REKAYASA 20 (1) (2022): 01-09

REKAYASA

Jurnal Penerapan Teknologi dan Pembelajaran

http://journal.unnes.ac.id/nju/index.php/rekayasa

Manufacture Bioplastic Composite made of Corn Starter and Poly Vinyl Alcohol (PVA) with the Addition of Beeswax

Adhitya Prian Ramadhan, Sari Purnavita*, Lucia Hermawati Rahayu

Chemical Engineering Department, Mangunwijaya Catholic Polytechnic 50241 Semarang, Indonesia

Email: saripurnavita.2018@gmail.com

DOI: http://dx.doi.org/10.15294/rekayasa.v20i1.37275
Submit: 22 June 2022; Revisi: 11 July 2023; Accepted: 2 August 2023

Abstract

Bioplastics are environmentally friendly plastics that naturally can be easily degraded. One of the natural ingredients that can be used is corn starch. This study aims to study the effect of heating temperature and the addition of beeswax on the characteristics of bioplastics. This study used two independent variables. This study used the heating temperature of the material at 60-80 °C and the addition of beeswax up to 2% of the total weight. The amount of poly vinyl alcohol and corn starch was dissolved in water and further to the plasticizer in glycerol with heating time. The characteristics to be obtained are the properties of bioplastics that have been synthesized against water resistance, tensile strength, and elongation tests. The lowest heating temperature of 60 °C had a minor water absorption of 42.85%. At a heating temperature of 65 °C, it gives the highest tensile strength and elongation, respectively, 5.15 Mpa and 29.39%. The addition of beeswax affects water resistance, tensile strength, elongation, and biodegradation values. Water resistance will be higher with the addition of beeswax. In addition to 2 g of beeswax, bioplastics have the highest tensile strength value, and elongation was obtained, respectively, 9.55 Mpa and 31.54%.

Keywords: corn starch, Polyvinyl Alcohol, beeswax, bioplastics, water resistance

INTRODUCTION

Human life in the modern era is not easily separated from plastic synthetic. Synthetic plastic is a trendy packaging material because it is flexible, lightweight, and not easily broken (torn). It is a wrapper or packaging for various kinds of food and objects. Synthetic plastic has the disadvantage that it cannot be destroyed automatically naturally (non-biodegradable). Used plastic waste will be difficult to beat, though has been stockpiled for a long time, resulting in the accumulation of plastic waste that can cause pollution and environmental damage.

The plastic problem in Indonesia is already troubling. Apart from China, Indonesia is the largest plastic waste dumping country in the ocean. Plastic waste carelessly discarded clogs drains and even builds up on the river, causing flooding. Synthetic polymers, raw materials for synthetic plastics, will be degraded within tens or even hundreds of years. If burned, plastic will produce carbon emissions that pollute the environment (Kamsiati et al., 2017).

Researchers continue to strive to produce environmentally friendly plastic called bioplastic or biodegradable plastic. Bioplastics are Eco-friendly plastic because it is readily decomposed by microorganisms compared to other plastics conventional plastic. Bioplastics have the same uses as synthetic or conventional plastics. Bioplastics are made from natural polymeric materials such as starch. Starch is obtained with how to extract vegetable ingredients that contain carbohydrates. Sources of carbohydrates that contain much starch include cassava, sago, sweet potato, taro, and corn. The types of starch that are widely used are potato starch and corn starch.

Starch is the result of agricultural commodities available in abundance in Indonesia. Indonesia is an agricultural country, which means Most of Indonesia's population has a livelihood as farmers or farming plants. Agriculture is one of the sectors that support Indonesia's economy and create food security for the people. Indonesia is the leading producer of various tropical agricultural products, such as corn. Corn contains 75-85% starch (Suarni, 2013). Lower starch concentration leading to decreased elongation at break was found in this phenomenon (Jumaidin et al., 2022). Making bioplastics from corn starch with the addition of corn flour shows that the addition of corn flour increases water resistance, tensile strength, and elongation (Sutanti et al., 2022). According to Sari (2019), bioplastics made of one component have brittle properties, so other polymer materials are needed to support the plastic properties. The polymer material that can be used is polyvinyl alcohol. Polyvinyl alcohol has high tensile strength, flexibility, and an oxygen barrier (Purnavita, 2018).

Beeswax is a lipid component that can reduce a packaging film's permeability (Purnavita, 2019). Beeswax is a natural compound that is hydrophobic and biodegradable, which is produced in beehives. The content of beeswax compounds is lipids, with the main components being hydrocarbons, esters, and free acids, which interact with each other between the hydrogen bonds between the ester carbonyl groups and the OH groups in starch. Material selection (beeswax) is based on the ease of degradation; the price is relatively low and easy to obtain. This research focuses on the manufacture of bioplastics from corn starch and Poly Vinyl Alcohol to get optimum conditions, namely the heating temperature of the material and the addition of beeswax to the characteristics of bioplastics. Characteristics of bioplastics in this study: Analysis was carried out, including water resistance, tensile strength, elongation, and biodegradation test.

METHOD

Material and Method

The material used in this study was cornna with the brand "maizenaku." other ingredients are Poly Vinyl Alcohol and glycerol from the chemical laboratory organic chemical engineering. the tools used in this research are an alcohol thermometer, beaker glass, hotplate, stopwatch, and magnetic stirrer.

This study uses two independent variables, namely the first independent variable is the heating temperature of the material (65°C, 70°C, 75°C, 80°C, and 85°C), as shown in Table 1. Independent variables The second is the addition of beeswax (0%; 0.5%; 1%; 1.5%; 2.0%) of the total weight.with the fixed variable is 2 g of glycerol, the amount of Polyvinyl alcohol and corn starch is 5 g each of which was dissolved in 50 mL and the heating time was 15 min. The dependent variables in this study were water resistance, tensile strength, elongation, and biodegradation tests.

Procedure for making bioplastics

Maizena weighed 5 g and dissolved with water as much as 50 mL. In other places, Poly Vinyl Alcohol is 5 g, and glycerol is 2 g dissolved in 50 mL of water. The two solutions are mixed, and then beeswax is added according to the research design. The mixture is heated at the temperature according to the research design. The solution is poured into the oven at 60 °C for a day.

Water resistance test (hydrophobicity)

The sample (bioplastic) was cut to a size of 2x2 cm. The initial weight of the sample to be tested is weighed (W0), and the petri dish is weighed with distilled water. This plastic sample is inserted and immersed in the container. After 10 seconds, the sample was removed from the container, and then the sample weight was weighed. The piece was then immersed back into the container containing distilled water. After 10 seconds, the sample was removed, and the sample was weighed. The same treatment was carried out until a constant final sample weight (W) was obtained, and the percentage of water absorbed by the plastic film could be determined using Equation 1 (Sutanti & Dewi, 2018).

$$\text{Absorbed water \%} = \frac{W - W0}{W0} \times 100\% \qquad [1]$$

Tensile strength test

Tensile strength is the maximum tensile force a film can withstand before the film breaks or tears. This test is carried out by preparing bioplastics with a size of 20x1 cm and installing the tools for the tensile test. A tool used to test the tensile strength of this bioplastic is Texture Analyzer Lloyd Instruments.

Elongation test

Elongation is the maximum length change when stretching untilthe film breaks. This test is carried out by preparing bioplastics with a size of 20x1 cm and installing the tools for the tensile test. The Lloyd- texture Analyzer instrument is used for this bioplastic elongation test.

Table 1. Research Design with Different Heating Temperature

Temperature (°C)	Fixed Variable	Dependent Variable
60 65 70 75 80	Weight of starch of 5 g Time of 15 min. Poly vinyl alcohol weight of 5 g Weight of glycerol of 2 g	water resistance tensile strength elongation

Table 2. Research Design with Various Variables Addition of Beeswax

Addition of Beeswax (g)	Fixed Variable	Dependent Variable
0 0.5 1.0 1.5 2.0	weight of starch of 5 g time of 15 min. Poly vinyl alcohol weight of 5 g weight of glycerol of 2 g the heating temperature of 65 °C	water resistance tensile strength elongation

Data Analysis

Analysis of the data obtained from this study was carried out descriptively. Data collection was carried out twice. An investigation is done to get the best results.

RESULT AND DISCUSSION

Effect of Heating Temperature on Bioplastic Characteristics

Bioplastic water resistance test

The percentage of water resistance is obtained from much or less air absorbed by the bioplastic. The water resistance test is carried out by weighing the initial weight of the bioplastic (Wo). Bioplastic soaked in distilled water for 10 seconds using a stopwatch to obtain a constant result, dried and considered again as W. The amount of air absorbed using the formula:

The water resistance properties of bioplastic films are determined by how much the bioplastic film absorbs water. The lower the water absorption value, the better the properties of the bioplastic film, while on the contrary, the higher the value of absorption of water, and quickly it is destroyed.

The heating temperature for making bioplastics' effect on water resistance is shown in Figure 1. The smaller the water absorption capacity, the better the quality of the bioplastic. A minor heating temperature of 60 °C has the most water absorption, 42.85%. The heating temperature of 80 °C has the most water absorption, equal to 64.71%. The lower the heating temperature, the less percentage of water absorbed by the bioplastic film. Excellent water absorption indicates that the bioplastic films are of low quality. Bioplastic film with the rate of water absorbed is higher, which is not durable and easily destroyed. Temperature affects water resistance (Pongmassangka *et al.,* 2020).

This study's results follow the results that starch and glycerol have hydroxyl groups that are easy to absorb water (Triani et al., 2019). The high temperature will increase the hydrophilic properties. The higher the heating temperature, the higher the hydrophilic bioplastics produced, so bioplastics with the highest heating temperature will absorb water with the highest percentage (has low water resistance). Production of starch gel film from several types of starch, including aloe vera thermoplastic, can produce high tensile strength and better water solubility (Abd Karim et al., 2022). Bioplastics can quickly improve mechanical properties, such as mixing water barrier properties with other polymers and nanofillers (Gadhave et al., 2018).

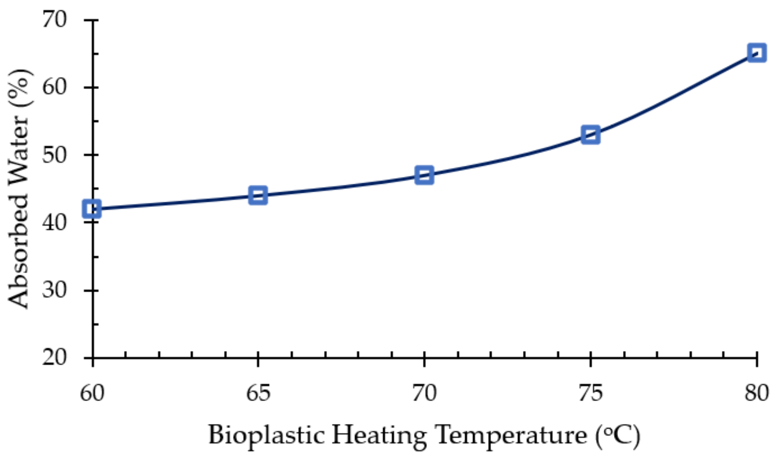

Figure 1. The effect of heating temperature on the amount of water absorbed by Bioplastic

Bioplastic tensile strength test

The tensile strength test determines bioplastics' tensile strength, resulting in tensile strength being the maximum tensile force a film can resist before the film breaks or tears. In the graph, the effect of bioplastics at various heating temperatures on tensile strength is shown in Figure 2. The greatest tensile strength was obtained at a heating temperature of 65 °C, equal to 5.15 Mpa. The lowest tensile strength is obtained at the highest temperature of 800 °C, equal to 0.38 Mpa. An important factor affecting the tensile strength of a bioplastic is the affinity between its constituent components (Putra, 2019). Affinity is a phenomenon in which specific molecules stick together and bond. The higher the affinity, the stronger the intermolecular bonds will be. Corn starch will be gelatinized at 62-70 °C (Aini & Purwiyanto, 2010). Polyvinyl alcohol can dissolve in water at a temperature of 65-70 ° C, so at that temperature, it has a vital tensile strength compared to the highest temperature because, at 65 °C, the constituent molecules of bioplastic material bind well. The interaction between starch and PVA reduces the free OH groups in the resulting bioplastic, resulting in a decrease in the characteristics of the material related to water absorption, namely degradation of the tensile properties (Judawisastra et al., 2017).

Bioplastic elongation test

The elongation test was carried out to determine the per cent elongation of bioplastic. The effect of the heating temperature of bioplastic on elongation material can shown in Figure 3. The highest elongation percentage is obtained at the heating temperature of bioplastics at 65 °C, which is 29.39%. According to Utomo (2013), the elongation percentage is the deformation effect. So that it gets bigger and stronger tensile, the elongation percentage will be even more significant. The percentage elongation was obtained at 65 °C as well. The manufacture of bioplastics produces complex three-dimensional PVA products through methods that can improve the mechanical properties of other biodegradable plastics (Zhou et al., 2021).

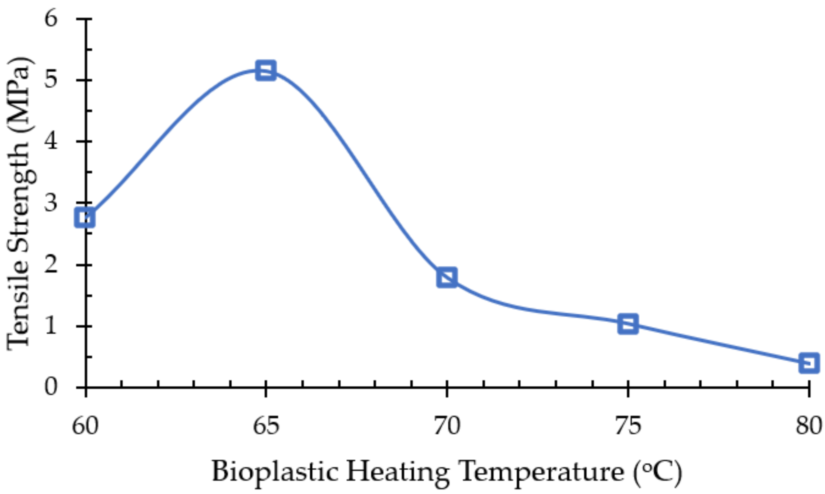

Figure 2. Tensile strength test results of bioplastics at various heating temperatures

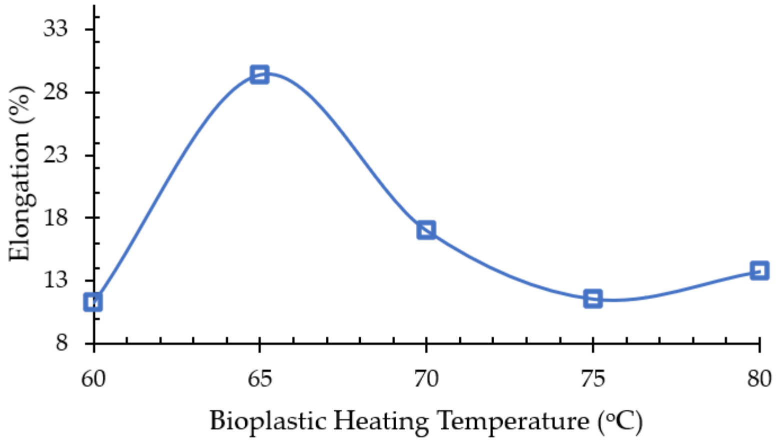

Figure 3. Elongation test results on variations in heating temperature

Effect of Addition of Beeswax on Bioplastic Characteristics

Bioplastic Water Resistance Test

The trend of content beeswax can affect the absorbed water is shown in Figure 4. The absorbed water by the bioplastic was as much as 90% when there was no beeswax in the material content. On the contrary, adding 2 g of beeswax to get minor water absorption is 47.06%. The more beeswax added the more water-resistant bioplastics are getting bigger. Beeswax is a lipid component that can reduce a packaging film's permeability (Nabila, 2019). Beeswax has hydrophobic properties that are more difficult to mix or dissolve in water. The hydrophobic properties of beeswax enhance the water barrier of bio-composites (Diyana et al., 2021). If beeswax is directed at the coating process, then beeswax can improve the material's water resistance properties (Hendrawati et al., 2021). Coating with beeswax is a suitable technique to reduce hygroscopic water vapour permeability (Reis et al., 2018)

Bioplastic tensile strength test

Figure 5 shows that the highest tensile strength was obtained at the addition of 2 g of beeswax, which was 9.55 MPa. Variations in the amount of beeswax used in the study, starting with the addition of 0.5 g of beeswax, showed that the greater the concentration of beeswax, the more beeswax bound by Poly Vinyl Alcohol as emulsifier to form more robust and more difficult molecular bonds to break. In plastics with a dense structure, with these characteristics, the tensile strength is excellent, and the elongation percentage is also more significant.

Beeswax serves to reduce the permeability of a packaging film. Beeswax is hydrophobic, which tends to be more challenging to mix or dissolve in water. The increase in the tensile strength value is also caused by the low water content in the bioplastic film sample. Hence, the molecular structure of the bioplastic film becomes tight.

Bioplastic elongation test

It can be seen in Figure 6 that the highest percentage of elongation was obtained in the variation of the addition of the most beeswax as much as 2 g, namely 31.54%. The rate of elongation is the effect of deformation. So, the greater the tensile strength, the greater the elongation percentage (Utomo et al., 2013). The tensile strength and per cent elongation values were higher or comparable to other bioplastic samples when the addition of beeswax reduced swelling (Rusdi et al., 2022

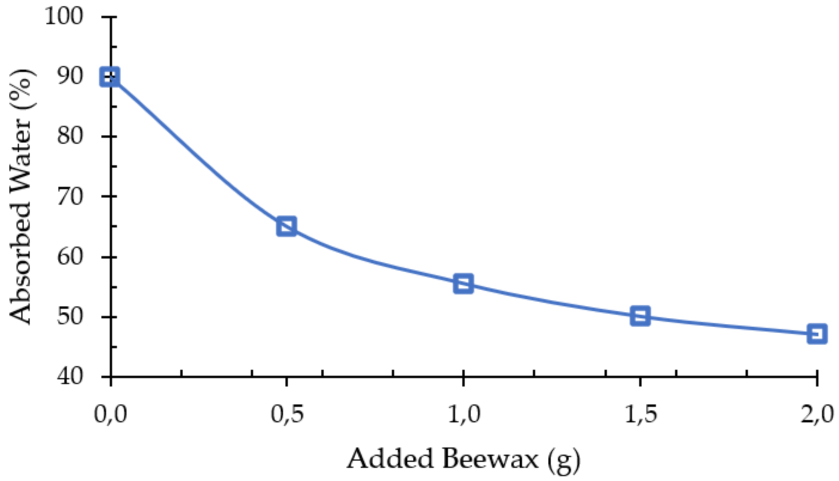

Figure 4. The effect of adding beeswax on the amount of water absorbed by bioplastic

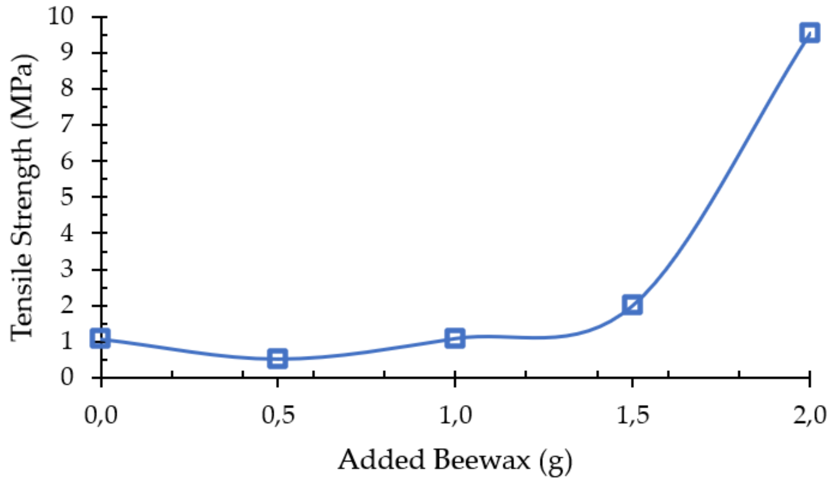

Figure 5. The results of the tensile strength of bioplastics on variations in the addition of beeswax

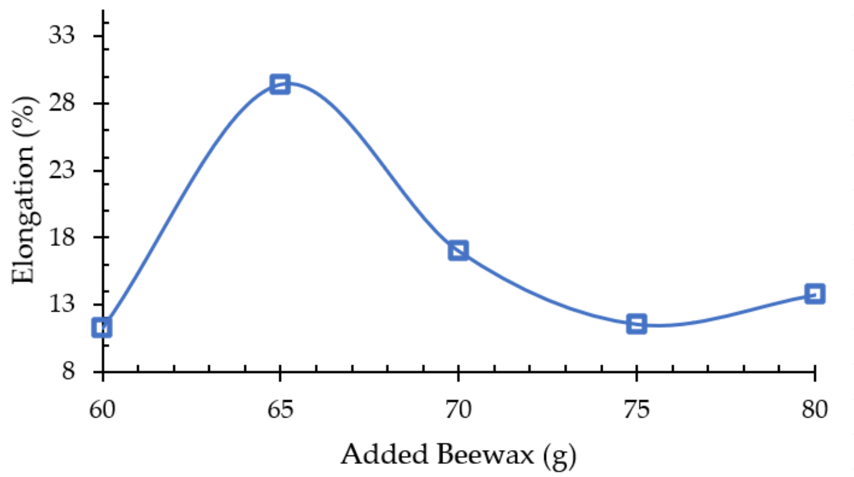

Figure 6. Bioplastic elongation test results on variations in the addition of beeswax

CONCLUSION

The heating temperature of bioplastics affects air resistance, tensile strength, elongation, and biodegradation values. At a temperature of 65°C, a process to make the bioplastic suitable for the capability material of the highest tensile and elongation strength, respectively 5.15 Mpa and 29.39%. The addition of beeswax affects the air resistance, tensile strength value, elongation, and biodegradation. Adding 2 g of beeswax makes characteristic bioplastics have the highest tensile strength and elongation, respectively, 9.55 Ma and 31.54%.

REFERENCES

Aini, N., & Purwiyatno, H. (2010). Gelatinization properties of white maize starch from three varieties of corn subject to oxidized and acetylated-oxidized modification. *International Food Research Journal*, *17*(4).

Diyana, Z. N., Jumaidin, R., Selamat, M. Z., & Suan, M. S. M. (2021). Thermoplastic starch/beeswax blend: Characterization on thermal mechanical and moisture absorption properties. *International journal of biological macromolecules*, *190*, 224-232.

Gadhave, R. V., Das, A., Mahanwar, P. A., & Gadekar, P. T. (2018). Starch based bio-plastics: The future of sustainable packaging.

Hendrawati, N., Wibowo, A. A., Chrisnandari, R. D., & Adawiyah, R. (2021, February). Biodegradable foam tray based on sago starch with beeswax as coating agent. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1073, No. 1, p. 012006). IOP Publishing.

Judawisastra, H., Sitohang, R. D. R., & Marta, L. (2017, July). Water absorption and its effect on the tensile properties of tapioca starch/polyvinyl alcohol bioplastics. In *IOP conference series: materials science and engineering* (Vol. 223, No. 1, p. 012066). IOP Publishing.

Jumaidin, R., Abdul Rahman, A. H., Sapuan, S. M., & Rushdan, A. I. (2022). Effect of sugarcane bagasse on thermal and mechanical properties of thermoplastic cassava starch/beeswax composites. *Physical Sciences Reviews*, (0).

Kamsiati, E., Herawati, H., & Purwani, E. Y. (2017). Potential development of biodegradable plastics based on sago starch and cassava in indonesia. *Journal of Agricultural Research and Development*, *36*(2), 67-76.

Nabila, P. Kusdarwati, R. Agustono. 2018. The Effect of Adding Beeswax as a Plasticizer to the Physical Characteristics of Chitosan Edible Film. Surabaya. Journal of Fisheries and Marine Instructors, Vol. 10, No. 01.

Pongmassangka, L.N., Bambang, A.H., dan Sri M. 2020. Optimization of Temperature and Drying Time on Making Bioplastic Composite of Maizena and Glucomannan Mixture. Journal of Agroindustrial Engineering and Management. 8(3):329-337.

Purnavita, S. & Anggraeni, A. 2019. Effect of Addition of Beeswax and Glycerol on Characteristics of Glucomannan Polyblends – Polyvinyl Alcohol (PVA). Chemical Engineering Innovation. 4(2):33-39

Purnavita, S., Utami, W.T. 2018. Production of biodegradable plastic from palm starch with the addition of aloe vera. Chemical Engineering Innovation. 3(2):31-35.

Reis, M. O., Olivato, J. B., Bilck, A. P., Zanela, J., Grossmann, M. V. E., & Yamashita, F. (2018). Biodegradable trays of thermoplastic starch/poly (lactic acid) coated with beeswax. *Industrial Crops and Products*, *112*, 481-487.

Rusdi, S., Nurrahman, I., Rizki, W. N., & Chafidz, A. (2022). The Effect of Beeswax and Glycerol Addition on the Performance of Bioplastic Film Made of Konjac Glucomannan. *Jurnal Bahan Alam Terbarukan*, *11*(2), 100-107.

Sari, N., Mairisya, M., Kurniasari, R, and Purnavita, S. 2019. Galactomannan-Based Bioplastics Extracted from Coconut Dregs with Polyvinyl Alcohol Mixture. Methane Journal. 15(2):71-78.

Suarni, I.U. Firmansyah, and M. Aqil. 2013. The Diversity of Starch Quality of Several Varieties of Corn. Research on food crop agriculture vol. 32 No.1.

Sutanti, S & Dewi, C.D. 2018. Characterization of Bioplastics Made from Kolang-Kaling with Monoglycerides from Coconut Oil. Chemical Engineering Innovation, Vol. 3, No. 2, October 2018, p. 48-53.

Sutanti, S., Mumpuni, A.P., Lucia, H.R., dan Handika, G.R. 2022. Characterization of Bioplastic Made from A Combination of Corn Starch and Corn Flour with Poly Viny; Alcohol (PVA) Adhesive and Glycerol Plasticizer. Joural of Chemical Engineering Scientific. 6(2):89-96.

Triani, T. A., Alamsjah, M. A., & Pujiastuti, D. Y. (2022). Application of Modified Starch on Carrageenan-Based Bioplastic's Cup From Eucheuma cottonii on Biodegradability and Water Resistance. Journal of Marine & Coastal Science, 11(3).

Utomo, AW. Argo, BD. Hermanto, MB. 2013. Effect of Temperature and Drying Time on Physicochemical Characteristics of Biodegradable Plastics from Aloe Vera (Aloe Vera)-Chitosan Starch Composite. Journal of Tropical Commodity Bioprocesses Vol.1,No.1.

Zhou, P., Luo, Y., Lv, Z., Sun, X., Tian, Y., & Zhang, X. (2021). Melt-processed poly (vinyl alcohol)/corn starch/nanocellulose composites with improved mechanical properties. International Journal of Biological Macromolecules, 183, 1903-1910.