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The Potential of Cassava Peel Waste as a Material of Biodegradable Plastic using Calcium Silicate Filler

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ABSTRACT

Biodegradable plastics are plastics that can be degraded and decomposed quickly by microorganisms in the soil. In this study, biodegradable plastic was made with starch from cassava peel waste, sorbitol as a plasticizer, and calcium silicate as a filler. This research was conducted to determine the effect of the amount of filler and the amount of plasticizer on biodegradation properties, tensile and elongation strength, and water absorption properties. The variables used in the plasticizer are 30%, 40%, and 50% (w/w) of the weight of cassava peel starch. While the variables used for filler are 1%, 3%, 5%, and 7% (w/w) of the weight of cassava peel starch. The results of the study showed that the highest biodegradation test results were 81.7% with 7% calcium silicate filler variables and 50% plasticizer sorbitol, tensile strength test obtained the highest value of 0.767 MPa on 3% calcium silicate filler variables and 30% sorbitol, elongation test with the highest value on the filler variable calcium silicate 7% and sorbitol 30% that is equal to 5.20% and the water adsorption test obtained the smallest value is 10.33% on the filler variable calcium silicate 1% and sorbitol 30%. The biodegradable plastic as a result of this research has met the standards for degradation ability based on the ASTM 6400 standard but has not met the standards for tensile strength, elongation, and water adsorption.

***Keywords*:** biodegradable plastic, calcium carbonate, cassava peel, sorbitol, waste.

1. INTRODUCTION

Garbage is one of the environmental problems that are difficult to overcome, especially plastic waste which takes tens to hundreds of years to decompose. The definition of waste itself is the result of the rest of human activities. Garbage is divided into many based on the source, nature, and form. Plastic waste is one type of waste based on its nature, namely inorganic waste. One of the characteristics of plastic waste is that it is not easy or difficult to degrade. Based on research conducted by Jenna R Jambeck from the University of Georgia, Indonesia is the second largest producer of plastic waste in the world after China.z

Plastic is a product commonly used by humans in daily life. There are many objects made of plastic such as chairs, tables, cabinets, and much more. Plastics are also commonly used as packaging or containers for a product. For now, domestic plastic needs to reach 2.3 million tons [1]. Plastic has many advantages such as being easy to form, low price, longer durability, and easy to produce. However, plastic also has the disadvantage that it is not easy to decompose. This lack of plastic can cause environmental pollution because if plastic is difficult to decompose, plastic will be buried which will cause pollution to soil and water. According to Winursito's research, the decomposition of plastic waste takes 10-12 years. As for plastic bottles, it takes even longer, namely 20 years because the polymer is more complex. Styrofoam takes even longer to decompose, which is 500 years to completely decompose [2]. Because the degradation time is quite long, the longer the plastic waste will accumulate which can cause pollution to the environment. From this problem, efforts need to be made to reduce pollution due to plastic

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waste, one of which is using biodegradable plastic.

Biodegradable plastics are plastics that can be decomposed naturally by the activities of microorganisms in the soil. In general, biodegradable plastics have the same uses as conventional plastics. This type of plastic is made of biopolymers. Biopolymers are polymers composed of renewable biomass. One example of a biopolymer that can be found easily is starch. One of the materials that can be used in the manufacture of biodegradable plastic is starch derived from plants, fruit flesh, tubers, and fruit skins [3]. According to Putra and Saputra, Indonesia is a country that has the potential to produce biodegradable plastics with the potential of its starch resources. Starch is the main ingredient produced by plants to store excess glucose. Starch is a copolymer composed of 2 types of constituents separated according to their solubility, namely amylose and amylopectin [4]. One source of starch that can be used as a basic material for making biodegradable plastics is starch from cassava peels. Cassava peel is a waste from cassava root crops. Cassava peels which are considered waste so far have only been disposed of and used as animal feed, even though cassava peels are rich in starch and have potential as plastic raw materials [5]. Cassava peel was chosen as a material to make biodegradable plastic because it is very affordable, can be found everywhere, and is in abundance. Cassava production in Indonesia in 2018 reached 19,341,233 tons according to the Central Statistics Agency. The presence of cassava peels reaches 15% of the weight of cassava [6], so the number of cassava peels in 2018 was 2,901,185 tons.

Afif et al. conducted a study on the Production and Characterization of Bioplastics from Avocado-Chitosan Seed Starch with Sorbitol Plasticizer, the results obtained for the addition of 2 grams of sorbitol plasticizer, the tensile strength value of 3.19 MPa was obtained where the more sorbitol added, the tensile strength of the plastic decreases. Then in the water absorption test, the water absorption value of plastic ranges from 50-80% depending on the amount of sorbitol added, and in the biodegradable test, this study gets a value of 37.52% to 44.39%, respectively, from 1-4 grams of sorbitol [7]. Likewise, a study entitled characterization of biodegradable plastics from muli banana peel waste starch with plasticizer sorbitol obtained biodegradable plastic which has tensile strength values ranging from 1.328 MPa to 1.039 MPa with 2 grams of sorbitol. Then the water absorption test obtained a value of 13.48% to 28.54% according to the addition of the material. And in the degradation test, the degradation value was obtained from 17.81% to 35.02% [4].

In the 2 studies above, the basic ingredients are starch from avocado seeds and banana peels. The starch content of avocado seeds is 23%, while the starch content of banana peels is 27.21 – 30.66% depending on the type of banana. In this study, the basic ingredient of cassava peel starch is 44-59% starch. Because according to Darni and Utami, mechanical properties are influenced by the amount of content of the components that make up bioplastics, namely starch, chitosan, and sorbitol as a plasticizer. This means that the higher the starch content of the base material, the more rigid and brittle the plastic will produce, therefore cassava peel is chosen instead of the cassava tuber itself because the starch content in cassava peel is lower than cassava tuber [8].

Biodegradable plastics made from starch have low mechanical properties and cannot hold water [8], so it is necessary to add materials that can improve these properties. The material is a plasticizer (plasticizer). Commonly used plasticizers are polyols such as sorbitol and glycerol because of their ability to reduce internal hydrogen bonds [9]. In a study conducted by Udjiana et al., the factor that caused the weak tensile resistance of the plastic produced was due to the addition of a plasticizer in the form of sorbitol. The variables used were 0%, 3%, 6%, 9% (w/w). The addition of sorbitol is considered too much than the amount commonly used so that it can reduce the tensile strength value of the biodegradable plastic produced because the addition of a plasticizer will reduce hydrogen bonds in the plastic, thereby increasing the flexibility of the plastic which causes the tensile strength value of the plastic to be small. The tensile strength values in their study were 62.22 MPa, 35.28 MPa, 16.66 MPa, and 11.76 MPa [10]. From the two studies above, the more the amount of plasticizer added, the lower the tensile strength value. However, the use of sorbitol produces biodegradable plastics with a tensile strength value that is much higher than glycerol, so in this study, sorbitol was chosen as a plasticizer.

In addition to plasticizers, fillers are needed to increase the rigidity of the plastic so that it is not too flexible, increase the strength of the plastic, and reduce the solubility. Filler can also affect the results of tensile strength analysis, water absorption test, and biodegradability test of the results of making biodegradable plastic. In this study, we used fillers in the form of calcium silicate and calcium carbonate. In a study conducted by Udjiana et al. using calcium silicate and calcium carbonate filler types, the result is that the addition of a filler in the form of calcium silicate can increase the biodegradation value and tensile strength of plastics, as well as the lowest water absorption value. While the effect of adding calcium silicate and calcium carbonate fillers, in the biodegradation test, the highest values were obtained at 2% calcium silicate and 8% calcium carbonate variables. In the water resistance test, the lowest value was found in the addition of calcium silicate filler as much as 8% and calcium carbonate as much as 2%, while in the tensile strength test, the highest value was obtained in the variable calcium silicate 6% and calcium carbonate 8% [11].

In this study, cassava peel was used as a source of starch for making biodegradable plastics, with the addition of a plasticizer in the form of sorbitol and a filler in the form of calcium silicate . No one has researched the combination of the ingredients used. Therefore, it is necessary to conduct research that is expected to be able to produce biodegradable plastic according to testing standards.

2. RESEARCH METHODS

2.1. Cassava Peel Starch Preparation

Cassava peel that has been washed with clean water and then cut into pieces. Pieces of cassava peel were soaked in a 1% NaCl solution by weight of cassava peel with 1 liter of water to reduce the cyanide content in the cassava peel. Furthermore, the cassava peel is washed again with clean water and then dried and mashed with a blender until it becomes flour.

2.2. Filler Preparation

The calcium silicate grinding process is carried out using a ball mill for about 30 minutes. The grinding powder filler is subjected to a screening process with a size of > 133 mesh. The filler powder resulting from the screening is ready for use.

2.3. Biodegradable Plastic Preparation

10 grams of cassava peel starch powder was dissolved in 200 ml of distilled water and then stirred until it became a starch solution. The solution was heated while stirring until gelatin was formed. The mixture was then added with sorbitol as much as 30%, 40%, and 50% (w/w) by weight of starch, and calcium silicate filler as much as 1%, 3%, 5%, and 7% (w/w) by weight of starch. The mixture was stirred until smooth by heating for about 10 minutes, then cooled to a temperature of about 50^{o} C, and then molded. The plastic molds were dried in an oven at 70 C for 6 hours, then dried in a desiccator for 24 hours. The finished plastic was tested for tensile strength, elongation test,

biodegradable properties, and water absorption properties.

2.4. Biodegradation Test Analysis

According to ASTM D6400 and EN 13432 standards, biodegradable plastics can be degraded by around 60%-90% for 180 days. Biodegradable plastic based on cassava peel starch was tested for its biodegradable properties by inserting a 3 x 3 cm sample into the soil. The first treatment was the initial weight before being degraded and after being degraded, it was weighed again to find out what the % change was.

2.5. Analysis of Tensile Strength and Elongation

The tensile strength testing process is carried out using a Machine Tester with type MCT - 2150. The test specimen has a standard size and shape that has been determined by the ASTM D882 standard. The test is carried out using the tip of the sample clamped by a tensile testing machine. Furthermore, the initial thickness and length of the sample were recorded. The start button on the computer is pressed then the tool will draw the sample at a speed of 10 mm/min. The value of tensile strength is obtained and the result of dividing the maximum stress by the cross-sectional area. The cross-sectional area is obtained from the product of the initial length of the sample with the initial width of the sample. While the elongation test (elongation to break) is a comparison of the addition of length that occurs after the tensile test with the previous one.

2.6. Water Absorption Test Analysis

Samples were cut to a size of 3 x 3 cm. The desired sample is placed in a desiccator for 15 minutes. The sample was weighed initially (W_0). After that soaked in water for 10 seconds. Then the sample was dried using dry tissue and the final weight was weighed. Repeat immersion until a constant weight is obtained.

3. RESULTS AND DISCUSSION

In this research, cassava peel is used as the basic material for making biodegradable plastic. The variables used in this study were the amount of plasticizer sorbitol and filler calcium silicate. The analysis carried out on biodegradable plastics is the biodegradation test, tensile strength and elongation test, and water absorption test on biodegradable plastic.

The dried cassava cultivars are mashed with a blender to obtain cassava peel flour (Figure 1) . From this process, the amount of cassava peel powder was 478.91 grams from 5 kg of cassava peel, so the % yield could be found at 9.5782%.

The manufacture of biodegradable plastic is done by the casting method. Overall, the biodegradable plastic produced from this research has the characteristics of blackish brown and not transparent, the surface is slightly rough, flexible, and does not break when bent. The test results show plastic is quickly degraded, does not absorb water, and has good elasticity but low tensile strength.

Figure 1. Cassava peel powder.

Based on the results of the biodegradation test (Figure 2) shows that the % biodegradability tends to increase with the addition of calcium silicate filler and sorbitol plasticizer. According to Udjiana et al., the ability of plastic degradation is related to the ability to absorb water where the more water content in the plastic, the more easily it will be degraded. Theoretically, calcium silicate has hydrophobic properties so it is difficult for plastic to absorb water and its biodegradability will decrease as the amount of calcium silicate increases [12]. However, in this study, the results obtained are inversely proportional to the theoretical. This can be caused by the reaction that occurs in the filler preparation process using HCl. The addition of HCl causes the biodegradation ability to increase because HCl will react with calcium silicate to produce hydrophilic calcium chloride, with the following reaction [13]:

$$CaSiO_{3(s)} + HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2SiO_{3(aq)}$$

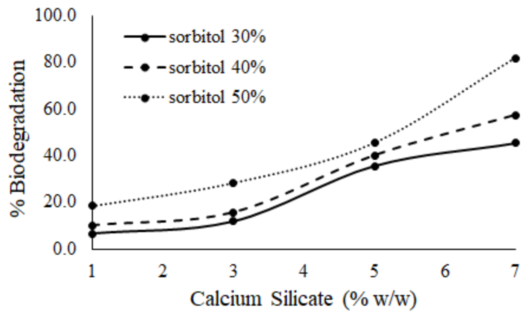

Figure 2. Biodegradation test of biodegradable plastics with calcium silicate filler and sorbitol plasticizer.

In addition, the increasing number of plasticizers also causes an increase in the % biodegradation of plastics, because the plasticizer used in this study is sorbitol which has hydrophilic properties. Thus, the increasing number of hydrophilic compounds in plastic causes the level of biodegradation to increase. The results of the biodegradation test conducted show that almost all plastic samples have a biodegradation percentage that meets the ASTM D6400 standard, which is more than 10% in 5 days.

Based on the results of the tensile strength test (Figure 3) shows that the tensile strength of plastic from cassava peel tends to increase along with the addition of calcium silicate filler, but decreases with the addition of sorbitol plasticizer. According to Udjiana et al., calcium silicate in water will form calcium hydroxide which can bind to the OH- group in cassava peel starch. Calcium silicate will also form hydrate bonds to form calcium silica hydrate (C-S-H) where this bond can increase the bonding strength of biodegradable plastics [12]. Munthoub and Rahman's research also states that the more calcium silicate fillers are added, the greater the tensile strength value of biodegradable plastic. While the effect of adding a plasticizer to the manufacture of biodegradable plastic will reduce the intermolecular hydrogen bonding of the polymer. So, it can reduce the tear resistance of the plastic and increase its flexibility of the plastic, thereby reducing the tensile strength value [5]. In other words, the more plasticizer added to biodegradable plastic, the lower the tensile strength will be. This is in line with the theory according to Lai and Padua, that the addition of plasticizers more than a certain amount of will produce films with lower tensile strength values [14].

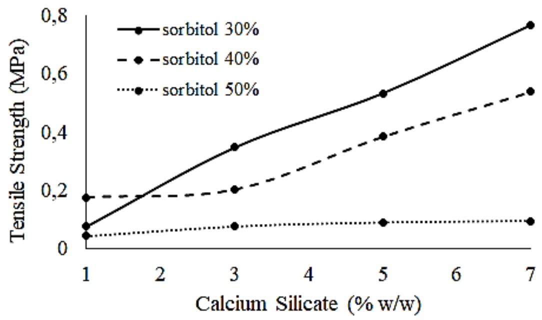

Figure 3. Tensile strength test of biodegradable plastics with calcium silicate filler and sorbitol plasticizer.

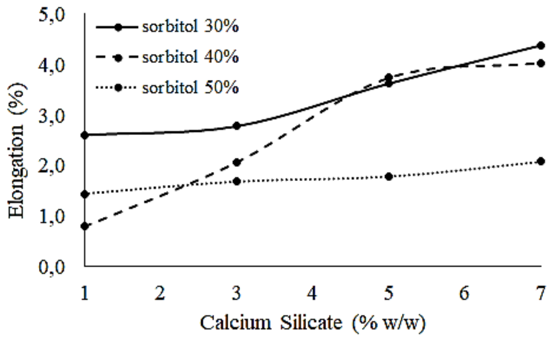

Figure 4. Elongation test of biodegradable plastics with calcium silicate filler and sorbitol plasticizer.

However, the tensile strength value produced in this study is still low when compared to the

research conducted by Purwanti, where the standard tensile strength value for the moderate properties class (standardized biodegradable plastic) is 1 – 10 MPa [15].
Based on the results of the elongation test of biodegradable plastic (Figure 4), it is shown that the tensile strength of plastic from cassava peel tends to increase with the addition of calcium silicate filler. Meanwhile, the addition of sorbitol plasticizer showed results that tended to decrease with the addition of 50% sorbitol. The elongation value produced in this study is still very low when compared to the research conducted by Purwanti, where the standard elongation value for the moderate properties group (standardized biodegradable plastic) is 10 – 20 MPa [15].
Based on the results of the water adsorption test (Figure 5), it appears that the addition of calcium silicate filler to biodegradable plastic tends to increase the plastic's ability to adsorb water. This is in accordance with the research results of Udjiana et al., that calcium silicate is solid and insoluble in water, so the resulting biodegradable plastic has a more tenuous structure so that water is easily absorbed [10]. In other words, the addition of calcium silicate filler is directly proportional to the water adsorption properties, where the more calcium silicate, the greater the water adsorption value.

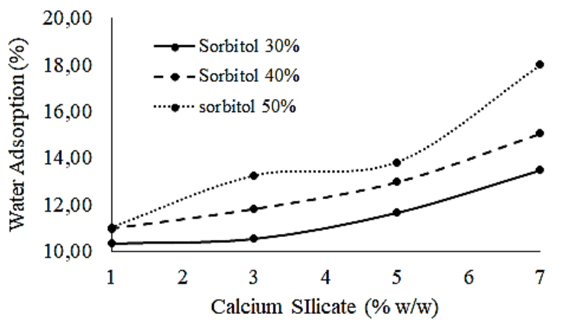

Figure 5. Water adsorption test of biodegradable plastics with calcium silicate filler and sorbitol plasticize.

The ability to adsorb water can also increase due to the bond between calcium ions (Ca^{2+}) in calcium silicate with hydroxyl groups from starch to form a network. The more calcium silicate is added, the greater the ability to adsorb water [10].
Furthermore, the % water absorption of plastics tends to increase with the addition of 50% sorbitol. Based on the theory, the addition of sorbitol to biodegradable plastics can increase the water absorption value of plastics. The increase in plastic absorption power is due to sorbitol having a chemical structure ($C_6H_{14}O_6$) which contains a hydroxyl group (-OH) which has hydrophilic properties so that the resulting biodegradable plastic easily absorbs water.

4. CONCLUSION

Based on the results of research on the use of cassava peel as a base material for biodegradable plastics, it was found that plastics with a good level of biodegradability were obtained by adding calcium silicate filler 7% (w/w) with sorbitol plasticizer 50% (w/w). While the plastic with the best tensile strength and elongation values was obtained by adding 7% (w/w) calcium silicate filler with 30% (w/w) sorbitol plasticizer. Plastic from cassava peel with the best percentage of water adsorption was obtained from 1% (w/w) calcium silicate filler with 30% (w/w) sorbitol as a plasticizer.

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