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The Effect of Plasticizer Type and Concentration on Cellulose Acetate-Based Bioplastic from Durian Skin

Rahmatullah[1*], Rizka Wulandari Putri[1], Leily Nurul Komariah[1], Harry Waristian[2], Alek Al Hadi[2], Kavin Handoko[1], Muhamad Fadhil Gufron[1]

[1] Department of Chemical Engineering, Faculty of Engineering, Universitas Sriwijaya, Indralaya 30662, South Sumatera, Indonesia

[2] Department of Mining Engineering, Faculty of Engineering, Universitas Sriwijaya, Indralaya 30662, South Sumatera, Indonesia

* Corresponding author's e-mail: rahmatullah@ft.unsri.ac.id

ABSTRACT

Bioplastic is a biodegradable and environmentally friendly material because it uses natural materials in the form of plant fibers. The plants with high fiber content can be converted to cellulose acetate as a raw material for bioplastics. Durian skin is a biomass waste that has the potential to be a raw material for bioplastics. Cellulose-based bioplastics are generally made by adding adhesives, plasticizers, and fillers. In this study, the manufacture of bioplastics used the cellulose acetate from durian skin with variations of plasticizer concentration, plasticizer type, starch adhesive, and chitosan. Glycerol and sorbitol were used as plasticizers with variations in concentration of 20%, 30%, and 40%. The mass ratio of cellulose and starch used was 1.5:1. Bioplastics were produced by adding chitosan, starch, and variations of plasticizers in each concentration which were achieved varying values in tensile strength, water absorption, density values, elongation values, Young's modulus, degradability, and different bioplastic surface structures. The best bioplastic result is bioplastic with 20% sorbitol concentration for a density of 0.852 g/mL, water absorption of 45.99%, tensile strength of 613.12 Kpa, elongation of 2.35%, and Young's modulus of 26090.21 Kpa. In addition, the degradation time without landfill has met the Indonesian National Standard (INS) for 45 days.

Keywords: bioplastic, durian skin, glycerol, sorbitol.

INTRODUCTION

Bioplastics are easily decomposed because they are made from natural materials, namely plant fibers. The manufacture of cellulose bioplastics has been widely developed in recent years. Cellulose is obtained from various sources, such as kapok fiber, areca nut waste, empty oil palm bunches, rice straw, and others (Rahmatullah et al., 2023; Tamiogy et al., 2019; Permadani and Silvia, 2022; Setiawan et al., 2021). However, cellulose is only used as a filler or modified as a cellulose derivative in the manufacture of bioplastics. The most commonly used cellulose derivative is cellulose acetate, which has excellent mechanical and thermal properties (Steven et al., 2022).

Durian skin is a biomass waste that is easily found in Indonesia and other Asia countries. Durian is generally only used for its flesh, while its skin and seeds become unutilized organic waste. Durian skin contains high amounts of cellulose of 50–60%, lignin 5%, and starch 5% (Safitri et al., 2017). Bioplastics that utilize cellulose are usually accompanied by the addition of plasticizers. The types of plasticizers such as glycerol, acetic acid, ethyl acetate, or sorbitol. Plasticizers are often added to cellulose acetate because this material allows the polymer to melt without undergoing thermal degradation and reduces stiffness (Permadani and Silvia, 2022).

Bioplastics are produced by adding starch as well as chitosan and sorbitol concentration have

advantages in terms of water absorption capacity, tensile strength, density value, degradability and on the surface structure of bioplastics, having disadvantages as far as elongation capacity and Young's modulus value are concerned (Rahmatullah et al., 2023). The addition of glycerol to cellulose-based bioplastic films can increase water resistance, tensile strength, and elongation percentage (Tamiogy et al., 2019; Permadani and Silvia, 2022).

Each of these studies has its own advantages and disadvantages to the bioplastic results. Therefore, further studies are needed on the manufacture of cellulose-based bioplastics, especially from durian skin waste, considering that no one has utilized durian skin as a raw material for bioplastics and observing the addition of starch adhesives, types of plasticizers, as well as effects of chitosan additives on the production of bioplastics with the characteristics that meet national bioplastic standards.

MATERIALS AND METHODS

Preparation of raw materials

Raw materials derived from durian skin waste were collected from traditional market waste in the Indralaya area, 500 g of durian skin was then cut into small pieces and cleaned from dirt using running water, then dried using an oven at a temperature of 100 °C until it produces a constant weight (136 g) to be carried out to the cellulose isolation stage.

Delignification process

The dried durian skin was mixed with a 12% NaOH solution (3.40 M) that has been diluted with distilled water. This delignification process ~~is~~ was carried out using a 1 L beaker glass. The NaOH solution was heated using a hotplate at a temperature of 75 °C for 3 hours until lignin came out, indicated by a change in the color of the solution to dark brown. The cellulose fibers were produced from the delignification process are filtered, then washed with distilled water until the pH was neutral. Furthermore, filtering was carried out using a cloth to reduce the water content without any durian skin fiber being wasted.

Bleaching process

The delignified durian skin fiber was then bleached to whiten and degrade the remaining lignin content. The chemical used is sodium hypochlorite (NaOCl) 3.50% (6.70 M) which has been dissolved using distilled water with a ratio of 1:1. This bleaching process was carried out by heating using a hotplate at a temperature of 75 °C for approximately 10 minutes. After the bleaching process, the durian skin fiber was neutralized using distilled water and heated in an oven at a temperature of 100 °C until constant weight was achieved.

Pretreatment synthesis of celullose acetate

Afterwards, 10 g of durian skin fiber cellulose was added with 50 mL of glacial acetic acid and 98% sulfuric acid, stirred until homogeneous and left for 1 hour at room temperature. This process was carried out using a three-necked flask covered with aluminum foil.

Cellulose acetate synthesis process

The results of the pretreatment process were subjected to the acetylation process by adding 50 ml of anhydrous acetic acid and 20 ml of glacial acetic acid, then the mixture was heated in a water bath at a temperature of 50 °C for 30 minutes. Furthermore, 50 mL of 70% glacial acetic acid and 0.14 mL (3 drops) of sulfuric acid were added to react for 3 hours at a temperature of 50 °C. Furthermore, it was left until the temperature decreased.

Purification of cellulose acetate

The synthesized cellulose acetate solution was poured into a beaker and 500 mL of distilled water was added with stirring until homogeneous, then filtered with a Buchner funnel and distilled water was added until neutral cellulose was obtained. The neutral cellulose acetate was dried in an oven at 100 °C until constant weight, then ground.

Bioplastics production

Afterwards, 1.50 g of starch was dissolved in 18 mL of distilled water and then heated for approximately 15 minutes continuously until gelatin was formed at a temperature of 70 °C. Cellulose acetate was added to the starch solution in an amount of 1 g. Then, 1 g of chitosan was added and plasticizers (glycerol and sorbitol) with varying concentrations. The solution was stirred and heated at a temperature of 50 °C for 15 minutes

until the solution thickened. The bioplastic solution was molded in a petri dish coated with aluminum foil first, and left to dry at room temperature to form a bioplastic sheet.

Bioplastic characteristics analysis

Density value testing

The bioplastic density value test was carried out based on the procedure by Darni et al. (2017), where the mass (g) of the sample to be tested was weighed using a digital scale.

$$\rho = \frac{m}{v} \quad (1)$$

where: ρ is density (g/mL), m is mass (gr), and v is volume (mL)

Scanning electrom microscopy (SEM) testing

Tests using a scanning electron microscopy (SEM) tool were carried out to analyze the surface and morphology of durian and tapioca seed starch-based bioplastics with the addition of cellulose acetate and chitosan.

Water absorption test

The water absorption test was carried out based on the procedure by Muhammad et al. (2020) by cutting the bioplastic sample with a diameter of 50 mm, then the bioplastic was weighed. The calculation of the amount of water absorption can be done using Equation 2

$$Penyerapan\ air\ (\%) = \frac{w - w_o}{w_o} \times 100\% \quad (2)$$

where: *Wo* is the weight of the dry sample (g), and *W* is the weight of the sample after being soaked in water (g)

Bioplastic tensile strength test

The tensile strength testing process of cellulose acetate-based bioplastic from durian skin produced was carried out using a universal testing machine (UTM).

Elongation ability test

Testing the elongation ability of cellulose acetate-based bioplastic from durian skin produced using the Universal Testing Machine (UTM).

Degradation ability test

Observing degradation ability of cellulose acetate-based bioplastics from durian skin was carried out based on the procedure by (Martucci and Ruseckaite, 2015). The decomposition time must be monitored periodically within 4 days with decomposing loose soil media having an acidity level of around pH 6–7. The test begins by weighing the bioplastic sample before the degradation test is carried out and reweighed after the 4 days degradation process. The soil that was still attached to the sample was cleaned by brushing it gently, sprayed several times with distilled water, and dried it at a temperature of 50 °C until a constant weight was reached. The percentage of degradation of the bioplastic sample can be calculated based on Equation 3:

$$Biodegradability\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100\% \quad (3)$$

Young's modulus test

The value of Young's Modulus was obtained based on the data value from the tensile strength test and the percentage elongation value, so that the calculation is produced using Equation 4.

$$E = \frac{\sigma}{\varepsilon} \quad (4)$$

where: E is Young's modulus (kPa), σ is the tensile strength (kPa), and ε is the percent elongation (%).

RESULTS AND DISCUSSION

Effect of addition of plasticizer type on bioplastic surface (SEM-EDX)

Analysis of scanning electron microscope and energy dispersive X-ray (SEM-EDX) on cellulose acetate-based bioplastic from durian skin was conducted to observe the surface and composition of bioplastic elements. The results of SEM analysis of bioplastic samples were carried out with a shooting distance of 13-14 mm at a magnification of 1000x with a shooting energy used of 15 kV are shown in Figure 1.

Figure 1 displays SEM test results on the surface of bioplastic with a concentration of 1.50 g of starch, 1 g of durian skin-based cellulose acetate, and 1 g of chitosan. The difference between the two samples lies in the concentration and type of plasticizer used. The morphology of the film on each bioplastic sample produced is uneven and there are cavities as well as lumps in the formed bioplastic matrix. The unhomogenous surface is caused by the unperfect

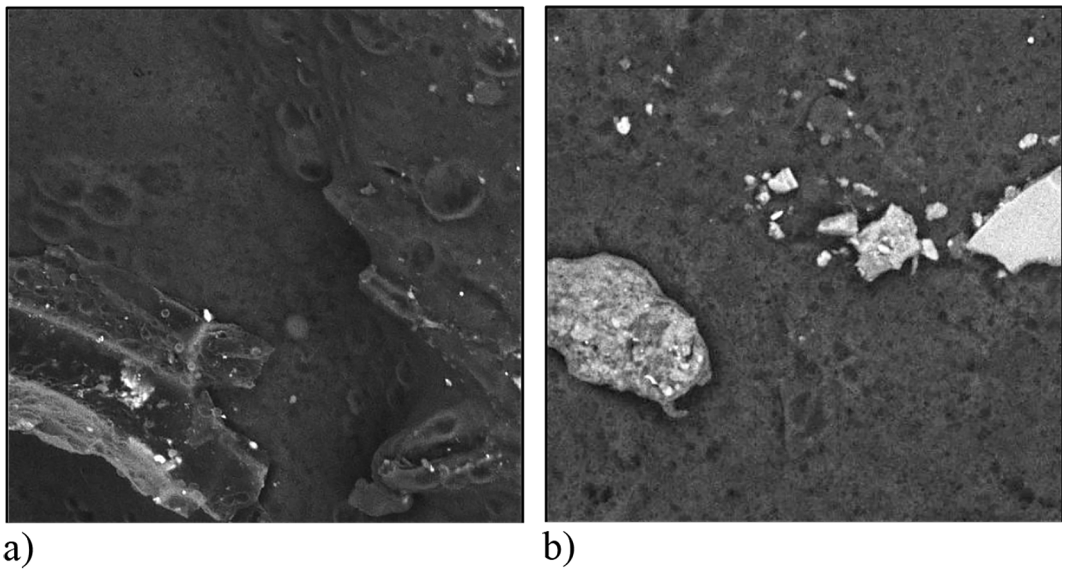


Figure 1. (a) Results of SEM test of 30% glycerol bioplastic, (b) Results of SEM Test of 40% sorbitol bioplastic

stirring process. A better stirring technique is needed using ultrasonic processing to increase the distribution of the filler (Marbun, 2012). The lack of homogeneity of the bioplastic surface is also due to the form of cellulose acetate which still has a fibrous form and is not perfectly smooth. The surface of the sample with 40% sorbitol shows the roughest results, while the sample with 30% glycerol shows smoother surface results. This case is because the glycerol has higher hydrophilic properties than sorbitol. Glycerol is able to bind water and easily soluble in water, because it has three polar hydroxyl groups, while sorbitol, on the other hand, has a more complex structure with more hydroxyl groups that can provide higher hydrophobic properties than glycerol. Glycerol plasticizer has hydrophilic properties and a smaller molecular weight compared to sorbitol, allowing for easier interaction with the polymer chain, thereby increasing the affinity for water (Tong et al., 2013). Glycerol homogeneity is better than sorbitol in bioplastic mixtures.

The lumps formed in the SEM test results are a mixture of starch granules and non-homogeneous chitosan. The starch flour used is made from cassava. The size of starch granules from cassava generally ranges from 4–35 μm (Suryani and Choirun Nisa, 2015), while the chitosan used has a non-uniform size of approximately 80 mesh. The test results on the surface of bioplastics show that bioplastics with a glycerol concentration of 30% have the best surface.

EDX results show that the bioplastic sample with 30% glycerol concentration contains N, O, C, and Cl elements, while the bioplastic sample with 40% sorbitol contains N, O, and Cl elements. The C element in the 40% sorbitol sample was not detected due to the lack of homogeneity of the bioplastic sample formed. The N, C, and O elements were obtained from tapioca starch ($C_6H_{10}O_5$), chitosan ($[C_6H_{11}NO_4]n]$), sorbitol ($C_6H_{14}O_6$), glycerol ($C_3H_8O_3$), sodium hypochlorite (NaOCl) and cellulose acetate ($[C_6H_7O_2(CH_3COO)_3]_x$). The presence of Na and Mg elements was obtained from NaOH and durian skin waste. Durian skin waste contains various vitamins, carbohydrates, fat, fiber, protein, calcium, folate, magnesium, phosphorus, potassium, copper, iron, manganese, thiamine, niacin, carotene, and riboflavin (Daosukho et al., 2012) (Fig. 2)

Effect of plasticizer type and glycerol and sorbitol concentration on bioplastic density

The density of the atoms of bioplastic material that interact with each other can be determined through a density test. Bioplastic with high density will affect the mechanical properties of the bioplastic itself. The mechanical properties of this bioplastic can increase and decrease. The effect of adding starch and the type of plasticizer as well as the concentration of glycerol and sorbitol on the density of bioplastic are shown in Figure 3.

The results of the study showed (Figure 3) that the density value of cellulose acetate-based

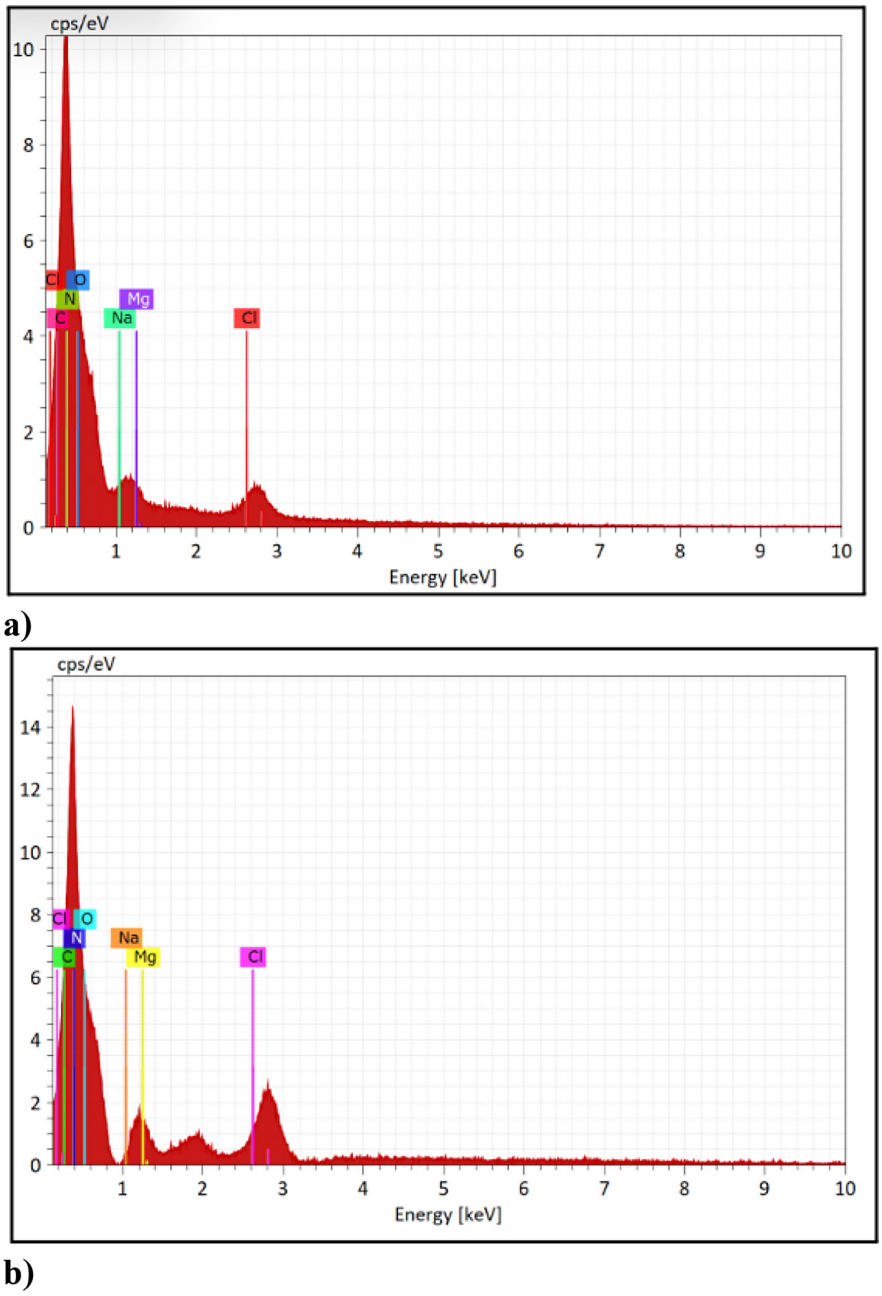


Figure 2. (a) Results of EDX analysis of glycerol spectrum 30%, (b) sorbitol spectrum 40%

bioplastic from durian skin was still fluctuating. This is influenced by the type of plasticizer and the molecular structure of each sample. The complexity of additional materials during the process causes the homogeneity of the bioplastic mixture (Tamiogy et al., 2019).

The density value of the resulting bioplastic ranged from 0.58–0.924 g/mL, where the lowest density was obtained from the sample with the addition of 30% glycerol plasticizer with a value of 0.586 g/mL. The highest density value was obtained from the sample with the addition of 30% sorbitol of 0.924 gr/mL. This phenomenon occurs because sorbitol has a higher molecular weight than glycerol, so it can cause a denser and tighter bioplastic structure. Molecular weight itself is directly proportional to density. The greater the molecular weight of a compound, the higher the density will be (Pratiwi et al., 2016).

Low density plastic indicates that the plastic has an open structure, making it easily penetrated by fluids such as water, oxygen, and carbon dioxide. The density value of plastic based on SNI (Indonesian National Standard) ranges from 0.94–0.95 g/mL for LDPE (low density polyethylene) plastic. The results of the bioplastic density test indicate that it

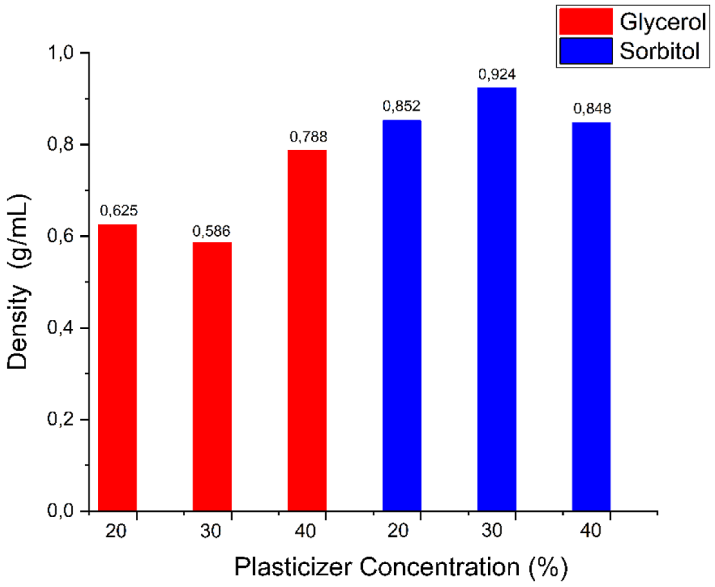


Figure 3. Bioplastic density results based on plasticizer type and concentration differences

has not met the standard, but for the sorbitol sample with a concentration of 30% it is almost close to the standard value of bioplastic density.

The effect of plasticizer type and glycerol and sorbitol concentration on bioplastic water resistance

The purpose of this bioplastic water resistance test is to determine the ability of bioplastics to absorb water, where the bioplastic is dipped in water and then dried and the difference in bioplastic mass before and after testing will be seen. The bioplastic being tested was expected to have a low water absorption capacity value. The higher the ability of the bioplastic to absorb water, the lower the quality of the bioplastic (Afif et al., 2018).

The results of the water absorption test show that the samples using plasticizers in the form of glycerol and sorbitol increased along with concentrations of glycerol used (Fig. 4). This is relevant to the study Intan and Wan Aizan (2011), which states

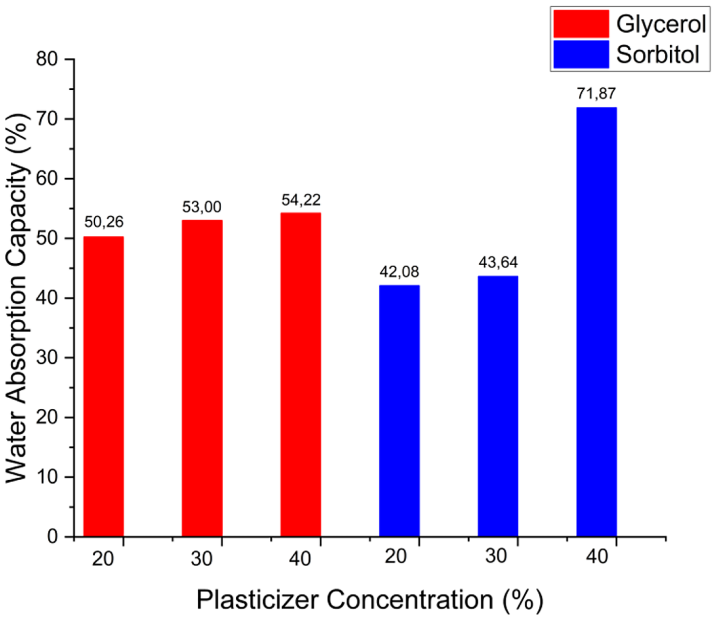


Figure 4. Water absorption capacity of bioplastics based on differences in plasticizer types and glycerol and sorbitol concentrations

that the water absorption value by plastic increases with the amounts of glycerol added. The water absorption capacity of samples using sorbitol plasticizer increased significantly with the concentrations used. The increasing concentration of plasticizer in edible film causes the rate of water vapor migration in the edible film, so that the water absorption capacity will be greater (Zahra et al., 2020). The highest water absorption capacity in samples using 40% sorbitol is 71.87%, while the highest water absorption capacity from using 40% glycerol is 54.22%. This is because sorbitol has many hydrophilic hydroxyl groups (Afif et al., 2018). The addition of starch and chitosan can also affect the water absorption capacity, because starch and chitosan have hydrophilic properties that have a major influence on water absorption. The hydrophilic properties of starch and chitosan are due to the large number of hydroxyl groups (OH-). The large value of water absorption is influenced by the large number of hydroxyl groups (OH-) from starch that have not been perfectly modified (Rozzana et al., 2022)

The effect of plasticizer type and glycerol and sorbitol concentration on the tensile strength of bioplastics

The tensile strength test of bioplastics was conducted to determine the effect of adding plasticizer types and their concentrations on the tensile strength of cellulose acetate-based bioplastics from durian skin. Tensile strength testing is a mechanical test that aims to determine the material response of a construction, component or fabrication assembly when subjected to a load. The tensile strength test aims to determine the ability of the bioplastic to withstand the load given until the bioplastic breaks (Andahera et al., 2019). The results of the tensile strength test are shown in Figure 5.

The tensile strength values based on the different types of plasticizers and concentrations of glycerol and sorbitol vary from 360.56 to 613.12 Kpa. The highest tensile strength value was obtained from the sample with a glycerol concentration of 30% and sorbitol of 20% with a load capacity of 613.12 Kpa, while the lowest tensile strength value was obtained fromthe sample with a glycerol concentration of 30% with a load capacity of 360.56 Kpa. Graph 5 shows that the tensile strength value of bioplastics is still fluctuating and has not been able to meet INS with a range of 24700–302000 Kpa. On the basis of the research conducted by (Tamiogy et al., 2019), it was stated that the tensile strength value of bioplastics was still fluctuating, which can be caused by the mixing of starch and cellulose acetate which is not homogeneous. The tensile strength value can also be influenced by the production process, material mixture (homogeneity), and processing conditions. The optimum tensile strength test value was obtained in the sample using 30% glycerol, which was 613.12 Kpa, a decrease in the tensile strength

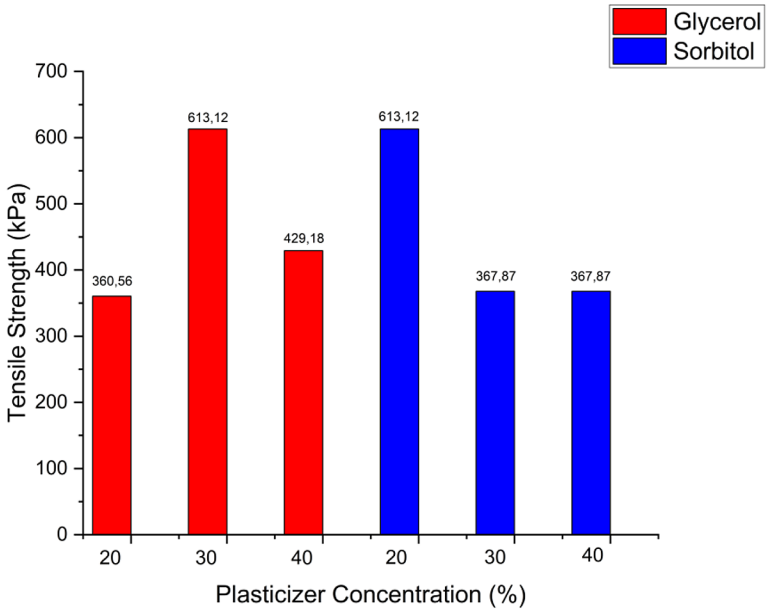


Figure 5. Tensile strength ability of bioplastics based on differences in plasticizer types and glycerol and sorbitol concentrations

value occurred in the 40% glycerol sample, which was 429.18 Kpa. The tensile strength value will decrease as the concentration of added glycerol increase 55. It is also happens for the use of sorbitol, the optimum value for using sorbitol at 20% is 613.12 Kpa, then decreases at sorbitol concentrations of 30% and 40% to 367.87 Kpa. This is in accordance with the research conducted by Azizaturrohmah (2019) and Rahmatullah et al. (2022) where the maximum tensile strength of cellulose acetate-based bioplastics was obtained at a 20% concentration of sorbitol. The decrease of tensile strength was influenced by the addition of plasticizers. This is because plasticizers have the ability to reduce glycolytic bonds between polymers, which is causing the bioplastic formed to be less rigid and more flexible (Fadlilah and Udjiana, 2023). The higher the concentration of plasticizer added, the more the interaction between bioplastic molecules will decrease and lead the weak bonds between bioplastic molecules, which can cause the tensile strength value of bioplastics to also be lower (Sumartono et al., 2015). The addition of 20% sorbitol can increase the tensile strength of bioplastics and has a higher value with the same concentration for glycerol plasticizer. This is because sorbitol has a longer and stiffer carbon chain than glycerol. Glycerol has a smaller molecular weight than sorbitol and it more easily enters the polysaccharide bond spaces, thereby increasing the amount of space in the bond and decreasing the intermolecular bonds (Supraptiah, et al., 2014). The molecular structure of sorbitol is difficult to insert into polysaccharide bonds, because the molecules of sorbitol are larger than glycerol, so that they can loosen the existing bonds According to Sitompul and Zubaidah, 2017). The addition of sorbitol can produce the bioplastics with greater tensile strength than glycerol, because sorbitol is in crystalline structure (Kumar et al., 2022). The tensile strength value is also influenced by the addition of starch and chitosan. The addition of starch can affect the tensile strength value with the greater the starch mass, the tensile strength value tends to increase (Dewi et al., 2021). On the basis of the research by Setiani et al., (2013) it was found that the addition of chitosan filler aims to improve mechanical properties. Plasticizers and fillers are added as composites or fillers to bioplastics. The amount of plasticizer and filler composition is able to fill the pore space in the bioplastic so that bioplastics that have good tensile strength are obtained, but if the amount of filler and plasticizer composition is excessive, it cannot fill the space in the pores of the bioplastic so that the bioplastic results obtained will be mechanically poor and easily broken (Melani et al., 2017).

The effect of plasticizer type and glycerol and sorbitol concentration on bioplastic elongation

The elongation value test on cellulose acetate-based bioplastic from durian skin aims to determine the percentage of changes in the length of the

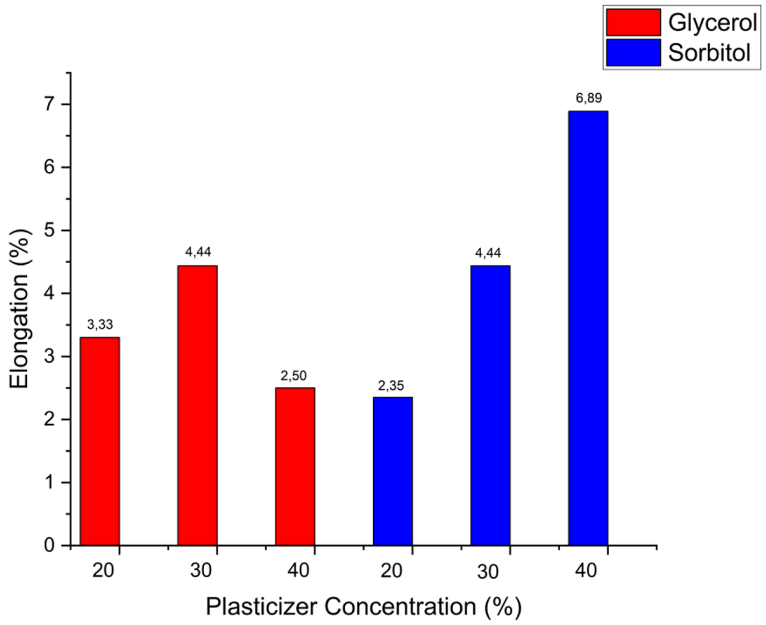


Figure 6. Elongation test results based on plasticizer type and differences in concentration

bioplastic before breaking. The addition of starch and chitosan as well as plasticizers will affect the elongation value produced by the bioplastic. Figure 6 shows the elongation value produced by the addition of plasticizers giving varying results. A significant difference in value was seen in sample 2 (glycerol 20%) and sample 5 (sorbitol 40%) where the highest elongation value was obtained for each type of plasticizer of 4.44% for glycerol and 6.89% for sorbitol. On the basis of the Figure above, it can be seen that the factors that affect the elongation value are the concentration of plasticizer and the type of plasticizer used in making bioplastics. An increase in plasticizer concentration is directly proportional to the increase in elongation value. This statement is relevant to the research of Kamaluddin et al. (2022) which states that an increase in plasticizer concentration will reduce hydrogen bonds, thereby increasing flexibility in bioplastics. The increase in elongation value in bioplastics is because plasticizers will cause a decrease in intermolecular bonds between amylose and amylopketin (Nuriyah et al., 2018).

The addition of plasticizers in the form of glycerol and sorbitol will increase the elongation value of bioplastics. The elongation value of bioplastics will affect the quality of bioplastics, where a higher elongation value indicates that the bioplastic has good mechanics. Sample 3 (40% glycerol) experienced a significant decrease in value compared to sample 2 (30% glycerol). The greater the addition of plasticizer, the greater the elongation value, but after addition at a certain concentration the value will decrease (Harumarani et al., 2016). The decrease in elongation value is influenced by such factors as less homogeneous mixing, so that the insertion of plasticizers into the film matrix has not taken place perfectly. The lack of homogeneity of bioplastics is also influenced by the size of the starch particles used. The larger the size of the starch particles, the more difficult it will be to mix the material, because the grains are not evenly distributed (Asngad et al., 2020).

Effect of chitosan addition and type of plasticizer and glycerol and sorbitol concentration on young's modulus value of bioplastic

The elasticity value of bioplastic can be determined by conducting a Young's modulus test on cellulose acetate-based bioplastic from durian skin. The Young's modulus value is obtained by calculating by comparing the tensile strength value to the percentage elongation value (Rifaldi et al., 2017).

Figure 7 shows the results of the Young's modulus test on each bioplastic sample. The highest Young's modulus value was obtained in the bioplastic sample with 20% sorbitol plasticizer of 26090.21 kPa. The lowest modulus value was also obtained in the bioplastic sample with the use of sorbitol plasticizer with a concentration of 30% of 5333.77 kPa. High sorbitol concentrations cause deficiencies in the tensile strength and Young's

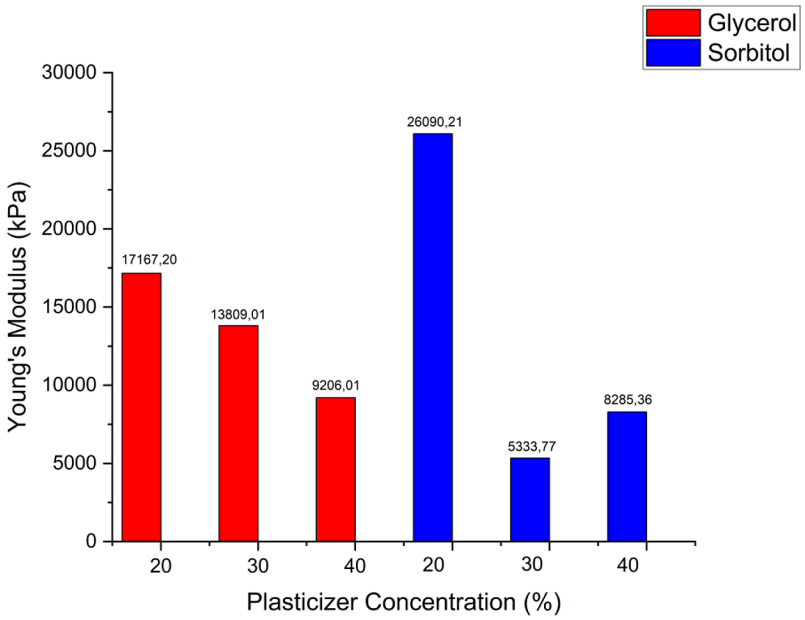


Figure 7. Young's modulus test results based on plasticizer type and concentration differences

modulus of bioplastics, but it can increase the elasticity of bioplastics (Azizati et al., 2022).

For the value of Young's modulus with glycerol plasticizer, it has the highest value at 20% addition of 17167.20 kPa, which then decreases with increasing concentration at 30 and 40% to 13809.01 kPa and 9206 kPa. The addition of glycerol concentration can increase the flexibility of the polymer chain (Harumarani et al., 2016). The addition of plasticizer also causes a decrease in intermolecular forces along the polymer chain, thereby increasing the flexibility of bioplastic (Huri and Nisa, 2014). The high percentage of elongation indicates that the edible film is bioplastic. The greater the glycerol composition, the bioplastic properties will increase the elasticity of the bioplastic but reduce the value of Young's modulus (Sanjaya and Puspita, 2011). The value of Young's modulus tends to decrease with increasing concentration of plasticizer. Bioplastic with a higher tensile strength value accompanied by a smaller percentage of elongation will obtain a higher Young's modulus value. This is because Young's modulus is directly proportional to the tensile strength value and inversely proportional to the elongation value.

Increasing the concentration of glycerol and sorbitol plasticizers will be able to increase the elasticity of bioplastics, causing a decrease in the Young's modulus value. The decrease in Young's modulus is caused by the increasing distance of bonds between molecules, because the saturation point has been exceeded so that excess plasticizer molecules are in a separate phase and reduce the intermolecular forces between chains, causing more release the chain movement so that flexibility increases (Kamaluddin et al., 2022).

The effect of plasticizer type and glycerol and sorbitol concentration on bioplastic biodegradation

The biodegradation ability of cellulose acetate-based bioplastic from durian skin fiber was tested to determine the time required for bioplastic to decompose completely if disposed of in nature. Bioplastic biodegradation testing was carried out using the soil burial method (direct contact with soil media) which is often used in testing the biodegradability of a material (Ballesteros-Mártinez et al., 2020). The mass of degraded bioplastic was calculated every day until the fourth day. The dimensions of each sample for biodegradation testing were 3.00 × 4.00 cm. The type of soil used for this test was humus soil, which can be found in various places and is commonly used for plants. The selection of humus soil as a test medium is because the microorganisms in humus soil will be able to decompose organic material in bioplastic. The addition of the type and concentration of plasticizer to the biodegradation ability of bioplastics has an effect on the results of the percentage of bioplastic mass degradation. The results of the percentage of degraded mass is shown in Figure 8. The results of the percentage

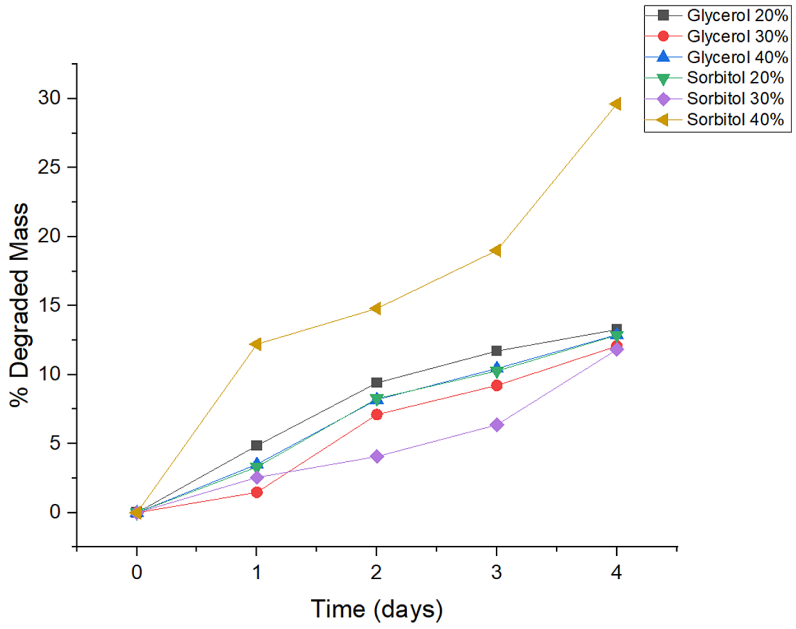
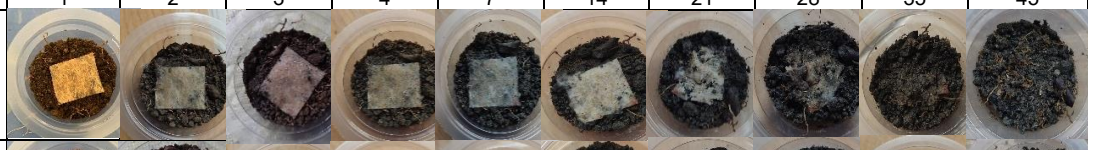


Figure 8. Results of percent mass degraded bioplastic

of bioplastic mass that was degraded experienced an increase in value in the four-day test period, the process of weighing the bioplastic mass was only carried out for 4 days because on the following day the bioplastic had started to soften and could not be weighed, then only physical observations could be made to see the changes that occurred. The increase in the percentage of degraded mass was obtained by testing biodegradation without being buried in the soil. The increase in the percentage of degraded mass occurred in each sample, which was influenced by the type and concentration of plasticizer. Testing was also carried out by comparing it to commercial plastic of the low density polyethylene (LDPE) type, where commercial plastic did not experience a change in mass within 4–45 days without being buried in the soil (Table 1). The bioplastic degradation testing process obtained the highest percentage of degraded mass results in sorbitol type plasticizer with a concentration of 40%, which was degraded by 29.62%. Similar to the research conducted by Rahmatullah et al. in 2022, where the degradation testing process without being buried in soil with the highest percentage of degraded mass was obtained in bioplastic samples with a sorbitol concentration of 40% worth 32.36%. While the maximum percentage of degradation for the bioplastic with glycerol plasticizer was at a concentration of 20% of 13.27%. The value resulting from bioplastic biodegradation can be influenced by several factors, one of which is the level of homogeneity in the mixing process. An inhomogeneous mixing process can cause bioplastic to be easily degraded by soil and vice versa. Inhomogeneous mixing will result in the formation of pores and spaces in the resulting bioplastic, causing water to enter the bioplastic more easily and accelerating the degradation process (Rahmatullah et al., 2022).

Bioplastic testing carried out without any soil filling can help in observing the development of the degradation process in bioplastics as seen in Table 1. Bioplastic on the 7th day began to look duller, accompanied by black spots on the surface of the bioplastic. This indicates that

Table 1. Biodegradation of bioplastic

Sample	Time (Day)									
	1	2	3	4	7	14	21	28	35	45
G20%										
G30%										
G40%										
S20%										
S30%										
S40%										
LDPE										

the bioplastic has undergone a degradation process. Significant changes occurred in the 2nd and 3rd weeks, where more black spots were formed, parts began to tear, and an increase in the mass degraded due to oxidation and microorganism activity (Andahera et al., 2019).

In the 4th week, most of the bioplastic samples had shrunk into smaller forms. Bioplastics are easily degraded because the bioplastics produced contain hydroxyl (O-H), carbonyl (C=O) and carboxyl (CO) ester functional groups. These groups have hydrophilic properties so that water molecules can cause microorganisms in the environment to enter the plastic matrix (Situmorang et al., 2019). On the 35th day, each of the bioplastic samples had degraded on most of its surface to become small, leaving a little and thinning. On the 45th day, most of the bioplastic samples had been decomposed by the soil or left a little or even no longer visible in their physical form. The presence of starch and chitosan components in bioplastics also affects the biodegradation process and makes the absorption of water vapor even higher. Sorbitol is a plasticizer that has an OH group, the presence of the OH group is hydrophilic which is able to bind water (Fadlilah and Udjiana, 2023). The hydrophilic nature of sorbitol makes plastic easy to decompose. Thus, it can be stated that the biodegradability test has met the standards of INS with a percentage value of > 60%. The addition of starch and chitosan to bioplastics brings good results in the degradation process because microorganisms are easier to grow due to the ability of starch to bind water and cause the surface of the bioplastic to become moist (Raden, et.al, 2016).

CONCLUSIONS

The addition of sorbitol and glycerol has different effects on the properties of bioplastics. Sorbitol increases elongation, density, and water absorption, but decreases tensile strength. In turn, glycerol increases tensile strength and density, but decreases water absorption. The combination of 20% sorbitol and 30% glycerol produces bioplastics with the best tensile strength and density values, namely 613.12 kPa, but its water absorption still does not meet SNI. Sorbitol has the best density value, namely 0.924 g/mL.

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