture of the material, as well as vice versa. Water absorbed by the ingredients can create an ideal condition for the growth of the parser microorganisms. So that the degradation process runs faster [15].

IV. Conclusion

The addition of sugarcane has a real effect on the value of water content, solubility, and biodegradability of the spoon. The moisture content of the material is inversely proportional to the addition of sugar cane with water content value between 3.78-2.16%. The addition of sugar cane causes the time of solubility in the water of biodegradable spoon is increasing with the highest time is 79 hours 50 minutes. The value of biodegradability of the highest spoon is in the treatment of adding a 0% cane pulp with a weight loss of 52.92%, but on the other hand, increasing the sugar cane which added the value of biodegradation, more increased.

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