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Effect of Heating Temperature, Combination of Lignin and Chitosan on Mechanical Properties of Biodegradable Plastics Soybean Shell Waste

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Abstract: ***Plastic waste from petroleum raw materials is difficult to decompose by microbes, causing a pile of plastic waste that continues to increase every year. According to Indonesia's domestic waste statistics, which consists of plastic waste, it is ranked second, amounting to 5.4 million tons per year or 14% of total waste production, and this number is expected to continue to increase every year. In order to anticipate global trends in the use of plastics, especially in the packaging industry, research needs to be carried out in finding new biodegradable plastic material alternatives, one of which comes from soybean husks. Research is carried out through the addition of chitosan and lignin in various compositions or variations in mass and temperature. Plastic characteristic tests are performed by measuring the mechanical properties (tensile strength) of biodegradable plastics and elongation. Research shows that soybean husk can potentially be used as a bioplastic because it has the ability to degrade up to 90% for 14 days, tensile strength of 15.9 mPA and water resistance of 31.6%. So, it can be concluded that at a heating temperature of 45^{0}C for 24 hours with the addition of a combination of chitosan and lignin obtained the mechanical properties of biodegradable plastic made from soybean husk which can be used as a substitute material for plastic.***

Keywords: Biodegradable, Bioplastic, Chitosan, Lignin, Resistance, Strength, Water

1. Introduction

The rapid development of the times and technology, causing a lot of industrial growth in the field of food processing. This is because as an effort to meet the level of human needs that are increasing along with the increasing population. In the process of food processing, an industry not only produces the main product, but also produces by-products such as waste. This allows the utilization of the waste so as not to pollute the environment and can increase the added value of the waste. This research focuses on finding materials to replace conventional non-biodegradable petroleum-based plastic packaging materials.

The basic ingredient of this study is soybean husk which is used as a source of starch, this is due to the starch content in soybean juice. Soybean husk starch has a cellulose content of 42%, hemy cellulose 16% and lignin 2% According to [1], lignin levels are expected to provide optimal mechanical properties and lignin levels provide optimal moisture resistance properties. In a study by [2] using Garut yam starch and cellulose as natural reinforcement, with 10% glycerol as the plasticizer, the bioplastic exhibited a tensile strength of 5.39 MPa and an elongation of 9.25%

The insolubility in water is often referred to strong intermolecular hydrogen bonding between cellulose molecules. Revisiting some fundamental polymer physicochemical aspects (i. e. intermolecular interactions) a different picture is now revealed cellulose is significantly amphiphilic and hydrophobic interactions are important to understand its solubility pattern. [3].

The addition of lignin in the manufacture of bioplastics can be a good reinforcing agent in PLA matrix polymers and is a potential candidate for the bioplastic material Lignin with a concentration of 5% in the manufacture of bioplastics can produce better surface adhesion and compatibility compared to concentrations above 5%. Mixing PLA and lignin can improve the physical and mechanical properties of PLA-lignin bioplastic films such as increasing tensile strength, elongation, and Young's modulus compared to bioplastics from pure PLA [4]. From a structural standpoint, it could be expected that cellulose would have a high solubility in water, due to the numerous hydroxyl groups that can form hydrogen bonds with water. However, in reality, cellulose is not only insoluble in water, but also in other solvents. This is due to the strength of the chains and the high inter-chain forces resulting from hydrogen bonding between the hydroxyl groups on adjacent chains. This factor is considered to be the cause of the high crystallinity of cellulose fibers. Then in the research of (Hamani, et al, (2019) in variations in drying temperatures, the results obtained were Tensile Strength 7.3 MPa and Water Resistance 39.9%.

Glycerol improved film extensibility but reduced film puncture strength, elasticity, and water vapor barrier properties. The plasticizing effect of water was highly temperature dependent. During hydration of gluten film, a sharp decrease in puncture strength, elasticity, and an increase of extensibility and water vapor transmission rate were observed at 5, 30 and 50°C for respective water contents of 30 (0, 8 aw,), 15 (0, 7 aw) and 5% (0, 4 aw), [5]. Making soybean husk flour starts from the husk of soybean seeds that have been washed thoroughly then steamed, at the time of steaming used belly orange leaves mixed in steaming water to reduce the aroma of langue on the husk of soybean seeds, 1 kg of soybean husk is added 3 grams of kaffir lime leaves, steaming is done for 20 minutes, Then proceed with the drying process can be done with a machine. dryer or with direct sunlight heat until the husk of soybean seeds is completely dry so that it is easy to grind, the last process of making soybean husk flour is ground with a grinding machine for flour and soybean husk flour can be used as a substitute or basic ingredient [6].

From the heating process at temperatures of 500°C, 600°C, and 700°C for 4, 5, and 6 hours, the best results were obtained at 50°C for 6 hours with variations of gelatine used in heating the plastic film. The results were a tensile strength of 1.04 MPa, an elongation of 54.99%, a Young's modulus of 0.019 MPa, and a biodegradability of 51.18%. The ingredients to produce the main ingredients of cassava skin starch were aquadest; chitosan; 3.5%: 44%, and 1.5%: 50% of vinegar solutions; and 1% of glycerol. The best result which had 1.04 MPa of tensile strength value, elongation of 54.99%, modulus young of 0.019 MPa, biodegradability of 51.18% with porous morphology and brownish flocks was obtained from 50 o C and 6 hours of drying temperature and drying time [7].

Soybean hulls are still not optimally utilized, generally only used as an addition to animal feed or discarded. Considering the composition of soybean hulls and vegetable waste, which contain 21.24% cellulose and 27.14% carbohydrates, they have great potential as alternative additive materials [8]. The addition of plasticizer results in a decrease in the transmittance value of the O-H group. From other tests, the best sample was obtained, which has a mixing temperature of 80°C and a plasticizer concentration of 10ml. This sample has a tensile strength of 0.035MPa and a degree of swelling of 61.6%. In terms of its degradation ability, the glucomannan film can undergo biological degradation for 9 days [9].

Figure 1: Soybean Ari Skin

Table 1: Comparison of Polymerization and Gelatinization

Process / Parameters	Polymerization	Gelatinization
Raw Materials	By-product compounds from coal or petroleum processing such as ethene, styrene and esters	Compounds taken from wood, tubers and fruit peels or nuts are starch and cellulose
lignin (g)	-	Weighing variations
Chitosan (g)	-	Weighing variations
Product	Synthetic polymers such as polyethylene, polystyrene, polyester and others	Natural polymers are bioplastics made from starch or cellulose

The gelatination process is a process that will be used because to make bioplastics from soybean husk, raw materials in the form of starch and cellulose are used with parameters according to Table 1.

2. Research Method

This study used the gelati nation method. This method is carried out by using glycerol as a plasticizer and cellulose from soybean husks as a polymer source so that when the two substances interact with lignin and chitosan weighing variations of 0-3 g, gelatin will form which will be heated to produce a plastic film. The bioplastics that have been made are tested for mechanical properties such as tensile strength and elongation properties at break using an autograph-shiatzu tool based on ASTM D882. Analysis Method through:

1) Mechanical Testing of Biodegradable Plastics

The sample to be tested is cut according to the standard, namely a circle with a diameter of 17 cm. The test is carried out by means of both ends of the sample clamped to the Autograph tool. The tensile test will obtain information on the tensile strength and elongation of the bioplastic. Account:

a) Tensile Strength (N/cm^2)

Tensile Strength (N/cm2) $= \frac{Tensile\ Strength\ force\ (F)}{Face\ area\ (A)}$

b) Elongation (%)

Elongation measurement is performed in the same way as tensile strength testing. Elongation is expressed as a percentage. Account:

Elongation (%) = $l - l_0$ x 100%

notes:

l = length after breaking

l_0 = First length

3. Results and Discussion

Bioplastics that have been made are tested for mechanical properties based on tensile strength and elongation properties when broken using an autograph-shiatzu tool based on ASTM D882 obtained. The optimal temperature for making bioplastics from soybean husks is at a temperature of 45^{o}C which is then heated for 1 day (24 hours):

For bioplastics the addition of lignin 2 grams at a temperature of 45^{o}C

$$Tensile\ Strong = \frac{F}{A}$$

$$15{,}9 = \frac{F}{(3{,}14x8{,}5x8{,}5)cm^2}$$

$$15{,}9 = \frac{F}{226{,}865}$$

$$F = \frac{15{,}9x226{,}865}{1000} = 3{,}6\ N$$

For heating bioplastics at 45°C

$$Water\ (\%) = \frac{W - W_0}{W_0} x\ 100\%$$

$$Water\ (\%) = \frac{0{,}3825 - 0{,}2906}{0{,}2906} x\ 100\%$$

$$Water\ (\%) = 31{,}6\%$$

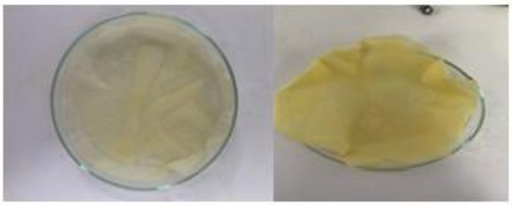


Figure 2: Plastic film before and after heating

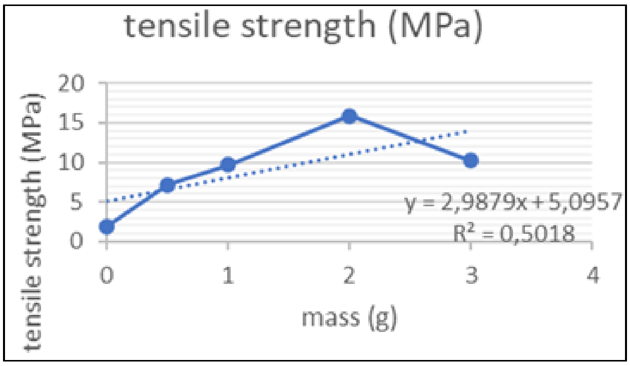
Table 2: Test Results of Tensile Strength and % Water Resistance

No.	Weighing (gr)	Tensile Strength (MPa)	%K. Water
1	Delignification	1, 9	52, 7
2	0, 5	7.2	47, 2
3	1	9.7	39, 2
4	2	15, 9	31, 6
5	3	2 0.2	25, 4

Table 3: Biodegradable Bioplastic Test Results

Week	Bioplastic Weighing Variations (g)				
	0,5	**1**	**2**	**3**	**Delignification**
1	Still intact 0 % (0 days)	Still intact 0 % (0 days)	Still intact 0 % (0 days)	Still intact 0 % (0 days)	Still intact 0 % (0 days)
2	Not whole, decomposed 25%	Not whole, decomposed 30%	Not whole, decomposes 40%	Not whole, decomposes 50%	Not whole, decomposed 25%
3	Not whole, almost 50% decomposed	Not whole, almost 50% decomposed	Already relegated	Already relegated	Not whole, almost 50% decomposed
4	Not whole, almost 80% decomposed	Not whole, almost 90% decomposed	Already relegated	Already relegated	Not whole, almost 90% decomposed
5	Already relegated	Already relegated	Already relegated	Already relegated	Already relegated

In this study, variations of chitosan weighing were made before the heating process in an oven temperature of 70°C - 80°C, each of which was carried out with a heating period of 1 day (24 hours). This variation is used to find at what mass bioplastic from soybean husks gets the highest tensile strength value so that the mass will be used as the optimal mass variation when printing.



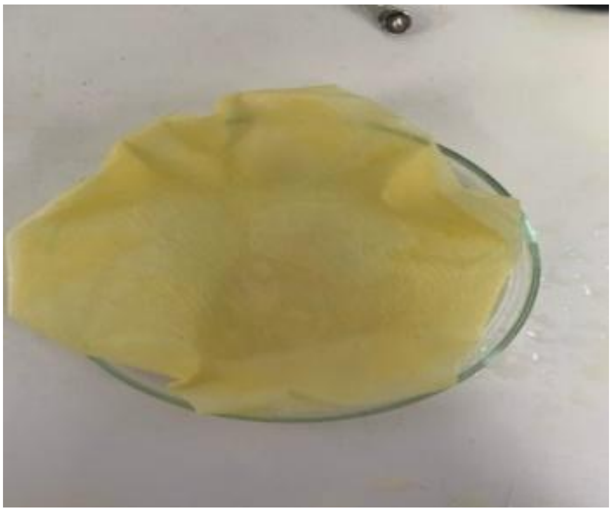


Figure 3: Graphics Bioplastics Strength

In Graphics 1. above can be seen the correlation that connects the weighing variation (g) on the X axis with the Tensile Strength (MPa) on the Y axis, following the equation y = 2.9879x + 5.0957 and R^2 = 0.5018. It can be seen that the optimal weighing variation where the highest tensile strength value is obtained is in the weighing variation of 1 g chitosan: 2 g lignin. At weighing 3 g, it can be seen that there is a decrease in tensile strength value which is quite drastically. According to their research journal entitled "The Effect of Lignin Concentration on Physical and Mechanical Properties of Polylactic acid (PLA)-Based Bioplastics [4]. "Higher lignin levels cause an increase in tensile strength values, because glycerol *plasticizers* are mutually reinforcing.

Elongation Test

An elongation test is carried out to determine the level of elasticity possessed by bioplastics. The elongation test has been carried out but was unsuccessful because the tool used did not output the test data (the elongation result is too small). This is thought to be due to the glycerol used (less concentrated or less volume) or the quality of the glycerol itself. Because referring to the research of with a ratio of glycerol use of 10%, 20% and 30% obtained elongation results of 9.25%, 14.32% and 20.68% [2]. It can be concluded that the higher the glycerol concentration, the greater the elongation.

Water Resistance Test

Water resistance tests are carried out to determine the occurrence of bonds in polymers and the degree or regularity of bonds in polymers. The process of diffusing solvent molecules into the polymer will produce a bulging gel. The nature of bioplastic resistance to water is determined by *swelling* test, which is the percentage of film bloating by the presence of water [10-11].

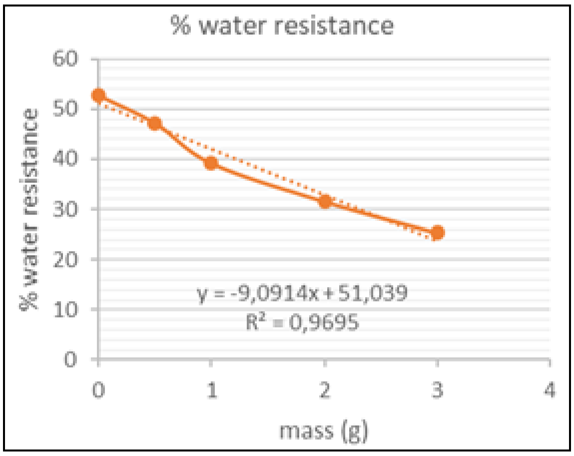


Figure 4: Graphics Bioplastics Water Resistance (%)

Biodegradable Test

The resistance test to microbes in this study was carried out visually because the composition of bioplastics that are easily digested by microbes causes very rapid damage. Bioplastic damage can be seen from changes in color and texture in bioplastics when buried with soil.

Biodegradability testing aims to determine the rate of degradation of bioplastics so that it can be estimated how long it will take for bioplastics to decompose. Biodegradability tests are performed with *soil burial tests*. Biodegradability testing aims to determine the rate of degradation of bioplastics so that it can be estimated how long it will take for bioplastics to decompose. Bioplastic samples are buried in the soil by maintaining stable soil temperature and moisture. Then, the bioplastics buried in the ground are visually viewed by checking every two days.

Biodegradability test with soil *burial test* method shows several weaknesses. Bioplastic samples in the form of films are difficult to control during testing. The reduction in the mass fraction of bioplastics cannot be determined thoroughly whether it is caused by the activity of microorganisms or degradation of water absorption entering the bioplastic. Therefore, the temperature and humidity of the soil used need to be maintained stable [10].

In Table 2 above, it can be seen that the lower the lignin variation, the longer the biodegradation rate where the longest degraded until fully decomposed is in the delignification process with a degradation time of 4 weeks and the fastest is in the weighing variation of 2 and 3 g with a degradation time of 2 weeks, so it can be concluded that the difference Variations in the addition of lignin can affect the biodegradation rate of bioplastics. The existence of this influence is caused by the higher temperature, causing bioplastic particles to undergo many physicochemical changes making plastic more homogeneous and tighter in structure, with these characteristics certainly causing microorganisms to be difficult to decompose the particles that make up plastic {12-13].

In ASTM standards, it is stated that bioplastics must decompose completely within 60 days, so bioplastics produced from soybean husk raw materials with glycerol from the extraction of used cooking oil and alcohol in accordance with specified standards with degradation time within 2-4 weeks. In Graph 2 a correlation is obtained that states the relationship between the weighing variation (g) on the X axis with the % water resistance on the y axis, following the following equation y =-9.0914x + 5 1.036 and R^2 = 0.9 695. It can be concluded that water absorption is affected by temperature, with % water resistance estimating linear equations.

The linear regression method represents for this data processing because changes in y are followed by non-fixed data on x in the specified region so that a larger reg receipt value is obtained. The decrease in heating temperature when printing tends to increase the water absorption in bioplastick, the lower the heating temperature used, the lower the water resistance, while the higher the heating temperature tends to reduce water absorption which means it has high water resistance.

4. Conclusion

Based on the research data obtained, it can be concluded as follows; The addition of lignin affects the results of making bioplastics at the optimum temperature for making bioplastics from soybean husks is at 45°C which is then heated for 1 day (24 hours). The degradation ability of bioplastics carried out in the soil is not affected by the heating temperature when drying. The higher the temperature (past the optimum temperature), the more fragile the structure of the bioplastic. And if the temperature is too low, the bioplastic still feels wet and not plastic. The optimal bioplastic water resistance is at the optimum temperature, so that if the temperature is lower, the water resistance will also be lower.

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