Engineering and Technology Journal e-ISSN: 2456-3358

Volume 08 Issue 12 December -2023, Page No. – 3143-3148

DOI: 10.47191/etj/v8i12.04, I.F. – 7.136

Utilization of Cassava Tubers (Dioscorea Alata) and Chitosan to Produce Biodegradable Plastic

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ABSTRACT: Plastic is a synthetic compound made from petroleum, which is very useful for various household and industrial purposes. This is due to the many superior properties of plastic compared to other materials. However, on the other hand, plastic made from petroleum raw materials still has several weaknesses, including product safety for health and after use it will become waste that is difficult to degrade, thus polluting the environment. Apart from that, the supply of petroleum raw materials is increasingly depleting and non-renewable. Plastic can be produced from raw materials that are safer for health and the environment. Several studies on the manufacture of biodegradable plastic have been carried out using raw materials in the form of organic materials whose main content is starch, however the strength and elasticity of the resulting plastic is still low. Therefore, in this research we will study the manufacture of biodegradable plastic from tubers that are not properly utilized, namely yam tubers (discorea alata) with the addition of chitosan as a reinforcement. This research was carried out by mixing the materials, heating then molding and drying. The variables studied include process temperature, process time, and the mass ratio of chitosan to starch. Next, mechanical tests were carried out, namely tensile strength and elongation, FTIR tests, and biodegradation tests with EM4 bacteria. The research was carried out using the variables process temperature, process time, and chitosan:starch mass ratio. Based on the results of research carried out with raw materials such as yam tubers and chitosan, optimal conditions were obtained using a time of 90 minutes, a stirring speed of 300 rpm, a temperature of 80 oC, and a mass ratio of chitosan to starch of 0.075. With these conditions, plastic was obtained with a tensile strength of 7.80 MPa and an elongation of 16.37%. Biodegradable plastic from yam tubers and chitosan can be degraded with the help of EM4 bacteria for 35 days, so the biodegradable plastic from yam tubers is environmentally friendly plastic.

KEYWORDS: biodegradable, chitosan, plastic, tubers, waste.

I. INTRODUCTION

Plastic is a polymer compound formed from the polymerization of small molecules or hydrocarbon monomers which form long chains with a rigid structure. Plastic is a synthetic compound from petroleum, especially short chain hydrocarbons which is made by the polymerization reaction of the same small molecules, so that it forms long and stiff chains and will become solid after the temperature at which it is formed (Handayani, R. 2016). The process of making plastic consists of heating, forming and cooling. This formation can be done by printing, pressing and heating. This process is carried out so that the plastic that has been formed will not change again. One of the synthetic plastics is HDPE. HDPE has a tensile strength value of 3100-500 Psi with an elongation of 100%. HDPE has material properties that are harder, stronger, opaque, and more resistant to high temperatures (Billmeyer, F. W. Jr. 1984).

Plastic packaging has several advantages, namely that it is strong but light, inert, does not rust, and is thermoplastic (heat seal) and can be colored. The permeability of plastic to water vapor and air means that plastic can play a role in modifying the packaging space during storage (Winarno, 1994).

The weakness of this material is that the monomers and other small molecules contained in plastic can migrate into the packaged food ingredients. The plastic used today is a synthetic polymer, made from petroleum (non-renewable) which cannot be degraded by microorganisms in the environment (Firdaus and Tjitro, S. 2002). The use of plastic from petroleum has a negative impact on the environment because it is difficult to decompose by microbes in the soil (Sanjaya and Puspita, 2013). Supervision management of plastics that have the potential to pollute the environment is difficult to control, as burning used plastic can cause exposure to carcinogenic substances, such as chlorine, poly chloro dibenzodioxins, and poly chloro dibenzofurans (Rahyani, 2011)

Based on existing facts and scientific studies as well as increasing public awareness of the importance of a sustainable environment, it is necessary to carry out research and development of biodegradable packaging material technology (Latief, 2001). Biodegradable plastic is plastic that can break down quickly in the environment and is environmentally friendly when it interacts with soil and microorganisms. One of the natural materials that can be used as a material for making biodegradable plastic is starch (Akbar et al., 2013). Indonesia, as a country rich in natural resources (agricultural products), has the potential to produce various biopolymer materials, so biodegradable plastic packaging technology has good prospects (Darni et al., 2008).

Based on the raw materials used, bioplastics are grouped into two groups, namely bioplastics, petrochemical base materials (non-renewable resources) with biodegradable additives, and bioplastics, base materials from renewable natural resources (renewable resources), such as plants containing starch and protein and cellulose. which come from animals (milk, egg whites, egg shells) and plants (sugar bagasse, tofu dregs, banana peels, jackfruit peels, tubers, seeds) (Selpiana, 2016).

Starch-based plastic is safe for the environment. In comparison, traditional plastic takes approximately 50 years to decompose naturally, while bioplastic can decompose 10 to 20 times faster. Burning bioplastics does not produce dangerous chemical compounds. Soil quality will improve with the presence of biodegradable plastic, because the decomposition of microorganisms increases the nutrients in the soil. However, most biodegradable plastics have poor mechanical properties. To compensate for the reduction in plastic strength due to the addition of starch, other materials are needed as plasticizers or plasticizers to increase the mechanical strength (Hidayat, R et al. 2015)

Likewise, the tensile strength, elongation value also decreases as the amount of starch increases. The decrease in mechanical properties (tensile strength and elongation) due to the addition of starch causes low surface interaction between the two polymers (Inggaweni, and Suyatno, 2015). The addition of taro starch tends to reduce the tensile strength. The more starch added to the composite, the lower the surface interaction, because the adhesion between the mixtures is lower (Waryat, et al., 2013).

Biodegradable plastic is plastic that can be made from conventional plastic, but is mixed with basic ingredients that are easily decomposed, namely from compounds contained in plants such as cellulose and protein. Making plastic with the addition of this material can facilitate the degradation process by bacteria by breaking the polymer chain into its monomers (Vilproux and Averous, 2006). Uwi or coconut yam (Dioscorea alata) is a type of tuber that has many cultivars. Uwi plants usually grow quickly and fertilely (see Figure 1), are spherical or cylindrical in shape, brown on the outer surface and white and yellow on the tuber flesh (see Figure 2). This yellow, brown-skinned yam grows through root tubers. The harvest time for this yam is around 8-9 months). Uwi tubers have a fairly high carbohydrate content, namely 19.8 grams per 100 grams. (Hapsari, R, 2014). Different types of cassava tubers have different starch levels. Starch, amylose and amylopectin levels in uwi flour (Winarti, 2013) can be seen in table 1.

Figure 1. Uwi root plant

Figure 2. Uwi tubers (Dioscorea alata)

Table 1. Starch, amylose and amylopectin levels of cassava tubers

Type of Flour	Grade starch (%)	Content amylose (%)	Content amyopectin (%)
Yellow yam (Dioscorea alata)	83,38	14,81	68,57
Purple yam (Dioscorea alata)	86,12	17,59	68,60
Purple-skinned yellow yam (Dioscorea alata)	86,68	17,32	69,36
Gembili (Dioscorea esculenta)	82,82	13,26	69,56
Uwi frog (Dioscorea pinthaphylla)	79,27	7,48	71,79
Gembolo (Dioscorea bulbifera)	84,80	18,98	65,82

Chitosan is a yellowish white amorphous solid, non-toxic, and is good as a flocculant and coagulant and easily forms membranes or films. Chitosan is a long chain polymer composed of glucosamine monomers. The properties of chitosan are that it is insoluble in water, has quite good chemical resistance, dissolves in acid solutions (Listiyaningsih, 2013).

The widespread use of chitosan is to modify the substance chitin which is slightly soluble in water. In the last few decades, commercial use of chitosan has been widely used to add additives to food products as a natural preservative. The ability of chitosan to increase the shelf life of food is very profitable in its use (Selpiana, 2016).

Chitosan has several beneficial properties, namely biocompatibility, biodegradability, hydrophilicity and anti-bacterial. Biocompatibility is the ability of a material to respond to a good biological response. Biodegradability is the ability to downgrade the physical chemical properties of a material, including demineralization, deproteination and pigmentation. The anti-bacterial function of chitosan makes the material non-toxic during degradation. Chitosan also has reactive, binding, chelating, absorbing, stabilizing, film-forming and clarifying components (Selpiana et al. 2016).

II. RESEARCH METHODS

Extracting starch from uwi tubers is done by grinding uwi, adding water with a ratio of uwi: water = 1:2, mixing and kneading until the starch is completely distributed into the water. The mixture is separated by filtering and squeezing, until the dregs are separated from the extract which contains water and starch. The extract was left for one day to allow the starch to precipitate, then the starch was separated from the water using . decantation and filtration. Starch is dried, crushed and sifted.

Cassava tuber starch with a certain weight and chitosan with varying chitosan:starch mass ratios were put into a glass beaker. The mixture was added with 0.5% acetic acid and glycerol. With certain comparisons. The mixture of ingredients is heated on a hotplate with stirring using a magnetic stirrer with varying temperature and process time. The mixture was molded and dried using an oven at 80°C for 3 hours.

III. RESULTS AND DISCUSSION

The results are biodegradable plastic, which is analyzed to determine the quality of the plastic, including tensile strength tests, elongation tests, FTIR tests, and biodegradation tests.

The tensile strength test of biodegradable plastic samples was carried out to determine the tensile strength and strain of each plastic sample.

Percent elongation (% Elongation) is the maximum change in length when stretching occurs until the plastic sample breaks. The elongation test of biodegradable plastic was carried out so that the elongation percentage of each plastic sample could be determined.

The functional groups contained in this plastic can be analyzed using the FTIR (Fourier Transform Infra Red) test, so that it can be estimated the type of functional groups contained in biodegradable plastic.

Biodegradation is the partial simplification or destruction of all parts of the molecular structure of a compound by physiological reactions catalyzed by microorganisms. Biodegradation ability is seen based on the length of degradation time by EM4 microorganisms. The method used in the biodegradation test is carried out by placing the plastic sample in a container then adding 10 mL of EM4 and leaving it to degrade.

A. *Effect of Process Temperature on Tensile Strength and Elongation*

To determine the effect of process temperature on the tensile strength and elongation of the plastic produced, the process temperature was varied in making plastic, namely 50 °C to 90 °C.

Table 2. Effect of process temperature on tensile strength and elongation

Temperature (°C)	Tensile Strength (MPa)	Elongation (%)
50	0,4747	1,5705
60	1,3013	5,2386
70	3,1198	6,0904
80	6,1875	15,6285
90	3,6917	12,1931

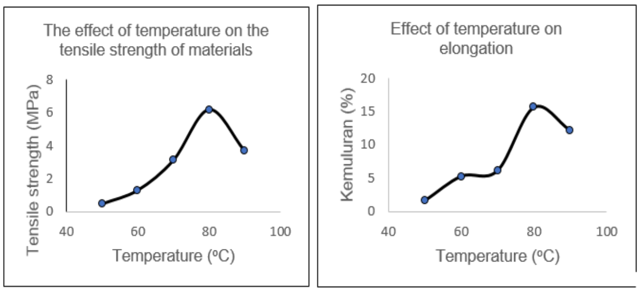

Figure 3. Effect of process temperature on tensile strength and plastic elongation

The process was carried out with a starch mass of 10 grams, a stirring speed of 300 rpm, 100 mL of 0.5% acetic acid, 2.5 mL of glycerol, a process time of 90 minutes and a chitosan : starch mass ratio of 0.1. The research results can be seen in table 2 and figure 3

Based on the graph of the tensile strength test results that have been carried out on plastic samples using a process temperature of 50° C to 80° C, it can be seen that the higher the process temperature, the greater the tensile strength. This is because, the higher the process temperature, the more perfect the gelatinization process is, the more perfect the gelatinization process, the greater the tensile strength of the resulting plastic. At a temperature of 80° C the tensile strength reaches 6.1875MPa, at this condition gelatinization has occurred completely so that optimal tensile strength can be obtained. At temperatures below 80° C, the gelatinization process is not yet complete so it does not form plastic with a thick solution but still forms a slightly runny solution which when dried in the oven cracks easily. This is because the bioplastic particles have not formed completely. Meanwhile, at process temperatures above 80° C, the tensile strength of the resulting plastic decreases. This is because by using temperatures above 80° C the complete gelatinization process has been exceeded, then decomposition occurs.

Likewise, from the elongation test, it can be seen that the higher the process temperature, the greater the elongation percentage. At a temperature of 80° C, the highest elongation percentage was 15.6285%, because at this temperature the gelatinization process took place perfectly.

B. Effect of processing time on tensile strength and elongation

The influence of processing time on the tensile strength and elongation of plastic was studied by processing at various times. The process was carried out with a starch mass of 10 grams, a stirring speed of 300 rpm, 100 mL of 0.5% acetic acid, 2.5 mL of glycerol, a process temperature of 80oC and a chitosan : starch mass ratio of 0.1. The research results can be seen there is table 3 and figure 4.

Table 3. Effect of processing time on tensile strength and elongation

Time (minutes)	Tensile (MPa)	Strength	Elongation (%)
45	2,8512		11,1636
60	3,9458		12,3166
75	4,1875		13,6764
90	6,1875		15,6285
105	1,2194		4,5974

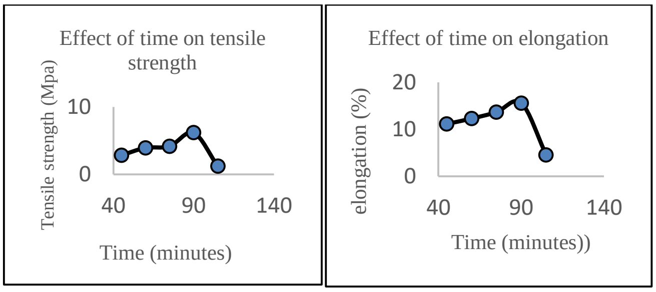

Figure 4. Effect of time on tensile strength and elongation of plastic

Based on the graph of research results that have been carried out using a processing time of 45 minutes, up to 105 minutes, it can be seen that the longer the processing time, the greater the tensile strength. This is because, the longer the process time, the more perfect the gelatinization process is and the greater the tensile strength of the resulting plastic. At 90 minutes the tensile strength reached 6.1875 MPa, in this condition gelatinization had occurred completely so that optimal tensile strength could be obtained. However, if it is used for more than 90 minutes, the tensile strength of the resulting plastic decreases. This is because too long a time can cause the tensile strength of the plastic to decrease because it has gone beyond the gelatinization process and the decomposition process has occurred. This shows that after complete gelatinization occurs, additional time will cause decomposition to occur, in accordance with the theory of Winarno (2002) which states that the heating time affects the gelatinization process.

Based on the percent elongation graph above, it can be seen that the longer the processing time, the greater the elongation percent. At 90 minutes the most optimal elongation percentage was obtained, namely 15.6285%, at that time the gelatinization process had occurred perfectly. However, over 90 minutes, the elongation percent decreases. This is because the gelatinization process has gone beyond the decomposition process. This shows that after complete gelatinization occurs, additional time will cause decomposition to occur, in accordance with the theory of Winarno (2002) which states that the heating time affects the gelatinization process.

C. The effect of the ratio of starch to processed chitosan on tensile strength and elongation

The effect of the chitosan:starch mass ratio on the tensile strength and elongation of plastics was studied using various processes. The process was carried out with a starch mass of 10 grams, a stirring speed of 300 rpm, 100 mL of 0.5% acetic acid, 2.5 mL of glycerol, a process temperature of 80oC and a time of 75 minutes. The research results can be seen in table 4 and figure 5.

Table 4. Effect of chitosan:starch mass ratio on tensile strength and elongation

Chitosan Mass (gram)	Chitosan : Starch Tensile	Strength (MPa)	Elongation (%)
0,25	0,025	1,3826	4,2594
0,50	0,05	4,5058	12,3429
0,75	0,075	7,8046	16,3714
1,00	0,1	6,1875	15,6285
1,25	0,125	5,5883	7,9222

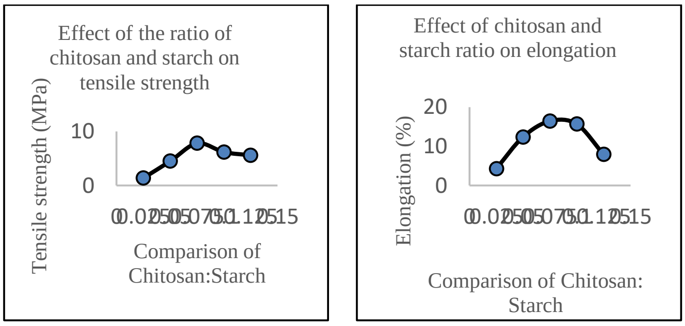

Figure 5. Effect of the ratio of chitosan and cassava starch on the tensile strength and elongation of plastic

Based on the graph of the tensile strength results that have been carried out using a chitosan:starch mass ratio variable of

0.025 to 0.125, it can be seen that the highest tensile strength is obtained at a chitosan:starch mass ratio of 0.075 with a tensile strength of 7.8046 MPa, that the more chitosan is added, the stronger it is. the pull will be greater. This is in accordance with Selpiana's (2016) statement, that the higher the chitosan composition, the tensile strength also increases, this is due to the hydrogen bonds formed in the plastic, the presence of these hydrogen bonds makes the plastic stronger and more difficult to break. This occurs because there are physical changes in the bioplastic particles. These results indicate that chitosan can be used as a reinforcement in making plastic. However, with a ratio above 0.075 the tensile strength value decreases

Based on the graph of the results of the percent elongation that has been carried out, it can be seen that the highest percent elongation was obtained at a chitosan:starch mass ratio of 0.075 with an elongation percent of 16.3714%. A chitosan:starch mass ratio of less than 0.075 causes the elongation to increase. This is due to the hydrogen bonds between chitosan-glycerol which makes the plastic more flexible. Meanwhile, a chitosan:starch mass ratio of more than 0.075 results in reduced plastic elongation, because the plastic becomes stiffer and less elastic. This is because the addition of too much chitosan means that more hydrogen bonds between chitosan and starch are formed in the plastic, which causes it to become stronger and more difficult to bend.

D. FTIR (Fourier Transform Infra Red) Test

FTIR characterization aims to determine the functional groups contained in the material and can also be used as an indicator that the plastic produced can still be degraded. From the results of functional group analysis using the FTIR technique, a spectrum was obtained as in Figure 6.

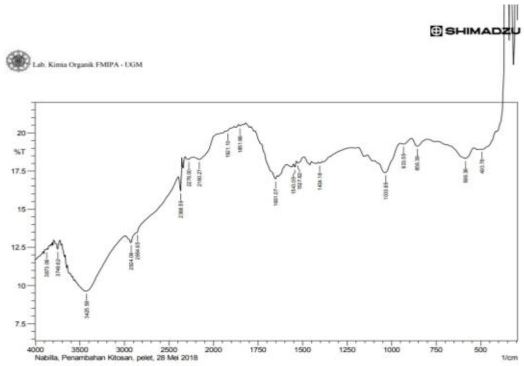

Figure 6. FTIR spectrum results

The image above shows the absorption of the O-H group at wave number 3425.58, at wave numbers 2924.09, 2854.65, 1404.18, 933.55, and 856.39 shows the absorption of the C-H group. C=O at wave number 1651.07, C-O at wave number 1033.85. Based on the opinion of Darni (2009) in Yuniwati (2017), that apart from the hydroxide group (OH), other functional groups found in biodegradable plastic films are carbonyl (CO) and ester functional groups, so that by having these functional groups the plastic film can be degraded. . The results of the FTIR tests carried out in this research showed that the OH, CO and ester functional groups were found, so the resulting plastic film was categorized as degradable. The results of this FTIR test show that all the groups contained in the plastic produced can be degraded.

E. Biodegradation Test

Bioplastics from cassava tuber starch were tested for their biodegradable properties using EM4 (Effective Microorganism) bacteria. The decomposition process of organic materials with EM4 molecules takes place by fermentation in both aerobic and anaerobic conditions. These bacteria will degrade bioplastics by breaking the polymer chains into monomers through enzymes produced from these bacteria. This process will produce organic compounds in the form of amino acids, lactic acid, sugar, alcohol, vitamins, proteins and other organic compounds that are safe for the environment.

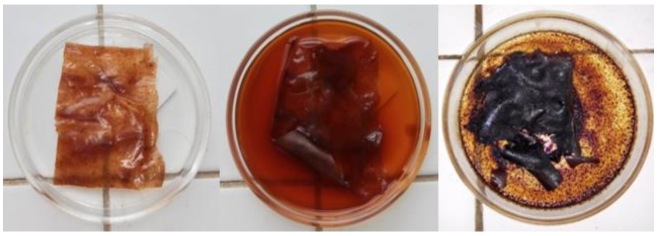

Figure 7. Uwi tuber plastic (left), plastic after being treated with EM4 (middle), plastic after 35 days degradation (right)

CONCLUSIONS

Based on the research results, it was found that the higher the process temperature, the greater the tensile strength and elongation, but at temperatures exceeding the gelatinization temperature, namely 80 oC, the tensile strength and elongation decreased. The higher the processing time, the greater the tensile strength and elongation, but at times exceeding 75 minutes, the tensile strength and elongation decrease and the higher the chitosan:starch mass ratio, the greater the tensile strength, but at a chitosan:starch mass ratio of more than 0.075, the elongation decreases. Based on the results of research conducted using a starch mass of 10 grams, a stirring speed of 300 rpm, 100 mL of 0.5% acetic acid, a glycerol volume of 2.5 mL, optimal conditions were obtained at a process temperature of 80 oC, a process time of 75 minutes, and a chitosan mass ratio. :starch of 0.125 with a tensile strength of 5.5883 MPa and elongation of 7.9222%. FTIR test results showed that biodegradable plastic contains OH, CO and ester functional groups. With the presence of these groups, plastic can be degraded. Biodegradable plastic from yam tubers and chitosan can be degraded with the help of EM4 for 35 days, so the biodegradable plastic from yam tubers is environmentally friendly plastic.

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