JOURNAL OF
NATURAL SCIENCES AND MATHEMATICS RESEARCH

Available online at http://journal.walisongo.ac.id/index.php/jnsmr

The effect of drying temperature on the characteristics of biodegradable plastic from Cassava pulp and Chitosan

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Received : 20 March 2021
Revised : 20 May 2021
Accepted : 1 Juni 2021

Abstracts

Conventional plastics made from polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC), polystyrene, and poly (ethylene terephthalate) are difficult to decompose. Bioplastics can reduce the amount of toxic waste generated from biological materials other than petroleum. The combination of cassava pulp and chitosan can be used as a candidate for the manufacture of biodegradable plastics. The optimal drying temperature can produce biodegradable plastics that have good quality. The method used to determine the effect is the mechanical properties test with ASTM D-638M standard and degradation test. The results of this study obtained 6 samples of biodegradable plastic with variations in temperature A=40˚C, B=50˚C, C=60˚C, D=70˚C, E=80˚C and F=90˚C. From the results of the mechanical properties test, the tensile strength values of each sample are A = 0,84 MPa, B = 1,78 MPa, C = 2,24 MPa, D = 1,58 MPa, E = 1,23 MPa and F =0,57 MPa. While the percent elongation value of each sample is A = 11,09%, B = 21,62%, C = 30,25%, D = 15,94%, E = 13% and F = 7,2%. The drying temperature in the process of making biodegradable plastics can affect its mechanical properties, namely the higher the drying temperature used, the lower the tensile strength value and the percent elongation, this is because high temperatures can damage the chemical structure and evaporated sorbitol which serves to increase flexibility. The higher the drying temperature also causes the biodegradable plastic to take longer to degrade. Sample A with the lowest temperature degraded the fastest for 28 days, while sample F with the highest temperature degraded the fastest for 46 days.

Keywords: biodegradable plastic; drying temperature; cassava pulp; chitosan

1. Introduction

As technology develops and population increases globally, plastic materials have wide applications in every aspect of industry and daily life [1]. Plastic packaging serves to protect food ingredients by specifically isolating food from outside influences. Good packaging materials must be safe for consumers and convenient to produce and when disposed of in an environmentally friendly manner [2]. Most conventional plastics made from polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC), polystyrene, and poly (ethylene terephthalate) are difficult to decompose, it takes about 300-500 years to decompose or completely decompose [3]. The accumulation in the environment causes disruption of the stability of the ecosystem so that it has become a threat to the planet [1].

To overcome the dangers of conventional plastics, it is necessary to develop plastic base materials derived from renewable natural resources, non-toxic, easily modified both physically and chemically [4]. Good basic materials are easily decomposed into water and carbon dioxide by the action of microorganisms when discharged into the soil in a short time, which are often referred to as environmentally friendly plastics [5]. Bioplastics can reduce the amount of toxic waste generated from biological materials other than petroleum [6]. Biodegradable plastics are generally made from compounds found in plants (cellulose, starch, collagen, casein, protein) and animals, namely lipids [7].

In 2010-2014, Indonesia was ranked 3rd in the cassava production center in the world [8]. Most of the cassava in Indonesia has been processed into tapioca flour. The industrial processing produces the remaining cassava dregs which causes environmental pollution for the land, air, and water. Cassava consists of a carbohydrate polymer that is widely used for environmentally friendly products and consists of amylose and chemically amylopectin (α-D-glucose with 1,4 and 1,6-branches) [9]. The weakness of cassava pulp flour is that it has strong intermolecular hydrogen bonds and cannot provide plasticity as a thermoplastic [10]. If the cassava pulp flour is heated with a plasticizer such as sorbitol through gelatinization, it can melt and flow better so that it has properties like synthetic polymers [11]. In addition, to improve its transparency and its mechanical properties, intermolecular interactions can be combined with other basic materials, such as chitosan.

Chitosan is structurally called an amino polysaccharide and it is the second most abundant biopolymer in nature after cellulose [12]. Chitosan is the main component of crustaceans, and it is mostly available as biological waste. Bio-compatibility, antibacterial properties and degradability have been studied in various applications [13]. Chitosan has been widely used as a synergistic support material in the development of heat-resistant composites [14].

Research on the synthesis of biodegradable plastics using cassava pulp waste and shrimp shell waste has been carried out by [15]. Based on 4 samples of mechanical properties test, the best biodegradable plastic was obtained, namely the sample with a composition ratio (cassava pulp: chitosan) (1.45:0.55) gr, with a tensile strength value of 1.97 ± 0.06 MPa and an elongation value. 22.89%. Based on these results, it is necessary to develop research to add information to determine the effect of temperature on characteristics in biodegradable plastic research [15].

The combined presence of cassava pulp and chitosan can be used as a candidate for making biodegradable plastics. Besides that, it is also a smart solution to reduce conventional plastic waste, cassava pulp waste and crustacean waste. It is hoped that in this study to make biodegradable plastic from cassava pulp and chitosan and to determine the effect of the optimum drying temperature to produce good quality biodegradable plastic.

2. Experiments Procedure

The manufacture of biodegradable plastic is shown in Figure 1. Drying varies at temperatures of 40°C, 50°C, 60°C, 70°C, 80°C and 90°C. To determine the quality of biodegerable plastic, mechanical tests and degradation tests were carried out.

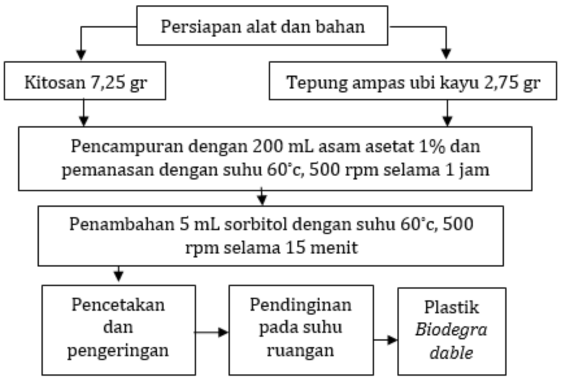

Figure 1. Procedure of Biodegradable Plastic Manufacturing

Mechanical properties test was carried out using a Texture Analyzer. This test uses the ASTM D-638M type M-III method randomly with 3 times the withdrawal of each sample [16]. The mechanical properties test produces the magnitude of the tensile strength, which was then measured the initial length (lo) and the final length (l). These data are used to calculate the percent elongation, where the percent elongation can be determined using Equation 1 [17].

$$\%\,\varepsilon = \left(\frac{l-l_0}{l_o}\right) \times 100 \qquad \text{... (1)}$$

The results of tensile strength and elongation are then used to determine the value of Young's modulus using Equation 2 [17].

$$E = \frac{\sigma}{\varepsilon} \qquad \text{... (2)}$$

The degradation test was carried out using the soil burial test technique, where the sample was buried in the soil and left in the open air. Before the samples were buried in the soil, each sample was weighed with a mass of 1 g and planted in a different container to facilitate observation. Observations and weighing of samples were carried out once every 3 days and continued until the samples were completely decomposed (mass 0 grams). Degradation can be known by observing the mass of plastic lost. The percentage of degradation can be known by using Equation 3[18].

$$\%\text{ lost mass} = \frac{W_i - W_f}{W_i} \times 100\% \qquad \text{... (3)}$$

where W_i is weight of plastic before degradation test and W_f is weight of plastic after degradation test.

3. Result and Discussion

The biodegradable plastic sample obtained is shown in Figure 2. It has a transparent texture, and one side of the surface is rough, but the other side is smooth. This plastic still has a sour smell resulting from the addition of acetic acid and cassava pulp flour.

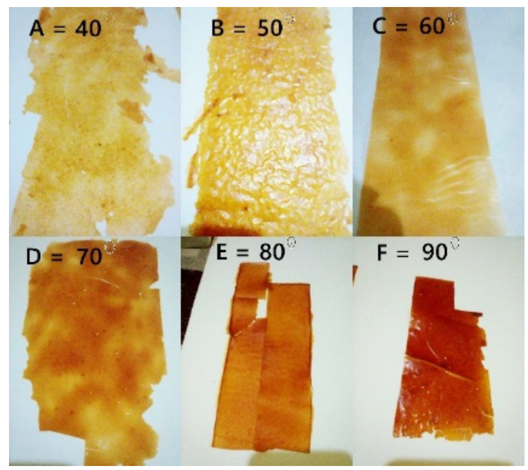

Figure 2. Biodegradable Plastic Samples Produced (each sample is ovened with a different drying temperature, namely sample A=40˚C, B=50˚C, C=60˚C, D=70˚C, E=80˚C and F=90˚ C)

The resulting biodegradable plastic samples have varying tensile strength values, percent elongation, and Young's modulus in each sample are shown in table 1. To simplify data analysis, the tensile strength, percent elongation, and Young's modulus were plotted against the drying temperature, respectively, which are shown in Figures 3, 4, and 5.

Based on Figure 3, the tensile strength of biodegradable plastic increases with increasing temperature up to 60˚C, while after passing this temperature, the tensile strength value decreases with increasing temperature. At high temperatures the more starch-cmc mixture is damaged and the sorbitol evaporates so that it will affect the tensile strength produced. In addition, the use of high drying temperatures can damage the chemical bonds of biodegradable plastic films. These results are similar to the results of research [19], which states that the temperature and drying time will change the physical properties that cause the starch to be gelatinized and the cells to undergo structural rupture to form a thinner and wider layer.

Table 1. Mechanical Properties Test Results

Drying Temperature	Tensile Strength (MPa)	Persen *Elongasi* (%)	*Modulus Young* (MPa)
40˚	0,84	11,09	0,075
50˚	1,78	21,62	0,084
60˚	2,24	30,25	0,074
70˚	1,58	15,94	0,099
80˚	1,23	13	0,095
90˚	0,57	7,2	0,079

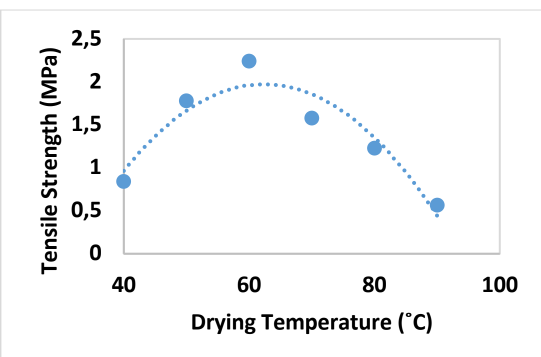

Figure 3. Tensile Strength of Biodegradable Plastic Samples

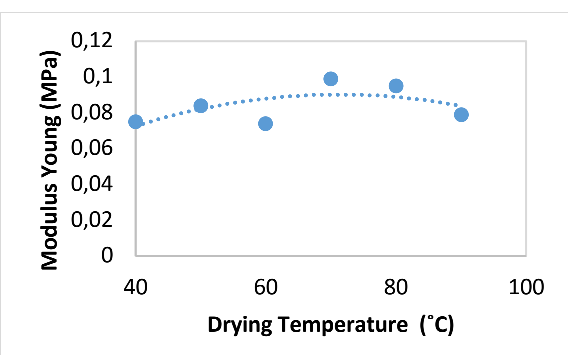

Figure 4. Young's Modulus Biodegradable Plastic Samples

Based on Figure 4, the Young's modulus of biodegradable plastic tends to increase up to a temperature of 50˚C. But at a temperature of 60˚C it decreased, then increased again at a temperature of 70˚C. Furthermore, the value of Young's modulus tends to decrease with increasing drying temperature. In general, the relationship between Young's modulus and tensile strength is directly proportional. The higher the tensile strength of biodegradable plastic, the higher the Young's modulus, and vice versa [20].

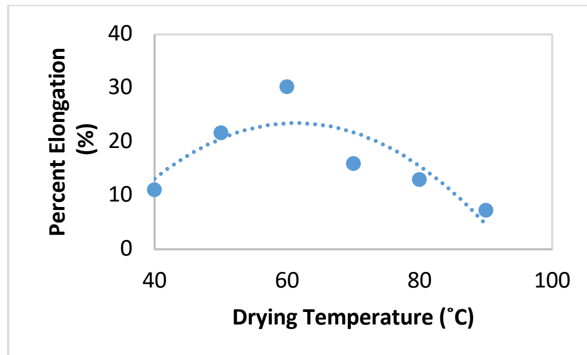

Figure 5. Percent Elongation of Biodegradable Plastic Samples

Based on Figure 5. the percentage of elongation of biodegradable plastic increases with increasing drying temperature up to a temperature of 60˚C. However, after this temperature, the percent elongation value decreased with increasing drying temperature.

The quality of biodegradable plastic is then compared with the quality of conventional plastics. Comparison of the quality of conventional plastics with biodegradable plastics based on the Indonesian National Standard (SNI) on plastics can be observed in Table 2.

Table 2. Comparison of the Quality of Conventional Plastics with Biodegradable Plastics.

Value	conventional plastic	Biodegradable plastic samples					
		40^0	50^0	60^0	70^0	80^0	90^0
tensile strength	24,7-302	0,84	1,78	2,24	1,58	1,23	0,57
% elongation	21-220	11,09	21,62	30,25	15,94	13	7,2

Table 2 explains that the quality of biodegradable plastic produced is still not good enough when compared to the quality of conventional plastics. Conventional plastic has a tensile strength of 24.7-302 MPa, while the resulting biodegradable plastic only has the best tensile strength in samples with a drying temperature of 60˚ of 2.24 Mpa. The percent elongation value of conventional plastics based on SNI is 21-220% while the biodegradable plastics produced have the same best elongation percentage values, namely in samples with a drying temperature of 60˚, which is 30.25%.

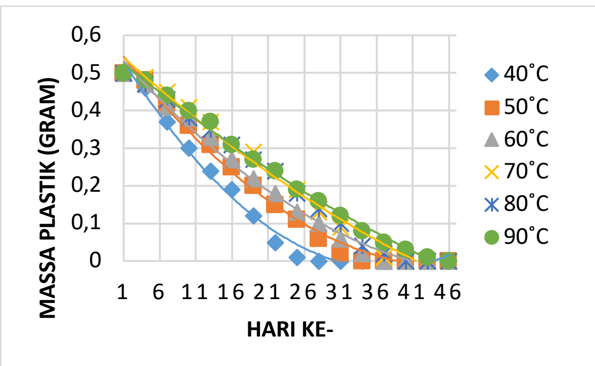

Figure 6. Biodegradable Plastic Sample Degradation Test

Figure 6 shows the degradation process of biodegradable plastic which can be seen by observing the mass of plastic lost for 46 days. Sample A (drying temperature 40˚C) degraded the fastest for 28 days. Sample F (drying temperature 90˚C) was degraded the longest for 46 days. The degradation process takes place faster along with the lower drying temperature of biodegradable plastic. On the other hand, the degradation process slows down as the drying temperature of the biodegradable plastic increases. The percentage of biodegradable plastic degradation can be observed in Table 3. Based on Table 3, it is known that the sample with a drying temperature of 40˚ showed a 100% degradation percentage on the 28th day. This happened because at the time of observation the sample decomposed completely (mass 0 grams). Mass degradation was also experienced by samples with a drying temperature of 50˚ by 88%, samples at 60˚ temperature by 80%, samples at 70˚ at 74%, samples at 80˚ at 72% and samples at 90˚ at 68%.

Table 3. Percentage of Degradation of Plastic Samples

Days to	Presentation of Biodegeradable Plastic Samples					
	40⁰	**50⁰**	**60⁰**	**70⁰**	**80⁰**	**90⁰**
1	0 %	0 %	0 %	0 %	0 %	0 %
28	100 %	88 %	80 %	74 %	72 %	68 %
34		100 %	96 %	92 %	92 %	90 %
37			100 %	98 %	96 %	90 %
40				100 %	100 %	94 %
46						100 %

Observations were continued until all samples were completely degraded in the soil. The percentage of sample degradation with a drying temperature of 50˚ on the 34th day is 100%, this indicates that the sample has been completely degraded. Mass degradation was also experienced by samples with a drying temperature of 60˚ by 96% with a residual mass of (0.02 ± 0.005) gr, samples at 70˚ and 80˚ by 92% with a residual mass of (0.11 ± 0.005) gr, samples of 90 by 84%.

Observations on the 37th day showed that the sample with a drying temperature of 60˚ had been completely degraded in the soil, so the percentage of degradation was 100%. Mass degradation was also experienced by the 70˚ temperature sample by 98% with the remaining mass (0.01 ± 0.005) gr, the 80˚ temperature sample by 96% with the remaining mass (0.02 ± 0.005) gr and the 90˚ temperature sample by 90% .

Observations on the 40th day showed that the samples with drying temperatures of 70˚ and 80 were completely degraded in the soil, so the percentage of degradation was 100%. However, the sample with a temperature of 90˚ has not been completely degraded, because there is still mass (0.03 ± 0.005) gr with a degradation percentage of 94%.

Observations on the 46th day showed that the sample with a drying temperature of 90˚ had been completely degraded in the soil, so the percentage of degradation was 100%. Based on the degradation events of the 6 samples in the soil, the biodegradable plastic from cassava pulp and shrimp shells is an environmentally friendly plastic.

4. Conclusion

The drying temperature in the process of making biodegradable plastic can affect the mechanical properties, namely tensile strength and percent elongation. The higher the drying temperature used, the lower the value of tensile strength and percent elongation, this is because high temperatures can damage the chemical structure and evaporate sorbitol which serves to increase flexibility. The higher the drying temperature also causes the biodegradable plastic to take longer to degrade.

Acknowledgment

The author wish to thank the Physical Education Department, Universitas Negeri Semarang, Indonesia.

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