International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 30 No. 2 January 2022, pp.209-217

The Effect of Additional Gum Arabic on the Manufacturing of Biodegradable Plastic from Bacterial Cellulose Propylene Glycol

Serliy Faudah[1], Ananda Putra[1*]

Department of Chemistry, Universitas Negeri Padang

Jl. Prof. Hamka, Air Tawar, Padang, Indonesia

Abstract – Biodegradable plastic is plastic that can be decomposed naturally by the activity of microorganisms. This study aims to determine the effect of adding gum arabic to biodegradable plastics from bacterial cellulose propylene glycol on physical properties, mechanical properties, biodegradation, fungtional groups and crystallinity. The bacterial cellulose propylene glycol is made from coconut water by adding glucose, urea, acetic acid and propylene glycol which is the inoculated by *A.xylinum*. The use of gum arabic variations used were 0%, 1%, 3%, 5%, and 7%. Based on the results of the study, it was found that the value of water content and swelling increased with the addition of gum arabic concentration. The optimum value of tensile strength and elasticity were obtained with the addition of 3% gum arabic of 29.89 MPa and 872.73 MPa. The FTIR spectrum with the addition of gum arabic and without the addition of gum arabic showed the presence of O-H bonds at wave numbers 3600-3200 cm^{-1}, C-H bonds at wave numbers 3000-2850 cm^{-1}, C-O bonds at wave numbers 1300-900 cm^{-1} and C=C bonds at wave number 1680-1600 cm^{-1}. The degree of crystallinity increased with the addition of gum arabic to 98.8%. The ability of plastic biodegradation increases with increasing concentration of gum arabic.

Keywords – Gum Arabic, Bacterial Cellulose, Biodegradable Plastic, Propylene Glycol.

I. Introduction

Plastic is a polymer material that is widely used in everyday life. Most products use plastic as a base and packaging material. The advantages of plastic are strong, lightweight, waterproof, and affordable. The plastics used today are synthetic plastics made from petroleum and cannot be decomposed naturally by microorganisms in the environment [1]. The amount of synthetic plastic that we use results in the accumulation of waste and is a cause of pollution and environmental damage. This cause the use of plastic packaging cannot be sustained widespread use because it will increase environmental and health problems in the future [2]. Therefore, other alternatives is needed in the manufacture of plastics, namely plastics that is more environmentally friendly and the raw material is easy to obtain, namely biodegradable plastic.

Biodegradable plastic is a type of plastic that can be degraded naturally by microorganisms found in the environment [3]. Usually conventional plastics are made from petroleum, natural gas, or coal. While biodegradable plastic are made of renewable material, namely from compounds contained in plants such as cellulose, starch, collagen, casein, proteins or lipids found in animals [4].

Cellulose was very abundant, inexpensive and widely available in carbohydrate polymers, which can be extracted traditionally from plants. In addition to being in plants, cellulose can also be produced by low-level animals namely bacteria [3]. Cellulose produced by bacteria was called bacterial cellulose (BC), the bacterium used was *Acetobacter xylinum* (*A.xylinum*). BC was made from coconut water, sugar, urea, acetic acid and propylene glycol which was inoculated with the bacterium *Acetobacter xylinum* [5].

In Krisnadi [6] research on biodegradable plastic with propylene glycol as a plasticizer and the tensile strength was 6.33 MPa. It can be seen that the biodegradable plastic produced is still unable to reach the standard of plastic that we usually use today, which are SNI plastic tensile strength ranges between 24.7-302 MPa. Therefore, the authors are interested to continue the research with addition of additives namely gum arabic. Expected with the addition of gum arabic will increase the tensile strength of the plastic produced. Gum arabic is able to bind particles in the empity space contained in the pores of the plastic so that when testing the tensile strength, the plastic provides a large force [7].

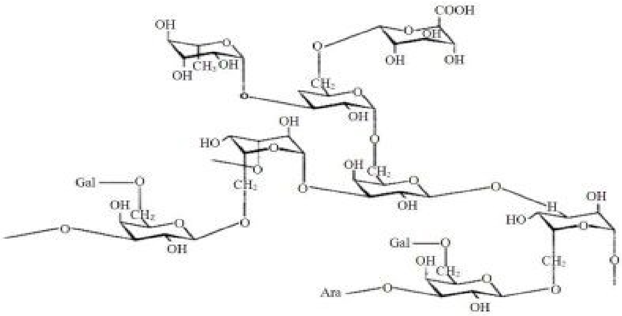

Figure 1. Gum Arabic Chemical Structure

II. Material And Methods

2.1. Tools

The equipment in this study were glassware, plastic container measuring 24x17x4 cm, cooking pot, stove, rag, newspaper, tissue roll, filter, rubber, stirrer, knife, scissors, pH paper, analytical balance, iron, evaporating dish, ovens, Tenssion Testing (Universal Tensile Strength), FTIR, and XRD.

2.2. Material

This study used ingredients including aged coconut water waste, aquades, A. Xylinum inoculum, granulated sugar ($C_{12}H_{22}O_{11}$), food vinegar acid (CH_3COOH), urea fertilizer ($CO(NH_2)_2$), technical NaOH from bratachem, gum arabic, and propylene glycol (PG).

2.3. Production of PG Bacterial Cellulose (BCPG)

The process of making PG bacterial cellulose using the method carried out by Agustin. Put old coconut water in a saucepan and heat it until it almost boils, then add 100 g of sugar, 10 g of urea, 5 mL of PG, and 20 mL of acetic acid, then heat until it boils. After boiling, put the sample in a plastic container and let it sit until it reaches room temperature. After reaching room temperature, it was inoculated with A. xylinum starter, then fermented for 2 weeks until it reached a thickness of at least 0.5 cm.

2.4. PG Bacterial Cellulose Purification

Bacterial cellulose that has reached its thickness should then be purified using 2% NaOH by soaking bacterial cellulose in 2% NaOH for 24 hours.

2.5. Synthesis of Bacterial Cellulose Propylene glycol-gum Arabic (BCPG-GA)

The process of making biodegradable plastic uses the method carried out by Andriani by soaking bacterial cellulose using gum arabic according to predetermined variations based on Gunawan, namely 0%, 1%, 3%, 5%, and 7% w/v. Then press the bacterial cellulose sheet using an iron between non-woven fabrics for 15 minutes which aims to reduce the water content in the plastic and prevent the plastic from breaking and shrinking.

2.6. Characterization of Biodegradable Plastics

2.6.1 Water Content Test (%WC)

The water content was measured by weighing BCPG-GA as the initial weight, then oven at 105^0C until the weight was constant. The percentage of water content calculated by the following equation.

$$\%\,\mathrm{WC} = \frac{\mathrm{W1} - \mathrm{W2}}{\mathrm{W1}} \,\mathrm{x}\, 100\%$$

Information:

W1 = Initial weight

W2 = Dry weight

2.6.2 Swelling Test

Swelling test is used to determine the ability of plastic to the bulging back. The results of the dry sample on the water content test were continued by soaking the plastic in 20 mL of water for 5 days, and then weighed until it was weighed constant.

$$\%\,\mathrm{Swelling} = \frac{W2 - W1}{W1} x\ 100\%$$

Information:

W1 = Initial weight

W2 = Constant weight

2.6.3 Tensile Strength Test

Tensile strength is the ability of a material to withstand a pull o dropping out. The tensile strength test using a tensile strength tools namely.

$$\mathrm{Tensile\ Strength\ (MPa)} = \frac{\mathrm{F}}{\mathrm{Ao}}$$

Information:

F = Load given (N)

Ao = Sample cross-sectional area (m^2)

2.6.4 Elongation Test

Elongation test is carried out with the same steps as the tensile strength test.

$$\%\,\mathrm{Elongation} = \frac{\mathrm{strain\ at\ break\ (mm)}}{\mathrm{initial\ length\ (mm)}} \times 100\%$$

2.6.5 Elasticity Test

The elasticity test can be seen from the tensile strength test and elongation.

$$\text{Elasticity (MPa)} = \frac{\sigma}{\varepsilon}$$

Information:

ε = Tensile strength

σ = Percent elongation

2.6.6 Biodegradation Test

Biodegradation test is a test carried out to find out how much the ability of biodegradable plastic to decompose by microbes in the soil. BCPG-GA plastic sheet is buried in the soil to a depth of 15cm. The burial process was carried out for 18 days. Before being buried, the mass of the plastic is weighed, then buried in the ground for 18 days with weighing intervals every 3 days. The percent mass loss of biodegradable plastic is determined using the equation:

$$\% \text{ Weight (W)} = \frac{W1-W2}{W1} \times 100\%$$

2.6.7 FTIR (Fourier Transform Infra Red Spectrophotometry)

Characterization of the structure of biodegradable plastics using the FTIR instrument aims to determine the functional groups and types of bonds contained in biodegradable plastics. Biodegradable plastic samples were characterized at a wave number of 4000 - 600 cm^{-1}.

2.6.8 XRD (X-Ray Diffraction)

The sample pieces are placed on top of the sample holder and inserted into the XRD tool. The monitor will produce a fractogram that can be used to determine the degree of crystallinity of biodegradable plastic samples.

$$\text{Crystalline degree } \% = \frac{a}{\text{wide area } (a+b)} \times 100\%$$

Information:

a = wide crystalline

b = Amorphous

III. Results And Discussion

3.1. Biodegradable Plastic

Bacterial cellulose propylene glucol samples that have been soaked in gum arabic for 4 days are then pressed using an iron between non-woven fabrics at maximum heat for 15 minute. The plastic sheet results are shown in Figure 2:

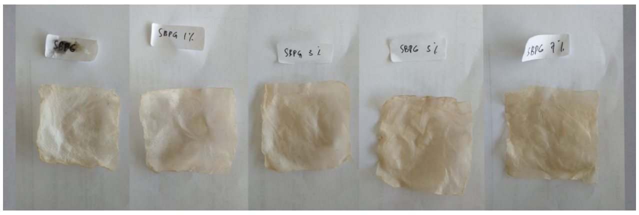

Figure 2. Bacterial Cellulose Propylene Glycol Gum Arabic

3.2. Water Content

Water content test is intended to determine how much water is contained in BCPG with additional of gum arabic. The effect of gum arabic addition to the percentage of water content of BCPG-GA plastic can be seen in Figure 3.

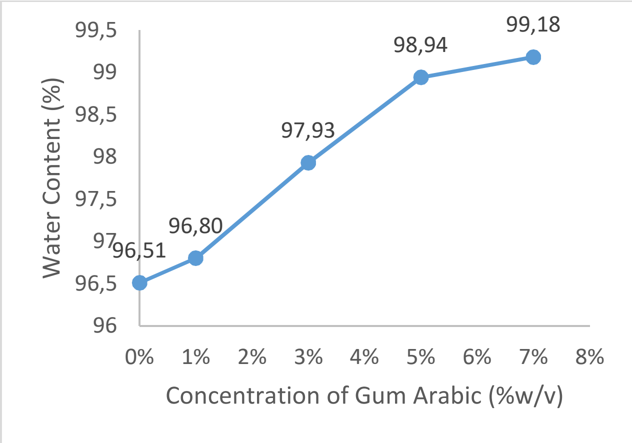

Figure 3. The Effect of Addition of Gum Arabic on the Water Content of BCPG-GA

Based on figure 3, it can be seen that the water content increases with each addition of gum arabic. According to research conducted by Gunawan, gum arabic is hydrophilic and has many hydroxyl groups so that it has the ability to bind water.

3.3. Swelling Test

Swelling test is used to determine the ability of plastic to the bulging back. The effect of the addition of gum arabic on the percentage of swelling degree can be seen in Figure 4.

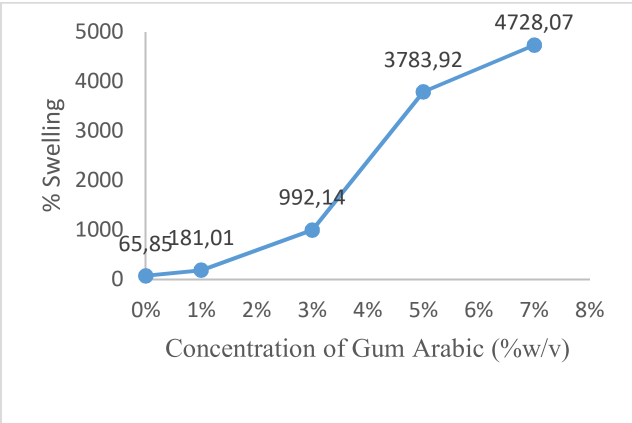

Figure 4. Effect of Addition of Gum Arabic on the swelling degree of BCPG-GA

Based on figure 4, the percentage of swelling degree increased with the addition of gum arabic. The amount of water absorbed by plastic increases with the increasing number of gum arabic added.

3.4. Tensile Strength

Tensile strength is the maximum tensile force that the plastic can withstand during the measurement process [8]. Tensile strength is one of the important analysis in the production of plastic, because the tensile strength can determine the quality of the plastic [7]. The effect of addition gum arabic to the tensile strength of BCPG-GA plastics can be seen in Figure 5.

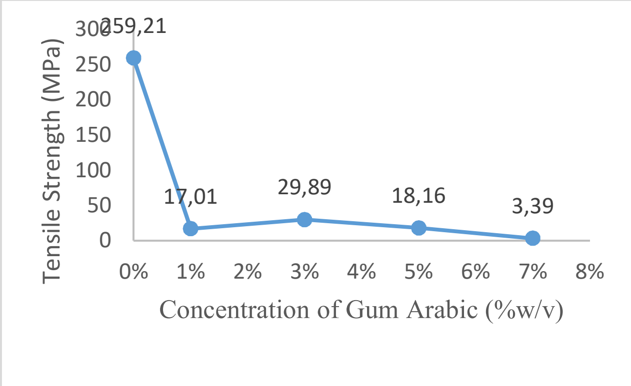

Figure 5. Effect of Addition of Gum Arabic on Tensile Strength of BCPG-GA plastics

Based on figure 5, The maximum tensile strength value among all variation of the addition gum arabic is BCPG-GA 3%, which is 29.89 MPa. According to defira research, the tensile strength value increases with addition of gum arabic concentration.

3.5. Elongation

Elongation is the maximum length value of the material when it is stretched or pulled to the precisely before the material breaks [9]. The effect of addition gum arabic to the elongation of BCPG-GA plastics can be seen in Figure 6.

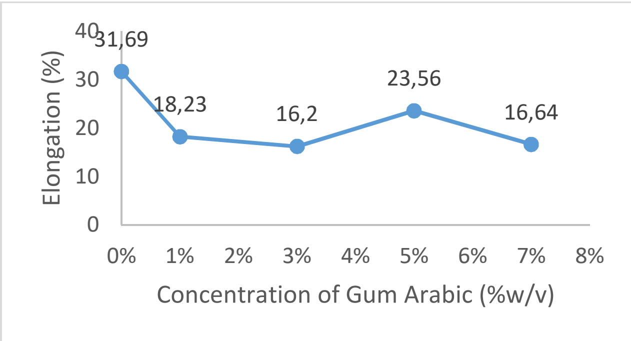

Figure 6. Effect of Addition of Gum Arabic on Elongation of BCPG-GA plastics

Based on figure 6, elongation of BCPG-GA 1% was 18.23% and reached maximum at BCPG-GA 5% that was 23.56%. While on the BCPG-GA 7% decreased to 16.64%. Addition of gum arabic was directly proportional to the percentage of elongation (bestova).

3.6. Elasticity

Elasticity is a measure of the stiffness of a material. Elasticity is the ratio between tensile strength and elongation. The effect of addition gum arabic to the elasticity of BCPG-GA plastics can be seen in Figure 7.

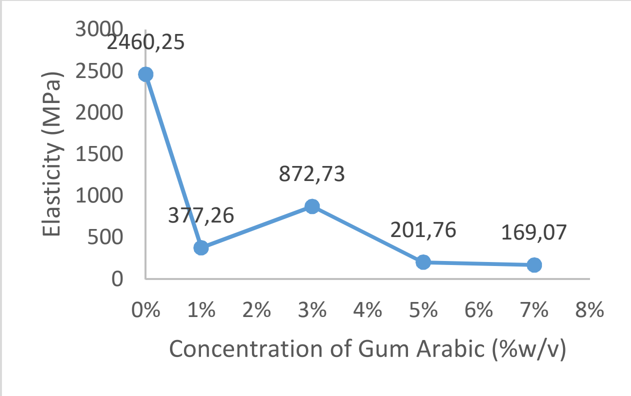

Figure 7. Effect of Addition of Gum Arabic on the Elasticity of BCPG-GA Plastics

Based on figure 7, it can be seen that the elasticity value decreases with the addition of gum arabic concentration. Based on variations in the addition of gum arabic the highest elasticity value is at BCPG-GA 3% plastics.

3.7. Biodegradation of Biodegradable Plastic

Biodegradation test is a test carried out to determine the level of resistance of biodegradable plastics to microbial decomposers, temperature, soil moisture, and physical and chemical factors in the soil. The effect of addition gum arabic to the BCPG-GA plastics can be seen in Figure 8.

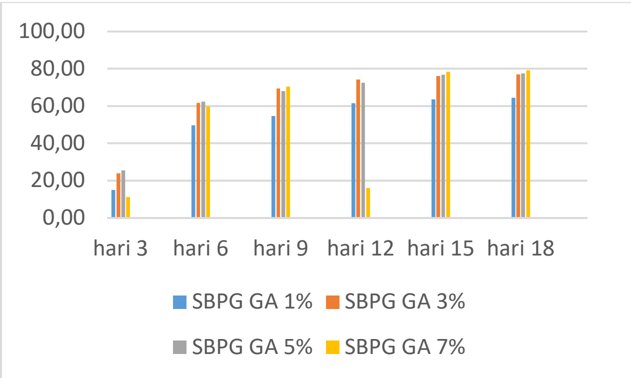

Figure 8. Effect of Addition of Gum Arabic on BCPG-GA Plastics

Based on figure 8, it can be seen that the addition of gum arabic caused BCPG-GA plastics degraded faster. The degradation ability of a plastic was related to the ability to absorb water. That was, the more water content of a material, the more easily degraded. Water is a medium or most bacteria and microbes, especially those in the soil. So that the water content cause the plastic to become more easily degraded [10].

3.8. FTIR

The characterization of the functional groups contained in edibles using the FTIR instrument was carried out at a wave number of 4000 - 500 cm^{-1}.

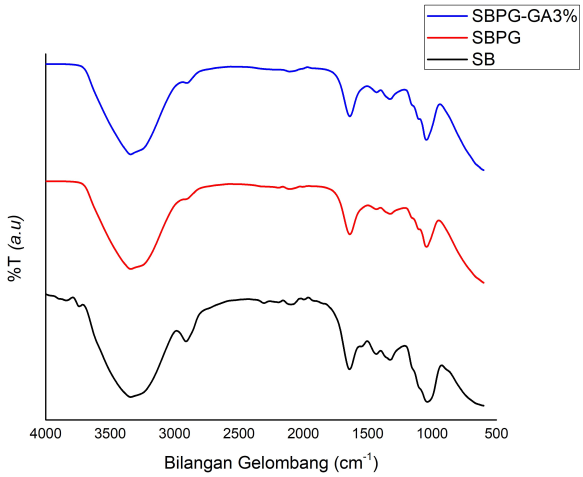

Figure 9. FTIR Spectrum of BCPG-GA Plastics

The first spectrum (SB), the second spectrum (SBPG) and the third spectrum (SBPG-GA3%) showed the presence of O-H bonds at wave numbers around 3600-3200 cm^{-1}, C-H bonds at wave numbers around 3000-2850 cm^{-1}, C-O bonds at the wave number is around 1300-900 cm^{-1}, and the C=C bond at the wave number between 1680-1600 cm^{-1}. Based on the functional group analysis test using FTIR, it shows that there is no new functional group formed. This shows that the process of making bioplastics accompanied by the addition of additives is a physical blending process.

3.9. XRD

The information obtained in the XRD analysis is in the form of a diffractogram graph that shows the peaks of the crystal structure of a material. Crystallinity test is carried out to determine the regularity of atoms or molecules of a particular structure, providing information about the polymer structure including amorphous and crystalline states. The crystalline structure will produce sharp peaks, while the amorphous structure will produce broad peaks. The diffractogram graph of the three biodegradable plastics samples is shown in Figure 10.

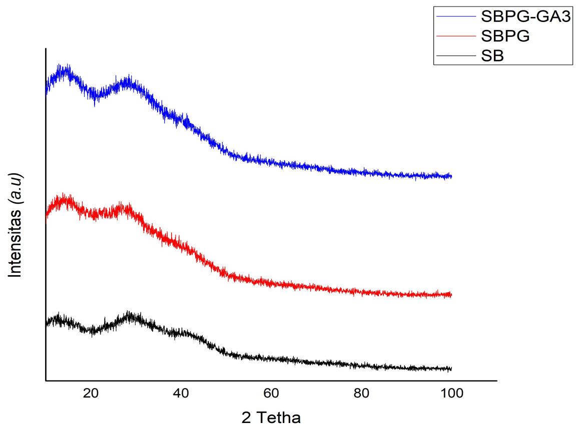

Figure 10. BCPG-GA Plastics XRD Diffactogram

The percentage of crystallinity degree of BC is 80.3% and amorphous percentage is 19.7%. At BCPG the percentage value o the degree of crystallinity is 98.3% and the percentage o amorphous is 1.7%. And the percentage of BCPG-GA 3% degree of crystallinity is 98.8% and amorphous percentage is 1.2%. This shows that the addition of gum arabic can increase the percentage of the degree of crystallinity plastics.

IV. Conclusions

Based on the research that has been done, it is obtained conclusion : The addition of gum arabic additives to BCPG can increase the percentage of water content and swelling test. Variations of gum arabic additives can increase the tensile strength and elasticity of BCPG plastics at a concentration of 3%. The addition of gum arabic additives did not add new groups of BCPG-GA and the crystallinity properties of BCPG-GA increase with the addition of gum arabic.

Acknowledgment

Thank you to Universitas Negeri Padang chemistry laboratory for providing facilities for this research. And thank you, Mr. Ananda Putra, M.Si., Ph.D as a supervisor and validator, Mrs. Dra. Sri Benti Etika, M.Si and Mrs. Dr. Desy Kurniawati, S.Pd, M.Si as a thesis examiner.

References

[1] A. Melani, D. Putri, and Robiah, “Bioplastik Dari Pati Kulit Pisang Raja Dengan Berbagai Bahan Perekat,” Distilasi, vol. 4, no. 2, pp. 1–7, 2019.

[2] S. Suryati, M. Meriatna, and M. Marlina, “Optimasi Proses Pembuatan Bioplastik Dari Pati Limbah Kulit Singkong,” J. Teknol. Kim. Unimal, vol. 5, no. 1, p. 78, 2017, doi: 10.29103/jtku.v5i1.81.

[3] S. Aripin, B. Saing, E. Kustiyah, U. Bhayangkara, and J. Raya, “STUDI PEMBUATAN BAHAN ALTERNATIF PLASTIK BIODEGRADABLE,” J. Tek. Mesin, vol. 06, pp. 79–84, 2017.

[4] R. Andriani and A. Putra, “Effect of the Safety of Chitosan Additive to Biodegradable Plastic Quality Based on Cellulose of Bacterial Glycerol from Coconut Water (Cocos Nucifera),” Int. J. Sci. Res. Eng. Dev., vol. 2, no. 4, pp. 392–396, 2019, [Online]. Available: www.ijsred.com.

[5] T. A. Agustin and A. Putra, “The Effect of Addition of Polyethylene Glycol (PEG) on Biodegradable Plastic Based on Bacterial Cellulosa from Coconut Water (Coconus Nucifera),” Int. J. Progress. Sci. Technol., vol. 17, no. 2, pp. 50–57, 2019, [Online]. Available: http://ijpsat.ijsht-journals.org/index.php/ijpsat/article/view/1398/742.

[6] R. Krisnadi, Y. Handarni, and K. Udyani, “Pengaruh Jenis Plasticizer Terhadap Karakteristik Plastik Biodegradable dari Bekatul Padi,” Semin. Nas. Sains dan Teknol. Terap. VII, no. 100, pp. 125–130, 2019.

[7] A. Gunawan, A. Amran, and A. Putra, “Effect of Gum Arabic on the Quality of Bacterial Celllose Sorbitol Plastic from Pine Apple (Ananas sativus) Peel Waste,” Int. J. Progress. Sci. Technol., vol. 12, no. 2, pp. 181–188, 2019, [Online]. Available: http://ijpsat.ijsht-journals.org/index.php/ijpsat/article/view/707/385.

[8] Zulisma Anita, Fauzi Akbar, and Hamidah Harahap, “Pengaruh Penambahan Gliserol Terhadap Sifat Mekanik Film Plastik Biodegradasi Dari Pati Kulit Singkong,” J. Tek. Kim. USU, vol. 2, no. 2, pp. 37–41, 2013, doi: 10.32734/jtk.v2i2.1437.

[9] D. NOFIANDI, W. Ningsih, and A. S. L. Putri, “Pembuatan dan Karakterisasi Edible Film dari Poliblend Pati Sukun-Polivinil Alkohol dengan Propilenglikol sebagai Plasticizer,” J. Katalisator, vol. 1, no. 2, pp. 1–12, 2016, doi: 10.22216/jk.v1i2.1113.

[10] G. Miftahul Jannah, Ratnawulan, “Analisis Penambahan Gula Jagung Terhadap Karakteristik dan Degradasi Plastik Biodegradable Air Pati Ubi Kayu (manihot utilissima),” Pillar Phys., vol. 1, no. April, pp. 81–88, 2014.