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Physical Mechanical Properties of Biodegradable Plastics from Cassava Starch with Variation of Bagasse and Glycerol

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Abstract

Environmental problems are related to plastic waste that difficult to degrade naturally. Polysaccharides in the form of gelatinized cassava starch and bagasse containing 52.70% cellulose can replace commercial plastic polymers. This research was aimed to determine the effect of variations in bagasse and glycerol on physical, mechanical and biodegradation tests. The study used 2 factors CRD consisting of the addition of bagasse and glycerol. The results showed that the addition of bagasse and glycerol reducing the brightness with a value range of 44.82-76.15 and increased absorption between 2.61-10.64%. The thickness occurred between 0.79-1.11mm. The tensile strength values are 8.30-14.33 MPa, inversely proportional to the elongation value between 11.85-94.22%, but directly proportional to the modulus young value between 0.09-1.24 MPa. The highest biodegradation values were 0% bagasse and 40% glycerol. The three best treatments were found in the combination treatment of bagasse and glycerol 0% 20%, 0% 30%, and 0% 40%.

Introduction

Environmental problems that occur throughout the world, especially in Indonesia, are closely related to the presence of plastic waste. Practicality encourages the use of plastics to become a lifestyle, even though the raw material for making plastic comes from petroleum, whose supplies are running low. This phenomenon also has an impact on environmental pollution because plastics are difficult to degrade naturally. Indonesia is the second largest contributor to plastic waste in the world after China, amounting to 187.2 million tons (Jambeck et al., 2015).

The solution to this problem is to replace conventional plastic base materials into materials that are easily degraded by the environment, called biodegradable plastics. This product is not only biodegradable but also renewable (Iriani, 2013). Biodegradable plastics have several advantages compared to plastics in general, such as relatively simple technology, the main raw materials are starch and fiber, the raw materials can be varied according to regional potential, and there is no use of dangerous chemicals.

The basic material for making biodegradable plastics is polysaccharides from gelatinized starch as a substitute for commercial plastic polymers. Gelatinization is a change in the structure of the starch granules at a certain temperature so that it experiences extraordinary swelling and cannot return to its original shape (Winarno, 2002). Starch obtained from cassava which is known as tapioca. The amount of cassava productivity has always increased from 2013-2015, reaching 235.84 Kw / Ha (Center for Agricultural Data and Information Systems, 2016). Aside from using tapioca, bagasse is also added. Bagasse is one of the

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residual waste from sugarcane factories that has not been fully utilized. The ministry of Agriculture reports that the current national sugarcane production is 33 million tonnes /year (Directorate General of Plantation, 2014). If it is assumed that the percentage of bagasse in sugarcane is around 30-34%, then the existing of sugar factories in Indonesia have the potential to produce bagasse on average 9.90-11.22 million tons / year. Milled sugarcane contains 10% dry bagasse, consisting of 52.70% cellulose or glucan, 20% hemicellulose or xylan, and 24.20% lignin. The amount of sugar production from year to year (2014-2016) is reaching 2.71 tons, this indicates that the production of bagasse is increasing every year (Center for Agricultural Data and Information Systems, 2016). The high cellulose content in bagasse waste can improve the properties of biodegradable plastics. The manufacture of biodegradable plastics using starch as raw material will produce products that are sensitive to moisture, brittle and stiff so that at this initial stage, the addition of fiber sourced from bagasse is added to cover these weaknesses.

Based on the description above, research on the physical and mechanical properties of biodegradable plastics from cassava starch with variations in the addition of bagasse and glycerol, needs to be done to produce good biodegradable plastics as well as an effort to minimize the use of plastic waste that is harmful to the environment. The objectives of this study are (1) To determine the effect of variations in the composition of bagasse and glycerol on physical and mechanical properties also the biodegradability of biodegradable plastic (2) Knowing the appropriate composition variations to produce the best biodegradable plastic.

Methods

This research is an experimental study using 2 factors completely randomized design (CRD). The research data were processed using Microsoft Excel 2010 and SPSS 16 version using the ANOVA method to determine the differences in treatment at the level of $\alpha = 0.05$. If the treatment shows a difference, a further test is carried out using Duncan's Multiple Range Test (DMRT) at a significant level of 5%. Furthermore, the best treatment is obtained by using the effectiveness index test. Data is presented in tabular form and then described descriptively.

Research Design

This research is an experimental study with 2 fators completely randomized design (CRD). The first factor is additional variation of bagasse flour using 4 levels, consisting of 0% (A0), 5% (A1), 10% (A2), and 15% (A3) by weight of the cassava starch. The second factor is the volume of glycerol with 3 levels, consisting of 20% (G1), 30% (G2), and 40% (G3) of the weight of cassava starch. Each treatment was repeated three times and observations were made twice (duplo).

Research Stages

Preparation

This research begins with the manufacture of bagasse flour and ends with the manufacture of biodegradable plastics. The bagasse is properly sorted, weighed, then dried under the sun until the moisture content is 5%. After drying, the bagasse is crushed using a blender to turn it into powder.

The process of making biodegradable plastics

The making begins with preparing 20 g of cassava starch and 20 ml of aquades. Cassava starch is put into aquades, then glycerol is added while stirring using a hotplate and stirrer. After being mixed then bagasse flour is added, the homogenization time is 30 minutes with a

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stirrer speed of 40 rpm. After that the dough is formed using an aluminum mold with a diameter of 22 cm and then dried using an oven at a temperature of 900C for 2 hours.

Analysis Procedure

The observation parameters consisted of color brightness level analysis, water absorption analysis, mechanical properties analysis consisting of thickness test, tensile strength test, and elongation test, biodegradation analysis, and effectiveness index test. In the effectiveness index test, the parameters analyzed were grouped into 2 groups. Group A consisted of the parameter "the higher the mean is the better". Group B consisted of the parameter "the lower the mean is the better".

Results and Discussion

Color Brightness Level Analysis

The following table is a picture of the 12 samples produced. Each sample shows the difference in color produced by each treatment.

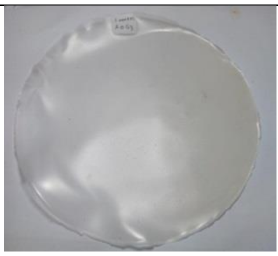
			
A0G1	A1G1	A2G1	A3G1
			
A0G2	A1G2	A2G2	A3G2
			
A0G3	A1G3	A2G3	A3G3

Figure 1. Biodegradable Plastics Film

Color is one of the observation parameters for biodegradable plastics because the brighter the sample, the more preferred it is to consumers and it resembles plastic packaging in general. Color is often used to determine changes that occur both physically and chemically in an agricultural product.

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Testing the brightness level of the biodegradable plastic color was carried out using a color reader. The value of the brightness level is obtained from the average of the five different measurement points. Measurement of the brightness level of the biodegradable plastic color obtained the L value (brightness level).

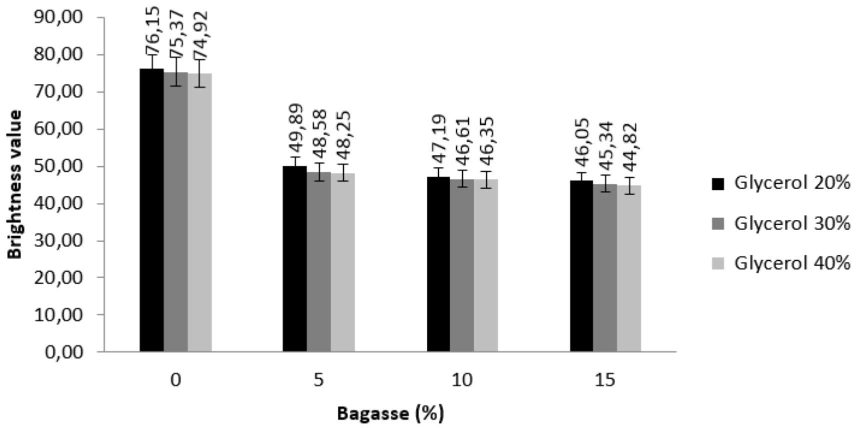

Figure 2. Color Brightness Value of Biodegradable Plastic

Figure 1.1 shows the brightness value of the biodegradable plastic color. The test results showed that the addition of bagasse and glycerol had a significant effect on the brightness level of the biodegradable plastic. The additional variation of bagasse 5%, 10%, and 15% causes a darker color brightness level than the addition of bagasse flour with 0% treatment. This happens because the dark color of the bagasse affects the color of the biodegradable plastic. The test results showed that the biodegradable plastic with the addition of 40% glycerol and the addition of 15% bagasse had the lowest color brightness level of 44.82. The addition of glycerol can increase the viscosity of the dough so that the brightness of the color decreases (darker), the increase in viscosity will affect the thickness of the biodegradable plastic, if the biodegradable plastic gets thicker, the brightness of the color will decrease due to light blending (Proborini, 2006).

Water Absorption Test

The water absorption test was carried out to determine the level of resistance of biodegradable plastics to water. The greater the water absorption value, the lower the resistance level of the plastic and the biodegradable plastic will be destroyed quickly. Conversely, if the smaller the water absorption value, the level of biodegradable plastic resistance to water will be greater and will not be easily destroyed in water.

The water absorption test was carried out following the standard procedure of ABNT NBR NM ISO 535. The samples were cut to the size of 2.50 x 5 cm. The initial weight of the sample was recorded first then the sample was dried in an oven at 60°C for 2 hours. After that the sample is weighed under constant conditions. Samples were immersed in aquades for 1 minute to determine the absorption of water. Then, water is removed from the surface of the sample by leaving it for 5 minutes and then weighing it (Matsui et al., 2004).

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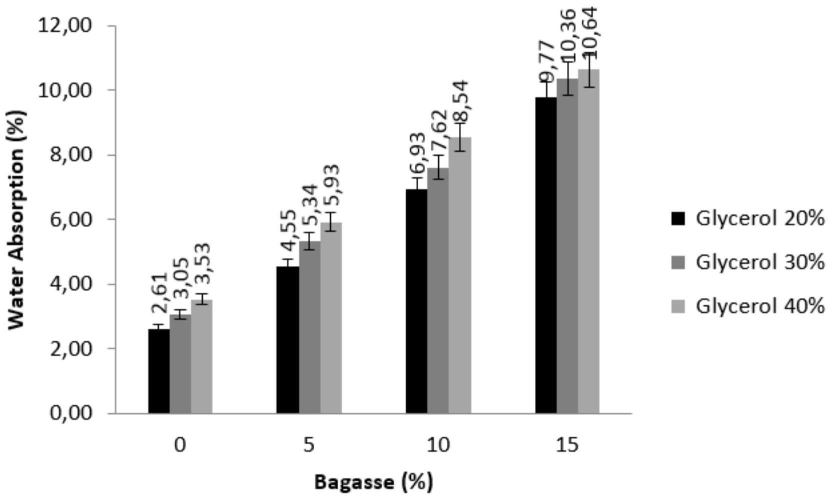

Figure 3. Biodegradable Plastic Water Absorption Value

Figure 1.2 shows the water absorption rate of biodegradable plastic. The test results showed that the addition of bagasse and glycerol had a significant effect on the water absorption of biodegradable plastic, but had no significant effect on the interaction between bagasse and glycerol. The variation of adding 5%, 10% and 15% bagasse caused a lower water absorption rate than the addition of 0% bagasse. This happens because bagasse which is hygroscopic makes biodegradable plastic easier to absorb water (Nasution, 2018). The results showed that the highest water absorption value was the addition of 15% bagasse and 40% glycerol with a value of 10.64%. This shows an increase in the water absorption capacity of biodegradable plastic along with the increase in the addition of 20%, 30%, and 40% glycerol. Glycerol is hygroscopic so it tends to bind water and can cause a moisture balance with its hygroscopic properties (Sitompul & Zubaidah, 2017).

Thickness Test

The thickness of the film is a property that is influenced by the molding plate and the concentration of dissolved solids. The thickness test was carried out to determine the effect of the thickness of each biodegradable plastic treatment. The thickness test uses a thickness gage tool where the thickness value is obtained from the average measurement results at three different points.

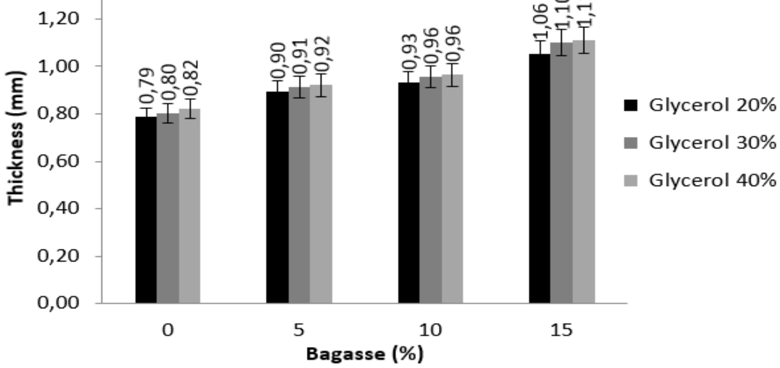

Figure 4. Biodegradable Plastic Thickness Test Value

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Figure 1.3 shows the value of the biodegradable plastic thickness. The test results showed that the addition of bagasse and glycerol had a significant effect on the thickness of biodegradable plastic, but had no significant effect on the interaction between bagasse and glycerol. Variations in the addition of bagasse 5%, 10%, and 15% resulted in a higher thickness value than the addition of 0% bagasse. The thickness of biodegradable plastic ranges from 0.79 - 1.11 mm. The results showed that the lowest thickness value is the addition of 0% bagasse and 20% glycerol with a value of 0.79 mm, while the highest thickness value is the addition of 15% bagasse and 40% glycerol with a value of 1.11 mm. This happens because it is influenced by the amount of total solids in the solution (Sumarto, 2008). Bagasse increases the polymer film matrix constituent which causes the film thickness to increase, while the addition of glycerol increases the viscosity of the biodegradable plastic dough which also causes the thickness of the biodegradable plastic to increase.

Tensile Strength Test

Tensile strength is the maximum tension achieved until the film can withstand before breaking. Ardiansyah, (2011) states that the tensile strength test is used to determine the magnitude of the force achieved when it reaches the maximum tension until the film breaks. Tensile strength test is done to find out how strong the biodegradable plastic is. The tensile strength test uses a universal testing machine where the tensile strength value is obtained from the maximum tensile strength value when it is broken.

Figure 1.4 shows the tensile strength test value of biodegradable plastic. The test results showed that the addition of bagasse and glycerol had a significant effect on the tensile strength of biodegradable plastics. The highest tensile strength value was obtained in the addition of 15% bagasse and 20% glycerol with a value of 14.33 Mpa. The additional variation of bagasse at 5%, 10% and 15% resulted in a higher tensile strength value than the addition of 0% bagasse. The tensile strength of biodegradable plastics ranges from 8.30 - 14.33 Mpa. This happens because cellulose has a straight and long polymer chain so it can increase the tensile strength value (Sulistyo & Ismiyati, 2012). The additional variation of glycerol at 20%, 30%, 40% causes the tensile strength value to decrease. This happens because glycerol molecule will disrupt the compactness of the constituent material molecules in the form of cellulose, so the intermolecular interactions decrease and the mobility of the polymer increases. This condition increases the flexibility of biodegradable plastics. Consequently, biodegradable plastics. experience elongation and reduce their tensile strength (Vanin et al., 2005). The resulting tensile strength test has not reached the Indonesian national standard for plastic of 24.7 - 302 MPa.

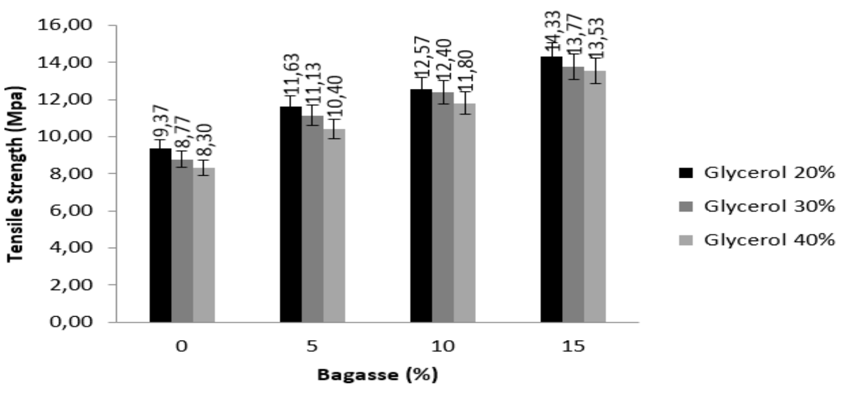

Figure 5. Biodegradable Plastic Tensile Strength Test Value

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Elongation

Elongation is a mechanical property of biodegradable plastics which is assessed from the percent maximum elongation of biodegradable plastics to break. Elongation can be calculated by comparing the length of the film at break and the length of the film before being pulled by the universal testing machine.

Figure 1.5 shows the elongation value of biodegradable plastics. The test results showed that the addition of bagasse and glycerol had a significant effect on the elongation of biodegradable plastics. The elongation value of biodegradable plastic resulted in a value between 11.85 - 94.22%. The additional variation of 5%, 10% and 15% bagasse resulted in a lower elongation rate than the addition of 0% bagasse. This happens because the addition of the bagasse material concentration increases the matrix formed. Biodegradable plastics become stiff and reduce the function of glycerol as a plasticizer, causing the elongation of biodegradable plastics to decrease when attracted to forces which will cause the film to break (Barus, 2002). The additional variation of 20%, 30% and 40% glycerol resulted in an increasing elongation rate of biodegradable plastic. This occurs because glycerol tends to decrease tensile strength and increase the elongation presentation. Glycerol can reduce the intermolecular forces and increase the mobility of the polymer chains so that the elongation presentation will increase (Akili et al., 2012). The elongation test results show that the value has reached the Indonesian national standard for plastics by 21-23%.

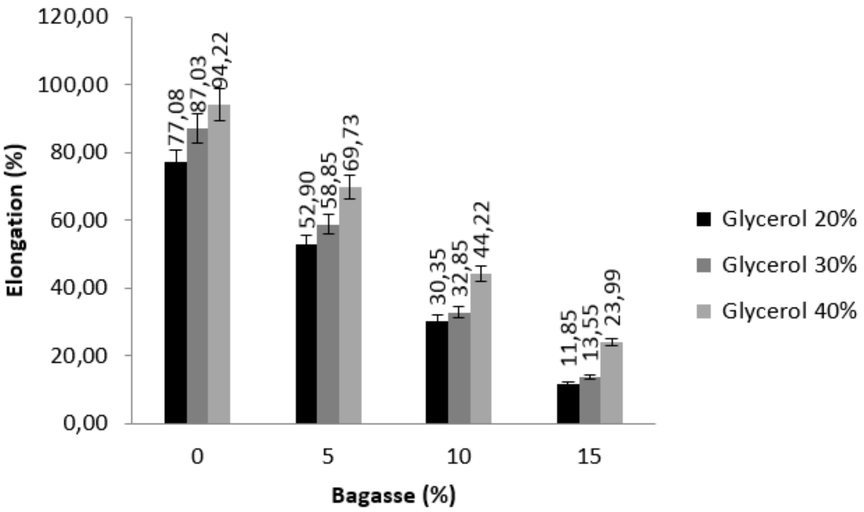

Figure 6. The Elongation Value of Biodegradable Plastics

Modulus Young

Modulus young is a measurement of the stiffness level of an elastic material that is calculated from the ratio between breaking strength and elongation at breaking. Sulistyo and Ismiyati (2012) state that the higher the modulus young value of the material, the smaller the elastic strain or the stiffer it is.

Modulus young is used to determine the stiffness value of biodegradable plastic by comparing the breaking strength (stress) and elongation at breaking (strain). The value of modulus young is directly proportional to the value of tensile strength and inversely proportional to elongation. The greater the modulus young value, the higher the stiffness of the biodegradable plastic.

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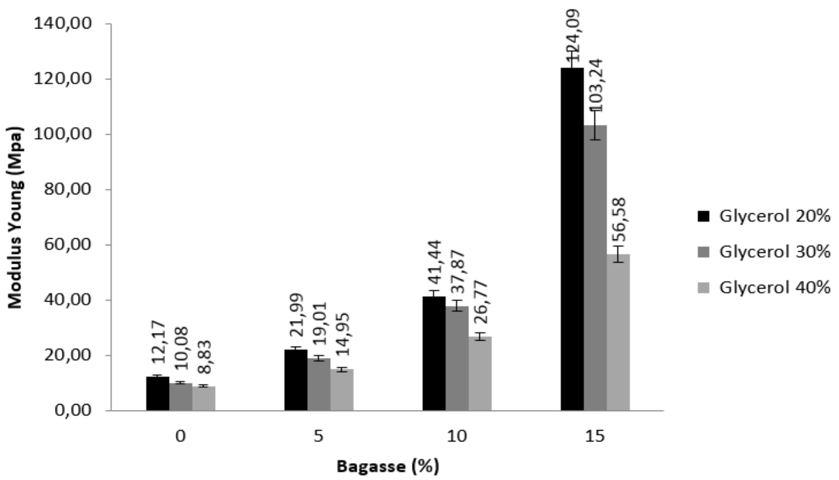

Figure 7. Modulus Young Values of Biodegradable Plastics

Figure 1.6 shows the modulus young of biodegradable plastics. The test results showed that the addition of bagasse and glycerol had a significant effect on the biodegradable plastic modulus young. The average modulus young values for biodegradable plastics were 8.83 - 124.09 Mpa. The results showed that the highest value of young modulus was the addition of 15% bagasse and 20% glycerol with a value of 124.09 Mpa. The additional variation of bagasse 5%, 10%, and 15% caused the modulus young value increase compared to the addition of 0% bagasse. This happens because the cellulose content in bagasse will increase the stress so that its physical properties will be more brittle. The characteristics of cellulose are strong and hard because it has a regular structure of hydroxyl groups, which results in biodegradable plastics becoming stiffer and brittle. This is consistent with the research of Barnett & Bonham (2004) which explains that the higher the cellulose content, the higher the modulus young value. The additional variation of 20%, 30% and 40% glycerol caused the modulus young value of biodegradable plastics to decrease. This happens because glycerol as a plasticizer will reduce the stiffness of biodegradable plastics. The type and amount of plasticizer added to the starch solution affects the characteristics of the plastic, especially its physical and mechanical properties. The effectiveness of glycerol as a plasticizer in biodegradable plastics from tapioca is supported by the size of the glycerol molecule which is much smaller than the cassava starch molecules which can easily enter between polymer chains, thereby reducing the flexibility of biodegradable plastics (Wittaya, 2012).

Biodegradation Test

Biodegradation is a branch of bioremediation which utilizes the activity of microorganisms to decompose large or complex compounds into simpler compounds that are more environmentally friendly (Yani et al., 2003). Degradation is caused by environmental conditions and occurs in one or more stages. Biodegradable plastics show a degraded state as a result of natural activities involving microorganisms such as bacteria, fungi, and algae. In this study, the biodegradation test occurred in aerobic conditions with the help of bacteria and fungi on the ground. The Biodegradation test shows how long it takes for biodegradable plastic to degrade using the soil burial test method by calculating the sample weight loss.

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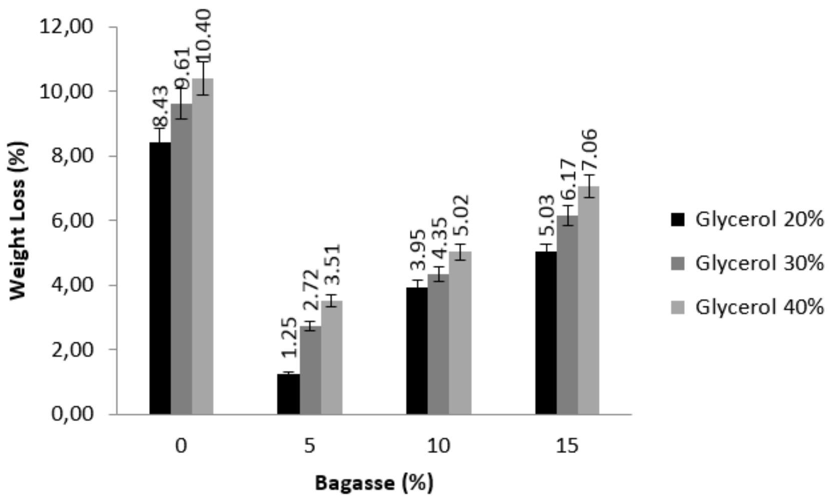

Figure 8. Biodegradation Test Value of Biodegradable Plastics

Figure 1.7 shows the biodegradation rate for 30 days. The test results showed that the addition of bagasse and glycerol had a significant effect on the biodegradation of biodegradable plastics. The additional variation of 5%, 10%, and 15% bagasse caused a lower biodegradation rate compared to the addition of 0% bagasse. The results showed that the highest level of biodegradation was in the addition of 0% bagasse and 40% glycerol with a weight loss value of 10.40%. This happens because cellulose degrades faster because of its hygroscopic nature, the more cellulose in plastics, the faster it is degraded (Behjat et al., 2009). The addition of 0% bagasse causes a higher biodegradation value. This happens because cellulose has a long polymer chain which results in a stronger physical properties of the plastic and is resistant to degradation so that it will reduce weight loss when bagasse is added. The additional variation of 20%, 30%, and 40% glycerol caused the biodegradation rate to increase. This happens because the nature of glycerol is easy to absorb water, causing biological activation such as microbes or fungi on biodegradable plastics (Wypich, 2003).

Determination of the Best Treatment

The best treatment is determined based on the effectiveness index method (Susrini, 2005). Variables are sorted according to priority and contribution to results. Give weight to each variable (BV) according to its contribution with a relative value of 0-1. This weight differs depending on the importance of each variable whose value is obtained as a result of treatment.

Normal weight (BN) is determined from each variable by dividing the variable weight (BV) with the sum of all variable weights. The higher the level of importance, the higher the value of the weighted variables given.

Determination of the best treatment for biodegradable plastics was carried out by using the effectiveness index test. Each test parameter is weighted to get the yield value for each treatment, the highest yield value determines the best treatment. The determination of the best treatment shows that there are three treatments that have the highest yield value (NH) consisting of the addition of 0% bagasse and 20% glycerol with a value of 0.652, the addition of 0% bagasse and 30% glycerol with a value of 0.651, the addition of 15% bagasse and 30% glycerol with a value of 0.641. Based on the results of the effectiveness index test, there are three highest weights consisting of tensile strength, elongation and water absorption. The treatment of adding 0% bagasse and 20% glycerol had a brightness level of 76.15, 2.61% water absorption, 0.79 mm thickness, 9.37 Mpa tensile strength, 77.08% elongation, 0.12

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MPa young modulus and 8.43% biodegradation. The treatment of adding 0% bagasse and 30% glycerol had a brightness level of 75.37, 3.05% water absorption, 0.80 mm thickness, tensile strength 8.77 Mpa, 87.03% elongation, 0.10 MPa young modulus and 9.61% biodegradation. The treatment of adding 0% bagasse and 40% glycerol had a brightness level of 74.92, 3.53% water absorption, 0.81 mm thickness, tensile strength 8.30 Mpa, 94.22% elongation, 0.09 MPa young modulus and 10.40% biodegradation.

Conclusion

Based on the physical and mechanical properties of biodegradable plastics from cassava starch with variations in the addition of bagasse and glycerol research, the following conclusions were obtained (1) The addition of sugarcane bagasse and glycerol concentrations can reduce the brightness level of biodegradable plastics between 44.82 - 76.15. The addition of bagasse and glycerol increased the water absorption value of biodegradable plastic, the resulting water absorption value was between 2.61 - 10.64%. The addition of bagasse and glycerol increased the thickness of the biodegradable plastic with a value between 0.79 - 1.11 mm. The tensile strength value is inversely proportional to the elongation value which is between 8.30 - 14.33%, but is directly proportional to the modulus young value, which is between 0.09 - 1.24 Mpa. The highest biodegradation value was in the addition of 0% bagasse and 40% glycerol with a weight loss value of 10.40%. (2) Based on the results of the effectiveness index test, there were three best treatments consisting of the addition of 0% bagasse and 20% glycerol, the addition of 0% bagasse and 30% glycerol, the addition of 0% bagasse and 40% glycerol.

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