

The Effect of Sorbitol Addition in Bioplastic from Cellulose Acetate (Sugarcane Bagasse)-Chitosan

Zidni Azizati^{1*}, Iseh Muhammad Zaenal Afidin¹, Lutfi Aditya Hasnowo²

¹Department of Chemistry, Faculty of Science and Technology, UIN Walisongo Semarang

²School of Nuclear Science and Engineering, National Research Tomsk Polytechnic University, Tomsk Oblast, Russia, 634050

*Corresponding author: zidni.azizati@walisongo.ac.id

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Abstract

This study aimed to determine the effect of sorbitol addition into cellulose acetate-chitosan bioplastic and its biodegradation properties. Cellulose was isolated from the pulp of sugarcane bagasse and acetylated to be cellulose acetate. Cellulose acetate was characterized by FTIR, the results of FTIR characterization contained C=O and C-O functional groups with wavenumbers of 1644.99 cm⁻¹ and 1059.86 cm⁻¹ which indicated the formation of cellulose acetate. Cellulose acetate-chitosan bioplastic and cellulose acetate-chitosan-sorbitol bioplastic has been successfully synthesized and characterized. The results of FTIR characterization showed that bioplastics had C=O and C-O functional groups at wavenumbers of 1644.99 cm⁻¹, 1059.86 cm⁻¹ which was indicated as cellulose acetate and N-H functional group at wavenumber of 1559.66 cm⁻¹ which was indicated as the presence of chitosan in bioplastics and there is an increase in absorption intensity of the O-H functional group which indicates that sorbitol has been successfully added to bioplastics. The addition of sorbitol could improve the percent of elongation from 14.0635% to 19.9379% and decrease the tensile strength from 6.3049 MPa to 0.6309 MPa. It also could increase water absorption from 16.68% to 88.73%, and could accelerate the bioplastic degradation process from 24 days to 8 days.

Keywords: sugarcane bagasse; cellulose acetate; bioplastic; chitosan; sorbitol

Introduction

Indonesia is a country that consumes a lot of plastic bags, which creates waste. Plastic waste in the soil will inhibit the path of water entering the soil so that reduce soil fertility. Plastic waste can also inhibit the air circulation of underground living organism and interfere with the movement of organisms that fertilize the soil, resulting in infertile soil (Purwaningrum, 2016). Making eco-friendly plastics, such as bioplastics that decompose easily, is one way to reduce the

problem of plastic waste. Bioplastics can be made from cellulose acetate, chitosan, and other natural resources (Lailyningtyas et al., 2020).

Cellulose acetate has mechanical strength, organized microfiber of structure, good transparency, biodegradability, easily soluble in non-polar solvents, and non-toxic properties that can be used to make films, packaging, membranes, and textiles (Safriani, 2000). It can be obtained from cellulose of industrial waste, then acetylated into cellulose acetate. In this research, because

bagasse has a low economic value, cellulose was isolated from it. According to Wahyusi & Utami, (2017), sugarcane bagasse contains 43-52 % fiber, 46.52 % water, and 2-3 % dissolved solids. To produce cellulose acetate bioplastics suitable for packaging, it must be combined with other materials such as chitosan (filler) and sorbitol (plasticizer).

Chitosan reduces brittleness and water absorption throughout bioplastics, while sorbitol acts as a plasticizer and is expected to decrease stiffness throughout bioplastics. As a result, the purpose of this research was to determine the effect of sorbitol addition to cellulose acetate-chitosan bioplastics to obtain the high performance of bioplastic.

Research Method

Materials and Tools

The tools used in this research are a stirrer (spatulla), magnetic stirrer, Pyrex beaker glass, thermometer, filter paper, funnel, plastic template, pipette, oven, universal testing mechine, and FTIR.

The materials were sugarcane bagasse as a source of cellulose acetate, DMAc (*Dimethylacetamide*) from Merck, Sorbitol, 98% glacial acetic acid from Merck, chitosan from CV. Chem Mix pratama, aquadest, H₂PO₄, H₂O₂, NaOH, NaOCl, ethyl ether from Merck, and composted soil.

Methods

Bagasse known as sugarcane pulp was cut into 0.5 cm then dissolved in 1 L of NaOH 10% and stirred at 100°C for 2 hours. The pulp was washed using distilled water and filtered, then the pulp was dissolved in 1 L H₂O₂ 2% and 125 mL NaOCl 5% at 60°C for 2 hours. The cellulose pulp formed was washed and dried at 105°C for 1 hour using an oven and characterized by FTIR.

The cellulose was acetylated into cellulose acetate by dissolving 5 grams of cellulose with 100 mL of phosphoric acid 85%, then added with 60 mL of glacial acetic acid 98% and stirred. Then precipitated and

hydrolyzed by adding ethyl ether for 10 minutes, followed by filtering and washing through warm water. The results were dried and analyzed by FTIR (Wahyusi & Utami, 2017).

Cellulose acetate which was produced by procedure before, is used in the production of bioplastics by dissolving 1.5 grams of cellulose acetate in 24 mL of DMAc and stirring until homogenous. Following that chitosan solution was prepared by dissolving of 1,3 grams of chitosan in 40 mL of 2% acetic acid, then stirred and heated at 40-50°C until homogeneous. The gel was poured into a template and dried. The bioplastics formed were peeled and characterized. This bioplastic was called as CA-C bioplastic.

The cellulose acetate-chitosan-sorbitol (CA-CS) bioplastic was synthesized by dissolving 1.5 g of cellulose acetate in 24 mL of DMAc and stirring until dissolved. Then, 1.3 g of chitosan was prepared by dissolving it in 40 mL of acetic acid 2%, stirring it, and heating it at 40-50°C until homogeneous. Chitosan was added with 0.5 mL, 1 mL, and 1.5 mL sorbitol until homogeneous (gel). Cellulose acetate gel and chitosan gel with sorbitol were mixed and stirred until homogeneous. The resulting gel was then characterized by placing it on a template. Tis product was named as CA-CS 0,5; CA-CS 1; CA-CS 1,5 bioplastics. Characterization carried out included FTIR test, mechanical properties test (tensile strength and percent elongation), water-resistance test, and biodegradation test.

The water resistance test was carried out by soaking the bioplastic sample for 3 minutes. The data obtained were then processed with the following equation:

$$A\% = \frac{W - W_0}{W_0} \times 100\% \dots\dots\dots (1)$$

Information:

- A = % absorption of water that can be absorbed by bioplastic
- W₀ = the initial weight before the bioplastic is immersed (g)
- W = final weight after soaking the bioplastic (g) (Illing & MB, 2017)

The biodegradation test on bioplastics was carried out by burying the sample in compost soil until it is completely degraded. The obtained data was then processed using the equations listed below:

$$\%W = \frac{W_i - W_f}{W_i} \times 100\% \dots\dots\dots(2)$$

Information:

- %W = % weight reduction of bioplastic
- W_i = the initial weight before the bioplastic is buried (g)
- W_f = is the final weight after the bioplastic is buried (g)

Results and Discussion

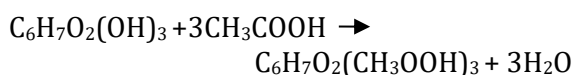
Cellulose Preparation

The prepared bagasse was dissolved in NaOH 10% and stirred at 100°C. This treatment aims to remove lignin and other substances so that only pure cellulose is obtained (Wahyusi & Utami, 2017).

Cellulose was redissolved in H₂O₂ and NaOCl which aims to remove the remaining lignin in the cellulose and whiten the cellulose, the cellulose was washed with distilled water to remove impurities and filtered to separate the solvent and cellulose. Cellulose was dried at 105°C, the dried cellulose was characterized using FTIR.

Cellulose Acetate Synthesis

The obtained cellulose was acetylated by dissolving it in acetic acid 98 % as an acetylating agent. In this process, phosphoric acid 85% was added which functions as a solvent and fiber surface opener so that the acetylation process can take place perfectly. This process would produce cellulose acetate with the following reaction:



(Wahyusi & Utami, 2017)

Diethyl ether was further added in this process in order to separate the phosphoric acid in the solution. Furthermore, cellulose and cellulose acetate were characterized using FTIR with the results in Figure 1.

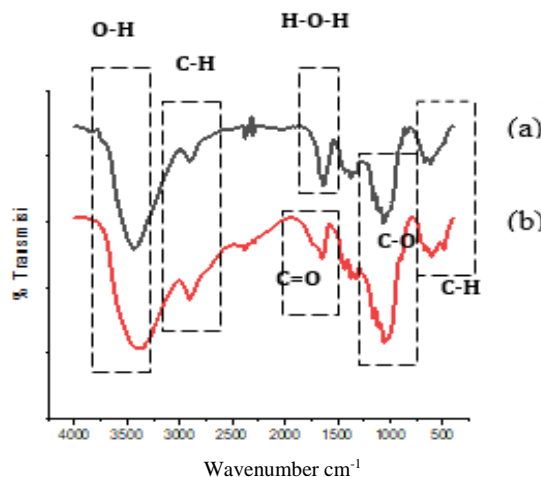


Figure 1. The FTIR spectra of (a) Cellulose and (b) Cellulose Acetate FTIR Results Analysis

Table 1. Results of Cellulose Absorption

Functional groups	Results of synthesis Cellulose Absorption (cm ⁻¹)	Results of Literature Cellulose Absorption (cm ⁻¹)
O-H	3435.72	3431.00
C-H	2936.45	2920
H-O-H	1636.65	1633.62
C-O	1061.12	1061.67
C-H	615.96	617.56

The FTIR analysis of cellulose synthesized from bagasse is shown in Table 1. There are functional groups O-H, C-H stretching, H-O-H, C-O, and C-H bending at wavenumbers 3435.72 cm⁻¹, 2936.45 cm⁻¹, 1636.65 cm⁻¹, 1061.12 cm⁻¹, 615,96 cm⁻¹ respectively.

The presence of functional groups O-H and C-H indicates that the cellulose obtained from bagasse is consistent with the findings of Rachmawaty, et. al. (2013) that the O-H and C-H stretching functional groups were the main functional groups in cellulose.

The results of the FTIR analysis in Table 2 indicate that the synthesized cellulose acetate has functional groups O-H, C-H stretching, C=O, C-O, and C-H bending resulting in absorption at wavenumbers 3354.24 cm⁻¹, 2903.6 cm⁻¹, 1644.99 cm⁻¹, 1059.86 cm⁻¹, 613.85 cm⁻¹, the presence of a carbonyl functional group (C=O) which is a functional group of an acetyl group (COO) at a wavenumber of 1644.99 cm⁻¹, which is indicated on FTIR indicated that cellulose acetate had formed. This is consistent with the findings of Nurhayati dan Kusumawati, (2014).

Table 2. Results of Cellulose Acetate Absorption

Name of Samples	Tensile Strength (Mpa)	Percent Elongation (%)
CA-C	6.3049	14.0635
CA-CS 0.5	5.7054	14.4986
CA-CS 1	2.1177	17.2215
CA-CS 1.5	0.6309	19.9379

FTIR Analysis of Bioplastics

The FTIR test was carried out to determine the functional groups present in bioplastics. The FTIR results of Cellulose Acetate Bioplastic (CA) powder, Cellulose Acetate-Chitosan Bioplastic (CA-C), and cellulose acetate-Chitosan-Sorbitol Bioplastic (CA-CS) were carried out to determine the functional groups present in the synthesized bioplastics. The results of the FTIR test are obtained as shown in Figure 2.

The synthesized CA-C bioplastics were carried out by FTIR test. Bioplastics with absorption at wavenumbers of 3388.8 cm⁻¹, 2920.28 cm⁻¹, 1650.3 cm⁻¹, 1559.66 cm⁻¹, 1032.86 cm⁻¹, 680.16 cm⁻¹ were obtained from the FTIR results. The absorption indicates the presence of the functional group O-H, C-H, C=O, N-H, and C-O. These functional

groups indicate that the synthesized bioplastic contains cellulose acetate and chitosan.

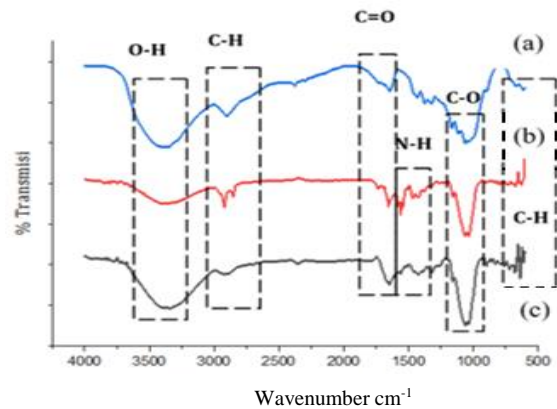


Figure 2. The FTIR Spectra of (a) CA powder, (b) CA-C bioplastic, (c) CA-CS Bioplastic

Functional groups	Results of synthesis Cellulose Acetate Absorption (cm ⁻¹)	Results of Literature Cellulose Acetate Absorption (cm ⁻¹)
O-H	3354.24	3486.97
C-H stretching	2903.6	2960.38
C=O	1644.99	1754.63
C-O	1059.86	1238.13
C-H bending	613.85	603.99

Table 3. Results of CA, CA-C, CA-CS Bioplastic Absorption

Cellulose acetate can be identified by the presence of a carbonyl functional group C=O and an ester (C-O) from the acetyl group Nurhayati & Kusumawati. (2014). The absorption band obtained also shows the presence of N-H groups derived from chitosan, specifically at a wavenumber of 1559.66 cm⁻¹.

FTIR analysis was carried out bioplastics made from CA-CS to determine the functional groups present in the synthesized bioplastics. The results of the FTIR analysis showed that the CA-CS bioplastic sample produced absorption at wavenumbers

3340.67 cm^{-1} , 2922.43 cm^{-1} , 1645.98 cm^{-1} , 1557.5 cm^{-1} , 1060.49 cm^{-1} , 895.49 cm^{-1} for CA-CS bioplastics which indicates the functional groups O-H, C-H stretching, C=O, N-H, C-O, C-H bending. Figure 2 shows that there are differences in the absorption intensity of the O-H group, with the intensity obtained being sharper and wider between bioplastics with and without sorbitol. These phenomena occur because sorbitol contains many O-H functional groups. As a result, it increases the absorption intensity of O-H functional groups (Masthura. 2019).

Mechanical Properties Analysis

Mechanical analysis carried out include tensile strength and percent elongation test. Tensile strength and elongation were carried out using a tensile strange device.



Figure 3. Cellulose Acetate Bioplastics

Table 4. Tensile Strength and Percent Elongation Analysis

Functional groups	Wavenumbers (cm^{-1})		
	CA	CA-C	CA-CS
O-H	3354.24	3388.8	3340.67
C-H Stretching	2903.6	2920.28	2922.43
C=O	1644.99	1650.3	1645.98
C-O	1059.86	1032.86	1060.49
N-H	-	1559.66	1557.5
C-H Bending	613.85	680.16	895.49

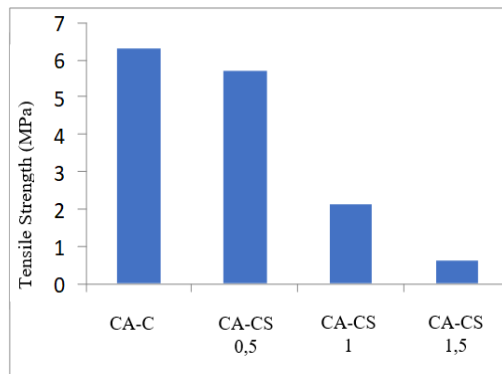


Figure 4. Effect of Adding Sorbitol to the Tensile Strength Test of Bioplastics

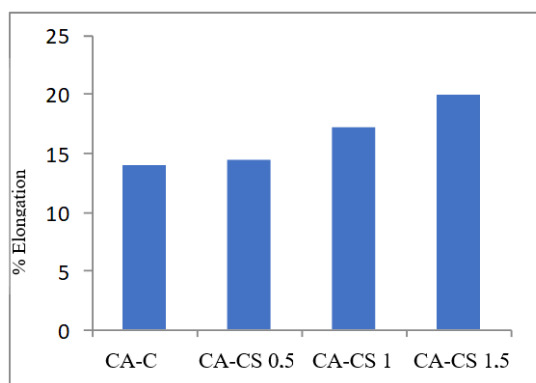


Figure 5. Effect of Adding Sorbitol on the Tensile Strength Test of Bioplastics

The tensile strength tests showed that adding sorbitol resulted in a decrease in tensile strength and an increase in percent elongation, indicating that the bioplastic was not stiff. The decrease in tensile strength is due to the use of sorbitol as a plasticizer to reduce intermolecular forces and increase the mobility of the bioplastic chain. This is consistent with Fitriana. et al. (2017).

The synthesized bioplastics have a tensile strength value of 0.63-6.30 Mpa and the elongation percent reaches 14.06-19.93%. While the Indonesian National Standard (SNI) for bioplastics is to have a tensile strength value and elongation percentage of 1-10 MPa and an elongation percentage of 1-20%. This shows that the bioplastic synthesized meets the bioplastic quality standard reported by Handayani. (2020).

Water Resistance Test

The water resistance test was carried out to determine the resistance of the synthesized bioplastics to water contact. The results of the water-resistance test carried out obtained the following results.

Table 4. Test Results of Water Resistance

Samples	Water Absorption %
CA-C	16.68
CA-CS 0,5	73.18
CA-CS 1	84.13
CA-CS 1,5	88.73

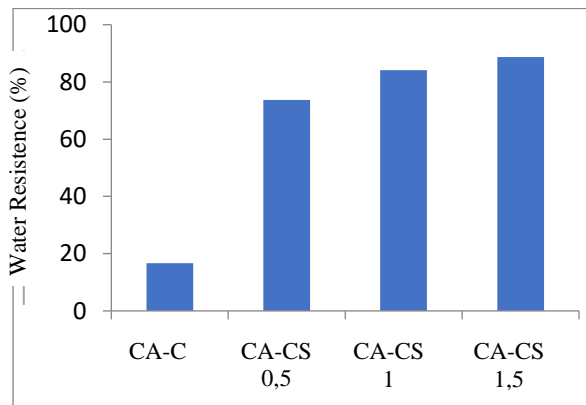


Figure 6. Effect of Adding Sorbitol on Percentage of Water Absorption

The results of the water-resistance test showed that adding sorbitol affected the amount of water absorbed by the bioplastic. The more sorbitol added, the higher the percentage of water absorption. The high percentage of water absorption is due to the use of sorbitol plasticizer, sorbitol is more hydrophilic so that the polymer bonds formed have high porosity and can bind water (Situmorang. et al., 2019).

High water binding ability will affect the ability of bioplastics as packaging. The lower the ability to bind water, the better the ability of bioplastics as packaging.

The synthesized bioplastics has a water absorption capacity of 16.68% to 88.73%

while the SNI for bioplastic water absorption is 21.5% at a temperature of 25°C and 69.09% at a temperature of 100°C (Sofia. et al., 2017). This shows that the only bioplastics that has met the SNI standard is CA-C bioplastics.

Biodegradation Test

The biodegradation test was carried out to determine the time of the synthesized bioplastic until it was degraded. It was conducted by burying the bioplastic sample in composted soil. The following data were obtained as a result of the research.

Table 5. Biodegradation Test

Time (Days)	Sample Degradation Percent %			
	CA-C	CA-CS 0.5	CA-CS 1	CA-CS 1.5
4	7.37	27.35	42.62	52.04
8	9.83	31.25	51.33	90.47
12	12.1	57.17	83.81	100
16	38.7	82.99	100	-
20	78.58	100	-	-
24	100	-	-	-

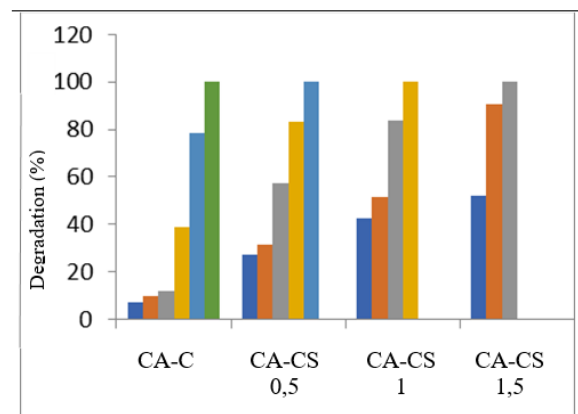


Figure 7. Effect of Adding Sorbitol on Degradation Time

According to the research findings, adding sorbitol to bioplastics affects the time required for bioplastics to degrade. The time required for bioplastics to degrade is directly proportional to the amount of sorbitol added. The more sorbitol added, the shorter the time required to degrade the sample. This happens because sorbitol is hydrophilic (having a strong affinity for water), so that in humid conditions it can make bioplastics easily degraded, and microorganisms can develop properly which can accelerate the degradation of the synthesized bioplastics.

The quality standard for biodegradation of bioplastics is that bioplastics can be degraded up to 100% in 60 days, while the resulting bioplastics take 24 until 12 days to be 100% degraded. It shows that the bioplastics produced to meet the quality standards of bioplastics reported by Handayani (2020).

Conclusions and suggestions

Conclusion

Based on the findings of the research, it is possible to conclude that Cellulose acetate bioplastics obtained from bagasse is brittle. Chitosan addition to cellulose acetate bioplastic can reduce brittleness while increasing tensile strength up to 6.309 MPa. Sorbitol addition to cellulose acetate-chitosan bioplastic can increase the percent elongation from 14.0633% to 19.9379% and sorbitol can increase water absorption from 16.68% to 88.73%. It also can reduce the degradation time from 24 days to 12 days.

Suggestions

It is suggested that further research be conducted on cellulose acetate and chitosan variations to determine the optimum conditions for bioplastics.

References

- Azizaturrohmah. (2019). Perbandingan Plastisizer Gliserol dan Sorbitol Pada Bioplastik Pati Sagu (*Metroxylon* sp.) Dengan Penambah an Minyak Kulit Jeruk Manis (*Citrus sinensis* L.) Sebagai Antioksidan. *UIN Sunan Ampel*.
- Fitriana. R. A., Septiana. R., & Darni. Y. (2017). *Pengaruh Filler Terhadap Karakteristik Mekanik dan Permeabilitas Uap Air Dari Edible Film Berbasis Low Methoxyl Pectin*. 05(02). 103–110.
- Handayani. J. (2020). *Pengaruh Penambahan Kitosan Dan Sorbitol Pada Pembuatan Film Bioplastik Dari Biji Alpukat Terhadap Karakteristik Bioplastik*. 41–47.
- Hidayati S., A. Sapta Zuidar. A. A. (2015). *Aplikasi Sorbitol Pada Produksi Biodegradable Film Dari Nata De Cassava*. 15(3).
- Illing. I., & MB. S. (2017). Uji Ketahanan Air Bioplastik Dari Limbah Ampas Sagu Dengan Penambahan Variasi Konsentrasi Gelatin. *Prosiding Seminar Nasional ISSN 2443-1109*. 3(1). 182–189. <https://doi.org/10.1017/CB09781107415324.004>
- Lailyningtyas. D. I., Lutfi. M., & Ahmad. A. M. (2020). *Uji Mekanik Bioplastik Berbahan Pati Umbi Ganyong (*Canna edulis*) dengan Variasi Selulosa Asetat dan Sorbitol*. 8(1). 91–100.
- Masthura. (2019). Pengaruh Jenis Plasticizer Terhadap Edible Film Berbasis Karaginan *Eucommia cottoni*. *Skripsi Fakultas Sains Dan Teknologi Universitas Islam Negeri Ar-Raniry*. 8(Fakultas Sains dan Teknologi Universitas Islam Negeri Ar-Raniry). 2019. <https://doi.org/10.22201/fq.18708404e.2004.3.66178>
- Nurhayati. N., & Kusumawati. R. (2014). Sintesis Selulosa Asetat dari Limbah Pengolahan Agar. *Jurnal Pascapanen Dan Bioteknologi Kelautan Dan Perikanan*. 9(2). 97. <https://doi.org/10.15578/jpbkp.v9i2>

.103

- Purwaningrum, P. (2016). Upaya Mengurangi Timbulan Sampah Plastik Di Lingkungan. *Indonesian Journal of Urban and Environmental Technology*. 8(2). 141. <https://doi.org/10.25105/urbanenvirotech.v8i2.1421>
- Rachmawaty, R., Meriyani, M., & Priyanto, I. S. (2013). *SINTESIS SELULOSA DIASETAT DARI ECENG GONDOK (Eichhornia crassipes) DAN POTENSINYA UNTUK PEMBUATAN MEMBRAN*. 2(3). 8–16.
- Ratnaningtyas, F., Studi, P., Kimia, T., Teknik, F., & Surakarta, U. M. (2019). *Pengaruh Plastisizer Sirbitol Dan Gliserol Terhadap Kualitas Plastik Biodegradable Dari Singkong Sebagai Pelapis Kertas Pembungkus Makanan* (p. Skripsi. Unuversitas Muhammadiyah Surakarta).
- Safriani. (2000). *Produksi Biopolimer Selulosa Asetat Dari Nata De Soya* (p. Tesis. Institut Pertanian Bogor).
- Situmorang, F. U., Hartiati, A., & Harsojuwono, B. A. (2019). Pengaruh Konsentrasi Pati Ubi Talas (*Colocasia esculenta*) dan Jenis Plastisizer Terhadap Karakteristik Bioplastik. *Jurnal Rekayasa Dan Manajemen Agroindustri*. 7(3). 457. <https://doi.org/10.24843/jrma.2019.v07.i03.p13>
- Sofia, A., Prasetya, A. T., & Kusumastuti, E. (2017). Komparasi Bioplastik Kulit Labu Kuning-Kitosan Dengan Plasticizer Dari Berbagai Variasi Sumber Gliserol. *Indonesian Journal of Chemical Science*. 6(2). 110–116.
- Wahyusi, K. N., & Utami, L. I. (2017). *Kajian Proses Asetilisasi Terhadap Kadar Asetil Selulosa Asetat DARI Ampas Tebu* *Study Acetylation Process On Acetyl Content Of Cellulose Acetate From Bagasse*. 12(1). 35–39.