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# The Effect of Sorbitol on the Mechanical Properties of Temu Ireng Rhizomes (Curcuma Aeruginosa Roxb.) Starch Biodegradable Plastic

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**Abstract**

Biodegradable plastic is made by mixing from temu ireng rhizomes starch matrix, sorbitol as a plasticizer, and chitosan as a filler through the melt intercalation method. heating process at $80^0$C and drying at 70ºC. The results show that the addition of chitosan and sorbitol has an effect on the characteristics of the plastic. The best tensile strength results on biodegradable plastic with a mass composition of starch: chitosan 5:5 gram without the addition of sorbitol is 4.03 MPa. The best percentage of elongation in plastic with a composition of starch: chitosan 8:2 gr and 3 ml Sorbitol is 99.68%. The best water resistance to biodegradable plastic was the composition of starch: chitosan 5:5 gr without the addition of sorbitol is 83.33%. And the best biodegradability in plastic with a composition of 5:5 chitosan without the addition of sorbitol was 100% for 9 days. FTIR test results show that biodegradable plastic have the same wavelength as their constituent raw materials. This shows that the resulting film only interacts physically.

**Keywords:** chitosan, temu ireng rhizomes starch, biodegradable plastic, sorbitol

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## INTRODUCTION

Plastic is an example of a chemical polymer that is very useful for daily needs because it can be used as food packaging, handbags, drink bottles, children's toys, equipment containers, furniture, clothing materials and others (Sasria et al. 2020). Plastic has a lack where plastic is made from non-renewable raw materials, namely petroleum. Plastics made from petroleum are difficult to decompose naturally or completely degrade over a long period of time in the earth's environment and some even require decades to decompose (Mery & Endaruji, 2015). The rapid increase in plastic production and consumption has caused serious problems with plastic waste, reduction of plastic waste also cannot by burning because it can emit harmful gases which can damage the environment and health (Ardiansyah 2011). Burning plastic can increase $CO_2$ levels in the air which can cause global warming. Whereas in recycling, only 25% of recycled plastic can be reused (Mery & Endaruji, 2015).

Based on this, other efforts are needed to overcome plastic waste. One that has been developed is biodegradable plastic derived from natural materials. Indonesia is a country that has a wealth of natural resources (agricultural products), so it has the potential to produce biopolymers, so biodegradable plastics have high prospects (Genalda and Udjiana 2021). Biodegradable plastic is a plastic material that is friendly to the environment because it can return to nature. Biodegradable plastics can be made from natural polymeric materials such as starch, cellulose and lignin found in plants, as well as casein, proteins and lipids found in animals (Averous, 2008). Temu ireng rhizomes can be used as a raw material for making biodegradable plastics because temu ireng rhizomes contains starch. temu ireng rhizomes starch is a type of starch that contains a hydrocolloid component which can be used to form a plastic matrix. Temu ireng rhizomes starch contains high amylose of around 24.45% and an amylopectin content of 75.54% (Nusa, Siregar, and Muzdalifah 2017). Starch-based plastics have lacks, where their hydrophilic properties and mechanical properties are still low, but these deficiencies can be overcome by adding or mixing chitosan which can be used as a filler (Saputra and Supriyo 2020). Chitosan is hydrophilic, able to hold water in its structure and form gels spontaneously, so that chitosan easily forms membranes or films. Chitosan has the ability to be developed as a material for making biodegradable plastics because it can be used as a stabilizer, thickener, emulsifier and forming a clear protective layer in food products. Chitosan is non-toxic, biodegradable, acceptable to the body, and a good plastic former (Kusumawati and Putri 2013).

The addition of chitosan as a filler in the manufacture of biodegradable plastics causes the plastic to be brittle, stiff and inelastic, therefore an additional material is needed, namely plasticizer (Vieira et al. 2011). The addition of plasticizers aims to reduce stiffness while increasing flexibility, elasticity and extensibility in biodegradable plastics (Ivanic et al. 2017). The addition of a plasticizer makes the properties of biodegradable plastic more elastic so that the elongation will increase even if it is pulled with a little pressure. Therefore the addition of sorbitol can increase the elasticity of biodegradable plastics so that the elongation value at break increases but the tensile strength decreases. (Afdal and Herawati 2022).

This research using temu ireng rhizomes-chitosan with the addition of sorbitol, were tested tensile strength, elongation, water resistance, biodegradability of temu ireng rhizomes starch and analyzed the characteristics of environmentally friendly biodegradable plastic from temu ireng rhizomes starch.

## METHOD

The manufacture of biodegradable plastic uses temu ireng rhizomes starch with the addition of chitosan and sorbitol. In the biodegradable plastic molding process in this research, the material composition was used with a comparison that can be seen in table 1

Table 1 composition of biodegradable plastic materials

| sample | composition | | |
|---|---|---|---|
| | **starch (gr)** | **chitosan (gr)** | **Sorbitol (ml)** |
| P1 | 10 | 0 | 4 |
| P2 | 5 | 5 | 0 |
| P3 | 6 | 4 | 1 |
| P4 | 7 | 3 | 2 |
| P5 | 8 | 2 | 3 |

Preparation of starch solution by mixing 50 ml of aquadest plus temu ireng rhizomes, stirred and heated on a hotplate for 25 minutes at 80ºC, while making chitosan solution by mixing 1% acetic acid solution with variations of chitosan added for approximately 25 minutes at 100ºC until obtained chitosan gel. The two solutions were mixed and various variations of the addition of sorbitol were carried out according to the variations in table 1. Then homogenize the solution which contains a mixture of starch, chitosan, sorbitol and distilled water by heating the betaraker containing the mixed solution on a hot plate with a temperature of 80-90$^{o}$C for 40 minutes while stirring is carried out using a magnetic stirrer. Before mixing this biodegradable plastic printed on a glass plate, the solution must be left for 15 minutes to remove any remaining air bubbles. If the air bubbles are not removed, the layer formed will be easily deformed (damaged) becausane there is a pinhole in the layer. After letting it rest, the process of moldcing biodegradable plastic is carried out. The process of printing the solution is done by pouring the solution onto a glass plate measuring 10x20 cm which has been cleaned using 96% alcohol with tape on both sides. Then the mixture is dried in the oven for 4 hours at 70°C after the printing and drying process in the oven is complete. After that, it was allowed to stand at room temperature and slowly removed from the glass plate, then stored in a desiccator (Aefif dkk., 2018).

**Water Resistance Test Biodegradable plastic**

The procedure for testing the resistance of biodegradable plastics to water is that biodegradable plastic samples are cut to a size of 3 x 3 cm, weigh the initial mass of the sample to be tested (m0). Then fill a beaker with distilled water, immerse the plastic sample in the container for 10 seconds. Then the sample is dried using a dry tissue and the final mass is weighed. Soak the sample back into the container, lift the sample every 10 seconds, then weigh the mass of the sample that has been immersed in the container (m1). Do the same until a constant final sample weight is obtained and calculate the percentage of water absorbed by the plastic film. The lower the water absorption value, the better the biodegradable plastic properties, while the higher the water absorption, the biodegradable plastic properties will be easily damaged.

The percentage development of biodegradable plastic is calculated using equation (1)

$$\%\ swelling\ = \frac{m_1 - m_0}{\mathrm{m_0}} \times 100\% \qquad (1)$$

With:
mo = dry sample mass (gr)
m1 = sample mass after soaking (gr)

The percentage of water resistance for biodegradable plastic is calculated using equation (2).

$$\%\ \text{water resistance} = 100\% - \%\ \text{swelling} \qquad (2)$$

**Tensile Strength and Elongation Test of Biodegradable Plastics**

The procedure for testing the resistance of biodegradable plastics to water is that biodegradable plastic samples are cut to a size of 3 x 3 cm, weigh the initial mass of the sample to be tested ($m_0$). Then fill a beaker with distilled water, immerse the plastic sample in the container for 10 seconds. Then the sample is dried using a dry tissue and the final mass is weighed. Soak the sample back into the container, lift the sample every 10 seconds, then weigh the mass of the sample that has been immersed in the container ($m_1$). Do the same until a constant final sample weight is obtained and calculate the percentage of water absorbed by the plastic film. The lower the water absorption value, the better the biodegradable plastic properties, while the higher the water absorption, the biodegradable plastic properties will be easily damaged.

To obtain the tensile strength value obtained using the equation (3):

$$\sigma\ =\ \frac{F}{A} \qquad (3)$$

Dimana :
σ = tensile strength (MPa)
F = tensile force (N)
A = sectional area ($mm^2$)

The total elongation value from the test results is obtained using the equation (4):

$$\varepsilon = \frac{\triangle L}{Lo} \text{ x } 100\% \quad (4)$$

Dengan :
ε = elongation (%)
△L = length increase (mm)
Lo = initial length (mm)
(Fateta dkk., 2020)

**Biodegradability Test (Soil Burial Test)**

Biodegradation of biodegradable plastic samples in each variation was then tested using a method soil burial test or the soil burial test method. This method aims to see the rate of degradation of the sample so that it can be predicted how long the sample will be decomposed by microorganisms in the soil. This method is also the simplest method because it is only done by burying the sample in soil whose physical and chemical properties are controlled and then calculating the residual mass of the sample in each unit of time (grams/day). The biodegradable plastic samples were dried, cut into length and width of 3x3 cm, then weighed until a constant weight was obtained as the initial mass (m0). and cleaning the sample from the soil then drying it until dry and weighing it until a constant mass (m1) is obtained. The first treatment is weighing the initial mass before it is degraded and then after it is degraded it is weighed again to find out what the % change (Hilmi et al. 2021).

The percentage of biodegradable plastic can be calculated using equation (4)

$$\% \text{ Degraded mass} = \frac{m_0 - m_1}{m_0} \times 100\% \qquad (5)$$

with:

$m_o$ = sample mass before planting (gram)
$m_1$ = sample mass after planting (gram)

**Analysis with FT-IR (Fourier Transform Infrared Spectroscopy)**

Chemical properties analysis by performing functional group analysis with FT-IR. Light transmission through the sample, measurement of light intensity with a detector, then compared with the intensity without the sample as a function of wavelength. The infrared spectrum obtained is then plotted as the intensity of the energy function, wavelength (μm) or wave number (cm-1). The sample was cut with a size of 0.5 cm x 0.5 cm, then put the sample on carbon tape. Then analyze using the FT-IR tool (Pelita et al., 2020). The resulting biodegradable plastic must contain a hydroxyl group (OH) and a carbonyl group (CO). It is this group that causes biodegradable plastics to be degraded properly (Afif dkk., 2018).

## RESULTS AND DISCUSSION

**Particle Size Analyzer (PSA) Characteristics Test Results**

Particle Size Analyzer (PSA) analysis was performed to determine the particle diameter size of black turmeric nanopathy. Observations of particle size measurements on the Beckman Clouter Technologies Particle Size Analyzer. The graph of the PSA results of temu ireng rhizomes starch can be seen in the Figure 1. The PSA test results of black meeting starch showed that the particle sizes of black meeting starch had different diameters, but the particles had an average diameter of 583.8 nm (0.584 μm) and had a polydespersity index of 0.567. The polydispersity index shows the particle size distribution where the range of the polydispersity index is between 0 to 1. This index. The smaller the index number obtained, the more homogeneous the particle size. A polydispersity index value close to zero indicates a homogeneous or uniform distribution of particles (Sanaji, Krismala, and Liananda 2019).

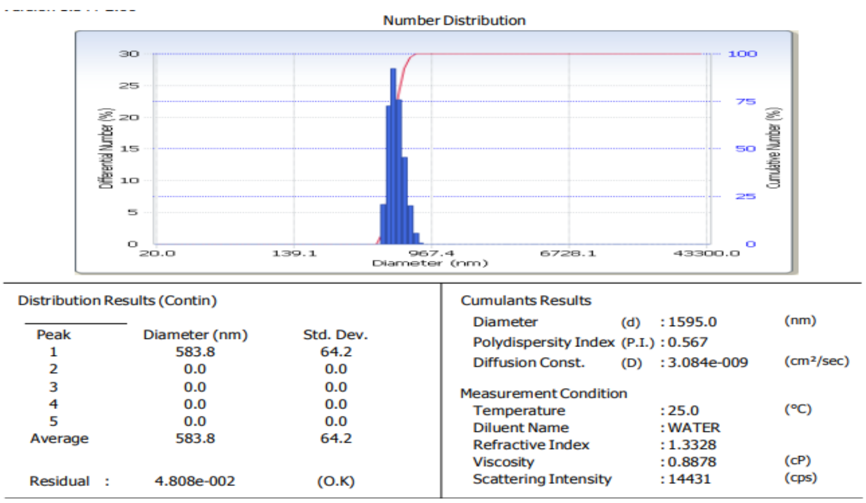

Figure 1 Graph of temu ireng rhizomes starch PSA test

**Mechanical Characteristics of Biodegradable Plastics**

Biodegradable plastic that has been released from the mold can be characterized, one of which is the mechanical test which includes tensile strength and elongation. The results of measuring the mechanical properties of biodegradable plastic can be seen in Table 2.

Table 2. Results of Measuring the Mechanical Characteristics of Biodegradable Plastics

| sample | thickness (mm) | tensile strength (MPa) | Elongation (%) |
|---|---|---|---|
| P1 | 0,35 | 3,64 | 31,80 |
| P2 | 0,9 | 4,03 | 33,39 |
| P3 | 1,1 | 2,27 | 63,19 |
| P4 | 0,6 | 3,36 | 49,34 |
| P5 | 0,85 | 1,75 | 99,68 |

**Tensile Strength Biodegradable plastic**

Based on research, the tensile strength without the addition of sorbitol has a greater value than the addition of sorbitol. The graph of the tensile strength test results can be seen in Figure 2

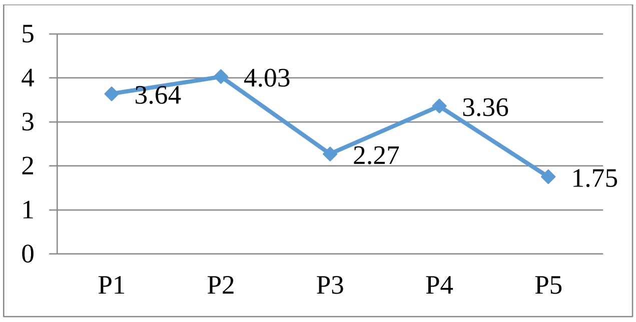

Figure 2 Graph of tensile strength test results

The results showed that the composition of chitosan had an effect on the tensile strength of the resulting biodegradable plastic. The more chitosan composition used, the greater the tensile strength value. In the starch composition of 8 grams, the addition of 2 grams of chitosan and in the starch composition of 7 grams, the addition of 3 grams of chitosan, the more chitosan is added, the greater the tensile strength value. In the starch composition of 6 grams with the addition of 4 grams of chitosan, the biodegradable plastic experienced a decrease in tensile strength, but in the composition of 5 grams of starch with the addition of 5 grams of chitosan, the tensile strength increased again. According to Aditya Nugraha et al., (2020) this was influenced by the addition of starch which caused the tensile strength value of the mixture to decrease. The more the amount of starch added, the lower the tensile strength value produced.

According to Hayati et al., (2020) the greater the use of chitosan concentration, the more hydrogen bonds there are in biodegradable plastic so that the chemical bonds of the plastic will be stronger and more difficult to break, because it requires great energy to break these bonds, of course, tensile strength. the greater it is. However, in samples P1 and P4 there was an increase in the tensile strength. This change in mechanical properties is related to the interaction between starch, chitosan and sorbitol. The increasing amount of starch, chitosan balanced by the addition of sorbitol causes not all of the chitosan to mix completely (less homogeneous distribution of chitosan) so that the tensile strength value increases and then decreases slightly. The results of this study are in line with the research of Nugraha et al., (2020) The criterion for tensile strength (tensile strength) for biodegradable plastics according to the SNI 7188.7:2016 standard is 24.7–302 MPa, while the minimum tensile strength value for biodegradable plastics based on JIS 2-1707 is 4 MPa. Thus, when viewed from the tensile strength value, the biodegradable plastic produced in this study does not match the tensile strength value based on the SNI standard, but for the P2 sample it meets the JIS 2-1707 standard.

**Elongation of biodegradable plastics**

Testing the elongation of biodegradable plastics is intended to see how much the percentage of maximum length increases in biodegradable plastics until they break. Like the tensile strength test, the elongation test is carried out using a tensile strength machine or Universal Testing Machine. The graph of elongation values can be seen in Figure 3

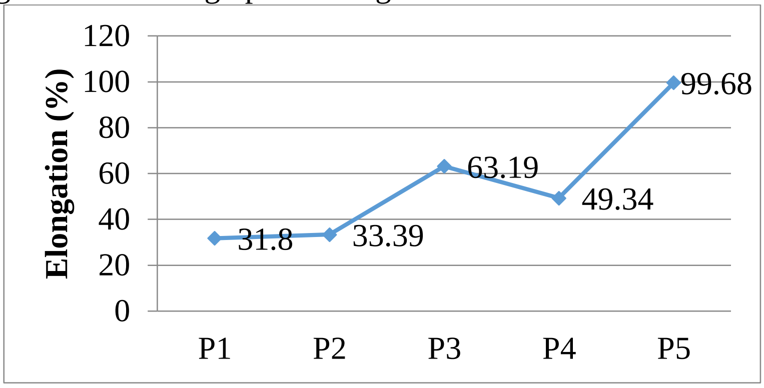


Figure 3 graph of the elongation value of biodegradable plastic

Figure 3 shows fluctuating results. The addition of a small variation of chitosan can affect its tensile strength and elongation properties, which is the greater. Sample P1 without the addition of chitosan had an elongation value of 31.80%, Sample P2 without the addition of sorbitol had an elongation value of 33.39%, then sample P3 experienced an increase in the elongation value of 63.19%. However, it decreased in the P4 sample, the elongation value was 49.34%. The elongation value again increased for the P5 sample, which was 99.68%. This is caused by several factors, one of which is the amount of starch which is not proportional to the concentration of chitosan and plasticizer, causing the elongation value to fluctuate. Sorbitol functions as a plasticizer which is located between the biopolymer chains so that the distance between the biopolymer chains increases and this affects the elasticity of biodegradable plastics and their elongation value tends to increase. The results of the elongation value are inversely proportional to the tensile strength value. The greater the percentage of elongation, the smaller the resulting tensile strength value (Muzdalifah 2022).

The results of the elongation tests that have been carried out can then be compared for suitability with the standard for elongation of biodegradable plastic SNI 7188.7: 2016. Based on the Indonesian National Standard (SNI) 7188.7:2016, the elongation is 21-220%. In terms of elongation, the biodegradable plastics in this study met SNI standards.

**Analysis Water resistance biodegradable plastic**

Swelling of biodegradable plastics occurs due to the adsorption process. The results of testing the water absorption capacity of biodegradable plastic can be seen in figure 4.

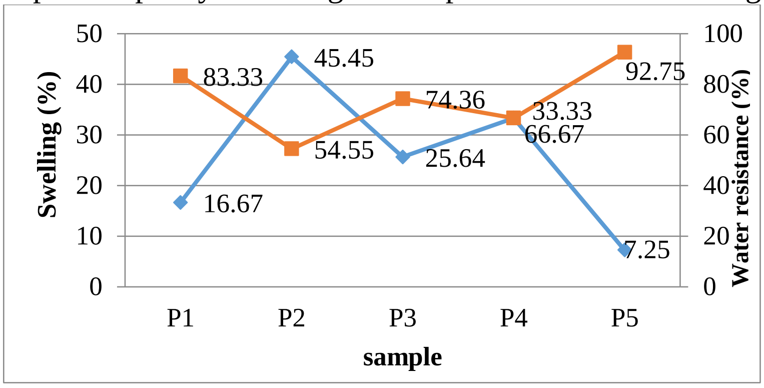


Figure 4. Graph of the Water Absorption Value of Biodegradable Plastic

Figure 3 shows that the results for samples P1 without the addition of chitosan have a water absorption value of 16.67% and a water resistance of 83.33%. P2 without the addition of sorbitol has a water absorption value of 45.45% and a water resistance of 54.55%, sample P3 has a water absorption value of 25.64, a water resistance of 74.36%. In sample P4 there was an increase in the value of water absorption and resistance to water where the value of water absorption was 33.33%, water resistance was 66.67%. However, in the P5 sample, the absorption rate decreased again, less than the P3 and P4 samples, where the P5 sample had a water absorption value of 7.25% and a water resistance of 92.75%. Of the 5 samples, the highest water absorption value was found in sample P2, without the plasticizer sorbitol, while the lowest water absorption value was found in sample P4 without the addition of chitosan.

The results showed that the addition of chitosan filler reduced the water absorption capacity of biodegradable plastics. thereby preventing the absorption of water into the biodegradable plastic. In general, starch is hydrophilic, but the addition of chitosan is expected to reduce the hydrophilic (water-loving) nature of starch, due to the hydrophobic nature of chitosan and it is insoluble in water. The greater the concentration of chitosan, the greater the % water resistance (Panjaitan et al. 2019). This is in accordance with research by Udjiana et al., (2019). The greater the addition of the plasticizer concentration, the better the resistance of the resulting biodegradable plastic or in other words, the lower the water absorption value (Unsa and Paramastri 2018).

The results of the water resistance test for biodegradable plastic that have been carried out can then be compared for suitability with the SNI 7188.7:2016 biodegradable plastic water resistance standard. Based on the Indonesian National Standard (SNI), the water resistance value for biodegradable plastic is 99%. The water resistance value of biodegradable plastic in this study (54.55–92.75%) still did not reach the SNI 7188.7:2016 standard.

**Analysis of results of biodegradable Plastic**

Degradation Testing The results of the tests that have been carried out, the results obtained for Sample P1 without the addition of chitosan have a degradation value of 100% in 10 days. Sample P2 without the addition of sorbitol had a degradation value of 100% within 9 days, sample P3 had a degradation value of 80% within 15 days, and sample P4 had a degradation value of 100% within 12 days. Sample P5 had a degradation value of 75.33% in 15 days. Of the 5 samples, the highest degradation value was found in sample P1 with a starch:chitosan composition of 5:5 without the addition of sorbitol, while the lowest degradation value was found in sample P5 with a ratio of starch composition :chitosan:sorbitol of 8:2:3. From the results of the degradation tests that have been carried out, it can then be compared for its suitability with the SNI 7188.7: 2016 standard for 100%

degradation in 60 days. From the degradation tests that have been carried out, the biodegradable plastics in this study met the SNI 7188.7:2016 standard. The graph of the relationship between the total degradation time of biodegradable plastic and the percent weight loss (mass) of biodegradable plastic can be seen in Figure 5.

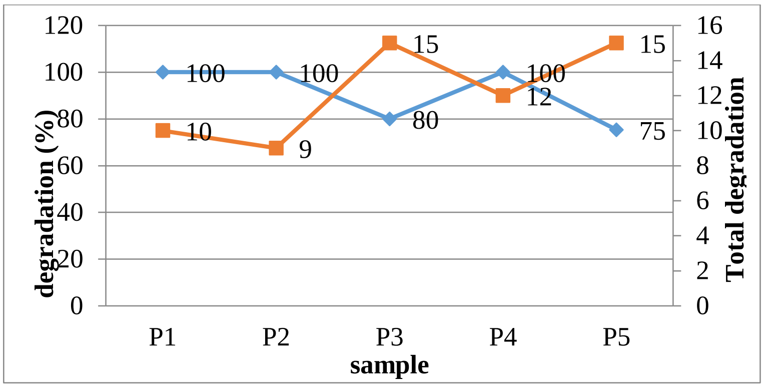


Figure 5. Graph of Total Biodegradable Plastic Degradation Time

Based on the graph above, it can be seen that the biodegradable plastic made from temu ireng rhizomes starch-chitosan with the addition of the plasticizer sorbitol in this study degraded completely within 12-20 days, without the addition of chitosan it was completely degraded within 10 days, and without the addition of sorbitol it degraded within 10 days. 9 days. This is because the composition used is based on starch which is a natural polymer so it is easily degraded in nature. In addition, other additives used such as plasticizers are also natural polymers that contain hydroxyl groups, so they are hydrophilic (water-loving) which causes biodegradable plastics to decompose easily. In this case, water is a place for microbial growth, so that if the water content is high, it will make it easier for biodegradable plastic to decompose (Octavianda, Asri, and Lisdiana 2016).

**Analysis FTIR Biodegradable Plastics**

FTIR testing was carried out to analyze the functional groups contained in this starch-based biodegradable plastic. From the tests that have been carried out, the functional group analysis results are not too different or almost the same, the only difference being the wave number value of each peak. The functional group test results can be seen in Figure 6.

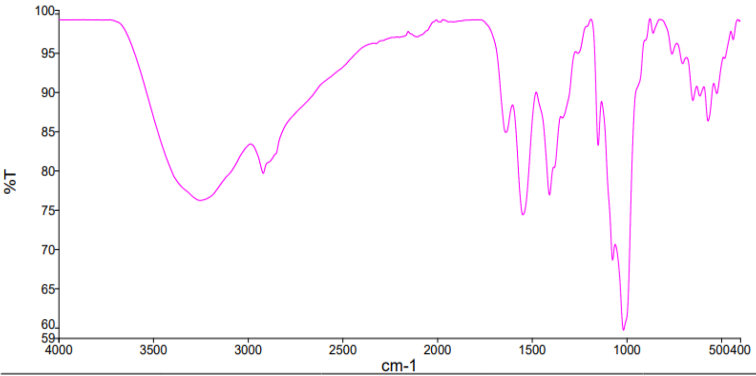


Figure 6. Functional Group Test Results for Biodegradable plastics

Biodegradable plastic film material from black turmeric and chitosan with the addition of plasticizer sorbitol and acetic acid as a catalyst, has a functional group which is a combination of specific functional groups whose constituent components include C-H, O-H, N-H, C≡C, C=O, and C=C, and there are also amide and ester functional groups in biodegradable plastic film samples. It can be seen that the resulting biodegradable plastic material is a physical blending process because no new functional groups have been found, and this is what causes the biodegradable plastic material to still have hydrophilic (water-loving) properties like its constituent properties. There are also carbonyl (CO) and ester functional groups in biodegradable plastic materials tested with FTIR, so that these biodegradable plastic materials can be degraded (Zaroh and Widyastuti 2019).

## CONCLUSION

Biodegradable plastic based on temu ireng rhizomes starch has different mechanical characteristics. The biodegradable plastic sample P2 has the highest tensile strength value of 4.03 Mpa (without sorbitol). The highest elongation value is in the P5 sample of 99.68%. sample P2 has the best water absorption value p5, of 7.25%. Biodegradable plastic based on temu ireng rhizomes -chitosan with the addition of sorbitol can decompose completely within 9-20 minutes.

## RECOMMENDATION

Based on the results of research on biodegradable plastics made from temu ireng rhizomes starch-chitosan with the addition of sorbitol, there are several suggestions that need to be made, namely to look for alternative additives that can improve mechanical and physical properties and not cause a sour odor. Further research is needed to use starch and chitosan with smaller or nano particle sizes.

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