Effect of Temperature Variations Gelatinizing of Biodegradable Plastic Starch Porang (Amorphophallus Oncophyllus) with Glycerol Plasticizers on Its Characterization

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A B S T R A C T

The development of plastic polymers is widely used in the food and non-food industries, biodegradable plastics derived from porang starch into environmentally friendly plastics. Plastics are made by adding chitosan and adding a 60% glycerol plasticizer by varying the gelatinizing temperature in the manufacturing process. The gelatinization temperature was used in the process when the starch granule was heated by adding chitosan and glycerol so that the development of starch granules expand and produced a viscous liquid to provide the desired solution quality. The variations in the gelatinization temperature used are temperatures of 70 ˚C, 80 ˚C, and 90 ˚C, then mechanical, physical and characterization tests were carried out on biodegradable plastics. The effect of the gelatinization temperature of biodegradable plastics on the strong value of Tensile is getting lower the temperature, the higher the tensile strength value until it reaches a value of 0.7034 Mpa and at the elongation value which decreases with the higher the gelatinization temperature. The highest elongation value was 124.96% at a gelatinizing temperature of 70 ˚C. Meanwhile, the degradation test showed a decrease in mass every week and began to degrade in the fourth week, which took 28 days. SEM analysis of biodegradable plastics showed that there are white parts that clump together, because the glycerol plasticizer has a thick texture so that it is not dissolved evenly. The spectra results showed no change in the wave number of the FT- IR spectrum of the starch, chitosan, and glycerol spectrums with O-H, C-H, and N-H functional groups.

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1. INTRODUCTION

The development of plastic polymer technology has brought many benefits in human life. Plastic is widely used both in the food and non-food industries, because plastic has advantages including transparent, flexible, lightweight, not easily broken, waterproof, and not corrosive [1]. Plastic has been widely used in everyday life. And often it is used only in one use. Today, the world's biggest concern is the problem of plastic waste. The main reason is that plastics made from petroleum-based polymers are not degraded by the environment. Plastic has a low degradability and is the main cause of waste formation. Concerns about non-renewable environmental resources, the use of recyclable resources to produce biodgradable plastics can maintain product quality and reduce the currently rising waste treatment problems. Due to the difficulty of decomposing, plastic waste tends to accumulate in final waste treatment plants and can damage the environment [2]. Plastic materials will interfere with human health and pollute the environment because plastic has the property of being difficult to degrade and takes up to 100-500 years to be perfectly decomposed. While bioplastics from cellulose have biodegradable properties and can decompose up to 67% within 2-3 weeks on active sludge media for wastewater treatment [3]. One solution to overcome the problem of plastic waste is to make environmentally friendly plastic (biodgradable plastic). Various efforts have been made to develop sustainable composite materials for a variety of industrial applications with renewable, biodegradable, low-cost, and non-petroleum-sourced properties. Bioplastics are plastics that can be degraded by microorganisms from sources of compounds in plants such as polysaccharides, cellulose, and lignin [4].

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Indonesia is a country with great potential as a center for bioplastic development because it has abundant natural resource potential [5]. Porang plant is one of the plants that belongs to the family Araceae and belongs to the genus amorphophallus [6]. Porang (Amorphophallus oncophyllus) is a type of starch-producing root crop that has many uses [7]. The temperature of starch gelatiniation can affect the change in the viscosity of the starch solution. An increase in temperature can increase the solubility of starch, granules will form a thick starch paste in the form of swollen starch granules like gels that are elastic [8]. The initial temperature of gelatinization indicates the minimum temperature required for cooking and the temperature at which the viscosity begins to increase during the heating process. The high initial temperature of gelatinization indicates that starch is more resistant to swelling and rupture of starch granules, while the low initial temperature of gelatinization indicates swelling and rupture of starch granules most easily in water media [9]. Variations in gelatinization temperature and their interactions have a marked effect on tensile strength, elongation at break and elasticity (modulus young) of bioplastics [10].

2. RESEARCH METHOD

Extraction of Porang into Starch

Porang tubers are taken and then washed thoroughly and peeled off the skin and then cut into chips. porang chips are mashed using a blender. Then the porang chips are added with water and mashed using a blender. filtered porang that has been smoothed with gauze and precipitated porang for 24 hours then precipitated in the form of starch and dried starch into the oven for 24 hours with a temperature of 60 ˚C. After the starch dries then mashed the starch with a blender then sifted with a sieve of 200 mesh.

Preparation of Biodegredable Plastics

1. Weighed a certain amount of starch and chitosan masses with a ratio variation of 70%:30%, 60%:40%, 50%:50%, 30%:70% and 40%:60% of the total mass of starch and chitosan which is 5 grams. A starch solution is made with a ratio of starch:aquades is 1:20(w/v) on a glass beaker of 500 ml.
2. Chitosan solution is made by dissolving chitosan which has been weighed into a solution of acetic acid 0.1 M chitosan: acetic acid 1:40(w/v).
3. A solution of glycerol with a concentration of 60% (v / w) is made. With a variation in gelatinization temperature of 70°C, 80°C, 90°C which will be used with a magnetic stirer rotation speed of 400 rpm for 30 minutes.
4. Chitosan solution is added slowly to the mixture.
5. Glycerol was added after 30 minutes with a concentration of 60%(v/w) in the starch-chitosan solution, then stirred for 15 minutes.Here is how to display a pop-up window from which to select and apply the AIP Conference Proceedings template paragraph styles:
6. After 15 minutes, then turned off the magnetic stirrer.
7. Cool the solution inside before molding.
8. Poured a solution of 50 ml into the mold, then in the oven at a temperature of 60oC for 24 hours.
9. After drying, it will be removed and put the solution in the desiccator for 24 hours.
10. Then removed the biodegredable plastic from the mold and then analyzed the data.

3. RESULTS AND DISCUSSION

Result of Tensile Strength Analysis

Tensile strength is the maximum stress that a bioplastic is able to withstand when stretched or pulled. Bioplastics with high tensile strength will be able to protect the products they pack from mechanical interference well [11]. The optimal composition of plastic is determined based on the mechanical properties of the material primarily on the tensile strength and elongation of the material. This mechanical property is obtained through tensile test experiments [3]. The mechanical properties of bioplastics are determined by measuring tensile strength and gluttony using the Universal Tensile Machine tool [12]. The tensile strength test is carried out so that the tensile strength and strain of each plastic sample can be known [13]. Tensile strength testing was carried out to determine the tensile strength and tensile stress of each biodegradable plastic sample.

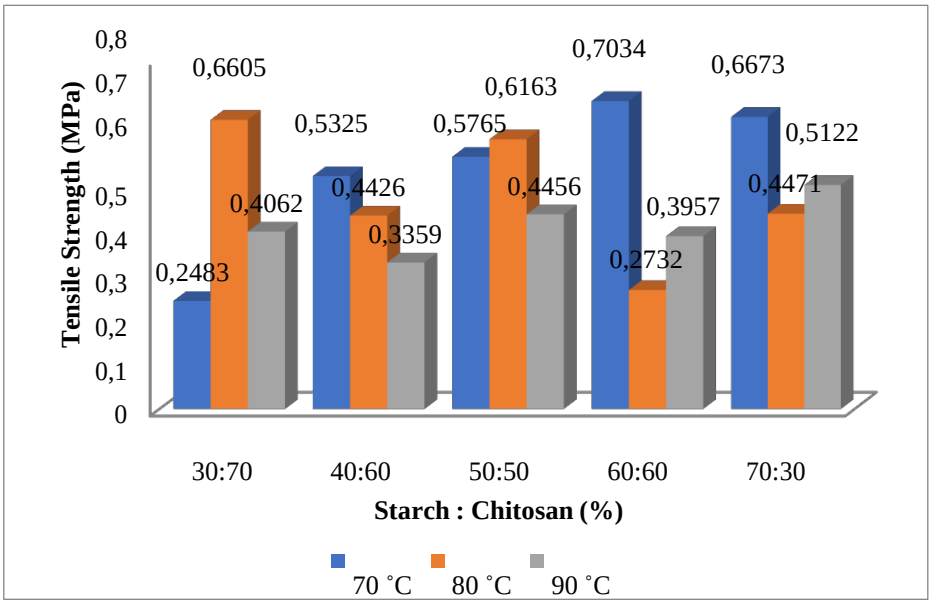


Figure 1. Grafik kekuatan tarik plastik biodegradable

Fig. 1 shows that tensile strength testing obtained a top value of 0.7034 Mpa using starch : chitosan 60% : 40% at a temperature of 70 ˚C. Shows the higher temperature resulting tensile strength value tends to be low, at a starch composition of 40% at a temperature of 70 ˚C the tensile strength value of 0.5323 MPa decreased to 0.4426 MPa at a gelatinization temperature of 80 ˚C and decreased back at a temperature of 90 ˚C to 0.3359 MPa. Likewise with starch 50%, where at a temperature of 70 ˚C the tensile strength value of 0.5765 MPa decreased at a temperature of 90 ˚C to 0.4456 MPa, the same thing happened in the composition of starch 60% and 70% which experienced a decrease in the tensile strength value. This is because when the temperature is high, the starch undergoes granules inflated so that the starch granules will be damaged and the viscosity of the solution will decrease [14].

Result of Elongation at Break Analysis

Lengthening testing at breakup is a percent increase in the length of the sample material measured from the initial length at the time of withdrawal to breaking [11]. The bond that occurs between starch molecules and chitosan is getting tighter and more compact so that it will cause bioplastics to become strong so that the film is more difficult to stretch or lengthen, this will certainly reduce the percentage of film extension [15].

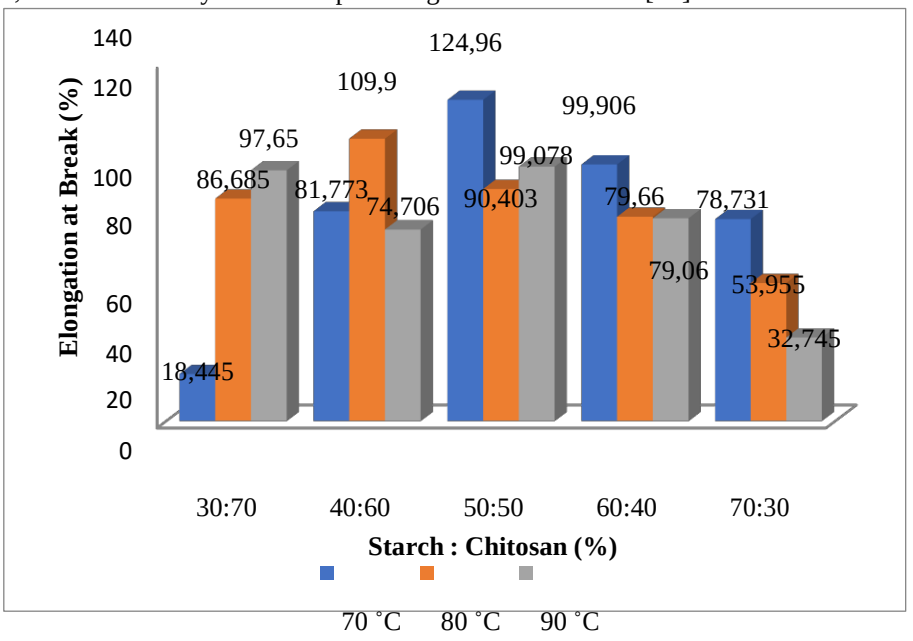


Figure 2. Graph of Elongation at Break Biodegradable Plastic

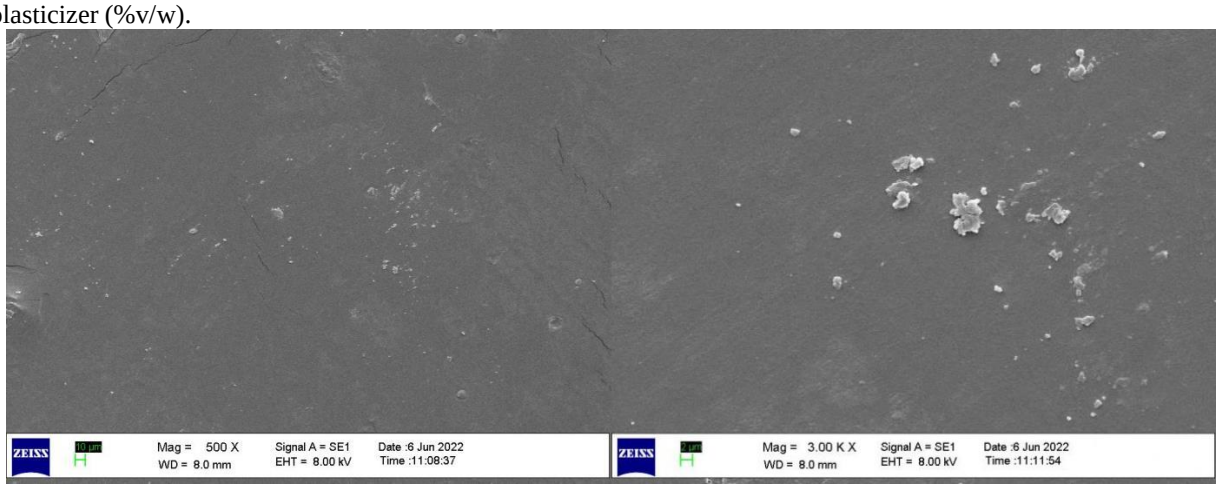
Fig. 2 shows that in the lengthening test the highest value obtained was 124.96 % at the ratio of starch : chitosan 50 % : 50 % at a temperature of 70 ˚C. Shows the effect of gelatinizing temperature on the elongation value, the higher the temperature, the lower the elongation value. The greatest extension value at break occurs at low

temperatures because the gelatinization process with low temperatures produces biodegradable plastics with a less dense structure, the water content in the material is more than biodegradable plastics with higher gelatinization

temperatures [16]. In addition, the starch concentration also affects the elongation value, where at a temperature of 70 ˚C it can be seen that the elongation value tends to decrease, in the composition of 50% to 70%, as well as what happens at temperatures of 80 ˚C and 90 ˚C. The addition of starch can have an influence on the elongation value, the higher the starch composition used, the lower the elongation value produced [17].

Result Of Scanning Electron Microscopy Analysis

Morphological analysis was carried out to determine the spread of particles on the surface of biodegradable plastic by SEM (Scanning Electron Microscopy) testing. [18]. Sem test results were carried out on samples with a size of 5x5 cm and tested on chitosan starch samples of 50% : 50% at a temperature of 80 ˚C. by using a 60% glycerol plasticizer (%v/w).



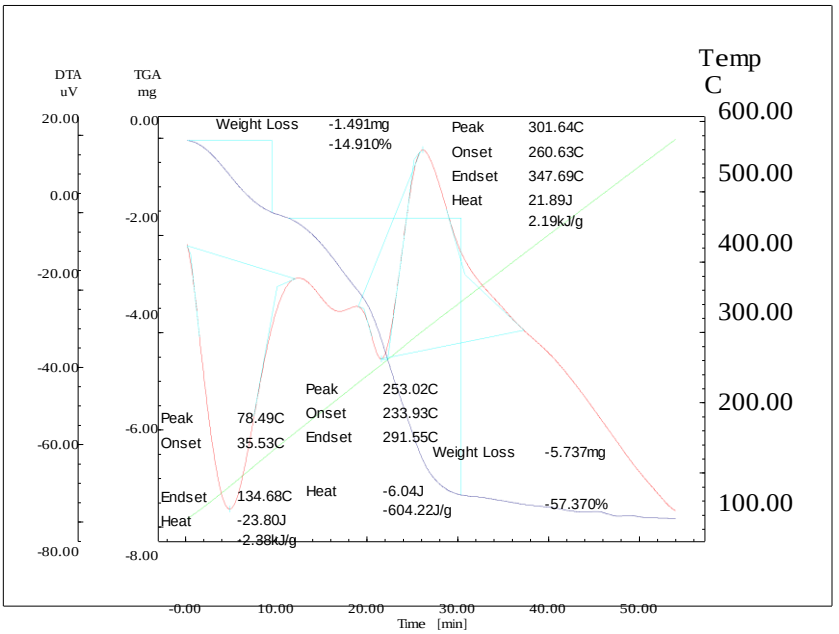
(a) (b)

Figure 3. The microstructure of biodegradable plastics at magnification of (a)500 × and (b)3000 ×

SEM testing is carried out aimed at determining the surface microstructure of biodegradable plastics that have been produced. In this test, the SEM test was carried out with magnifications of 500 × and 3000 ×. In the (Fig. a) 500 × magnification, you can see the appearance of biodegradable plastic where the flat surface looks black which is almost thoroughly indicating that the solution is well mixed, but it can be seen that there is a structure that is not tight and there are visible broken parts (cracks). Cracks that occur due to the size of amylopectin are still too large [19]. Magnification of 3000 ×, the white lumps of the plasticizer are increasingly clearly visible. The presence of white lumps on the surface of the plastic indicates that the results of the constituent components of the plastic have not been completely mixed, this can happen due to a poor stirring process, or the solution has not fully reached its gelatinizing state [20].

Result of Thermogravimetric Analysis

TGA is the most common, simple, and fast technique for kinetic analysis for devolatile processes. Kinetic analysis has become a topic of interest to many researchers engaged in the field of thermal decomposition [21]. This test is carried out with the aim of determining the properties of a sample, and in the process includes the processes of phase change, melting, softening, decomposition and oxidation.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Onset 233.93C
Endset 291.55C
Heat -6.04J
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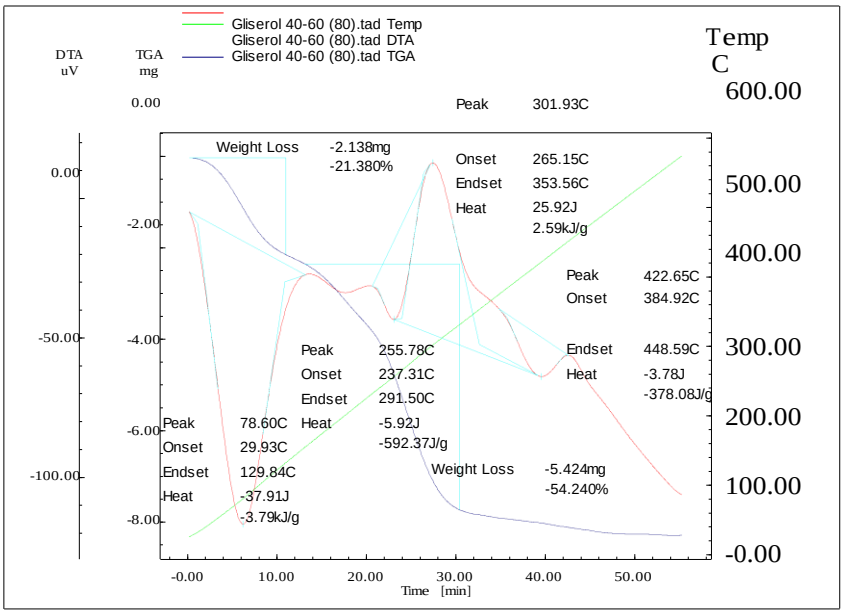
(a)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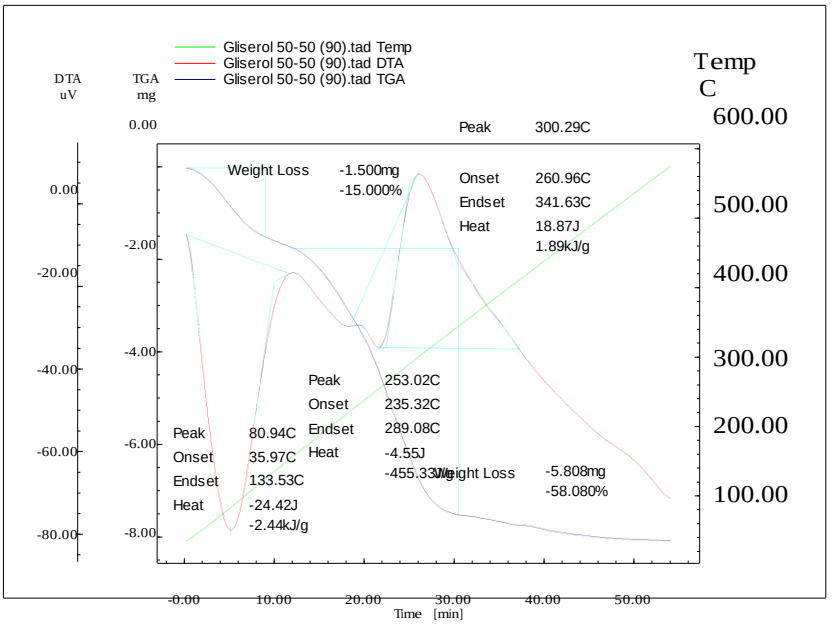

c)

Figure 4. Graph of Thermogravimetric Analysis of biodegradable plastics with gelatinizing temperature a)70 ˚C, b)80 ˚C, c)90 ˚C.

Fig. 4 shows that the occurrence of a mass decrease due to a rise in temperature is informed by the The TGA Thermogram while to be able to see the heat in each mass reduction process can be given to the DTA Thermogram. Fig. 4 shows the occurrence of a mass decrease due to a rise in temperature is informed by the TGA thermogram while to be able to see the heat in each mass reduction process can be given to the DTA thermogram. Visible biodegradable plastic with a composition of porang starch ratio: chitosan 50%:50% with a gelatinization temperature of 70 °C (Fig. 4a) there was a decrease in mass by 1.491 mg in the temperature range of 32.40-125.06 °C, then there was a decrease in the second mass of 5.737 mg in the temperature range of 125.06-283.61 °C. According to [22], there was a decrease in mass due to the evaporation and decomposition process of bidegradable plastics.

Result of FT-IR Analysis

FT-IR testing is carried out aimed at determining the process that occurs in mixing physically or chemically in biodegradable plastic samples. The test is carried out by cutting biodegradable plastic samples and then adjusting to the existing spectrum [23]. FT-IR analysis can see the interaction of the composition with macromolecules in biodegradable plastics.

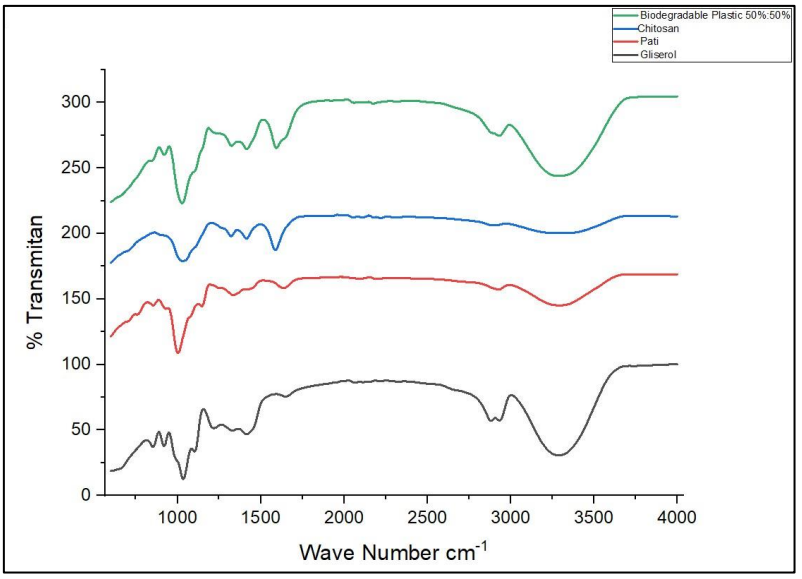

Fig 5. FT-IR Biodegradable Plastic

FT-IR spectra analysis on chitosan was found in absorption with a wave number of 3259.46 cm-1 indicating the O-H group, then at a wave number of 1413.75 cm- 1- indicating a C-H group, and for a wave number of 1587.48 cm-1 indicating an N-H group. furthermore, for ft-IR spectra analysis on glycerol there is absorption at wave number

3287.43 cm-1 indicating the O-H group, wave number 2932.70 cm-1 indicating the C-H group. FT-IR analysis of porang starch there is an uptake in the wave number 3285.52 cm-1 indicating the O-H group, the wave number 2929.19 cm-1 indicating the C-H group, and the wave number 1638.84 cm-1 indicating the N-H group. And in ft-IR analysis on biodegradable plastics porang starch shows the occurrence of absorption at the wave number 3282.15 cm-1 which indicates the O-H group, the wave number 2930.55 cm-1 indicating the C-H group, and the wave number 1593.79 cm-1 indicating the N-H group. The presence of wave shifts in the O-H and N-H groups is a form of interaction in the form of hydrogen bonds between amylose-amylopectin-chitosan in bioplastics [24]. FT-IR results show that the process of making bioplastics is a process where there is hydrogen interaction between chains [25].

4. CONCLUSION

The results of the analysis of bioplastic characteristics obtained the highest tensile strength value of 0.7034 MPa, and the highest elongation value of 124.96 %, where the higher the temperature of gelatinization makes the value of tensile strength and elongation of bioplastics tends to decrease. SEM results that show that there are uneven parts in the constituent components, and FT-IR results that show the same groups as the constituent components, namely O-H, C-H, and N-H.

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REFERENCES

1. M. Luthfi, S. H. Sumarlan, B. Susilo, Wignyanto, R. Zenata and L. P. R. Perdana, The Glycerol Effect on Mechanical Behaviour of Biodegradable Plastic from the Walur (Amorphophallus paenifolius Var. sylvestris) (Nature Environment and Pollution Technology, Malang, 2017), pp. 1121-1124.
2. Haryanto and F. R. Titani, Bioplastics from Tapioca Flour and Cornstarch (Techno, Purwokerto, 2017), pp. 001-006.
3. D. Fibriyani. F. Arinta, and R.D. Kusumaningtyas, Processing Cassava Onggok as Biodegradable Plastic Using Glycerin Plasticizer from Used Cooking Oil (Indonesian Food Technologists, Semarang, 2017), pp. 74-77.
4. S. S. Udjiana, S. Hadiantoro, M. Syarwani and P. H. Suharti, Manufacture and Characterization of Biodegradable Plastic from Taro Tubers (Xanthosoma Sagittifolium) with The Addition of Chitosan Fillers and Calcium Silicate (Journal of Chemical and Environmental Engineering, Malang, 2019), pp. 10-19.
5. E. Permana, D. R. Gusti, I. L. Tarigan, Y. Andika and A. C. Nirwana, Bioplastic Physical Characteristics of Gadung Tuber Starch and Palm Fronds (Science Tech, Jambi, 2021), pp. 45-54.
6. T. Estiasih, W. D. R. Putri, and E. Waziiroh, Tubers and Their Processing (UB Press, Malang, 2017), pp. 24-26.
7. N. E. Wardani, W.A. Subaidah, and A. Muliasari, Extraction and Determination of Glucomannan Levels from Porang Tubers Using DNS Method (Journal of Science and Health, Mataram, 2021), pp. 383-391.
8. K. Nisah, Study Effect of Amylose and Amylopectin Content Of Tubers Against The Physical Characteristics of Biodegradable Plastics with Glycerol Plastizicer (Biotic, Banda Aceh,2017), pp. 106-113.
9. S. Du, H. Jiang, Y. Ai and J. Jane, Physicochemical Properties and Digestibility of Common Bean (Phaseolus Vulgaris L.) Starches (Elsevier, Xian, 2014), pp. 200-205.
10. Y. Zhang, M. Hu, K. Zhu, G. Wu and L. Tan, Functional Properties and Utilization of Artocarpus Heterophyllus Lam Seed Starch from New Species in China (Elsevier, Hainan, 2017), pp. 1395-1405.
11. Y. R. Hasanah and Haryanto, Effect of Calcium Carbonate ($CaCO_3$) and Clay Filler Addition on Mechanical and Biodegradable Properties of Plastics from Tapioca Waste (Journal Techno, Purwokerto, 2017), pp.96-107.
12. N. Hidayati, P. Rahayu, R. N. Rachma and H. Anggraini, Effect of Glycerol Plasticizer Addition on Mechanical Properties on Bioplastic Manufacturing from Chitosan-Tuber Porang (Amorphophallus Muelleri Blume) (Journal Technology, Surakarta, 2021), pp.23-22.
13. R. Handayani and M. Yuniwati, The Effect of Temperature and Time on Tensile Strength in the Process of Making Plastic from Hood and Pineapple Leaf Fibers (Journal of Innovation and Process, Yogyakarta, 2018), pp. 16-21.
14. M. H. S. Ginting, R. Hasibuan, R. F. Sinaga and G. Ginting, Effect of Starch Gelatinization Temperature Variations on Tensile Strength and Elongation at Break of Taro Tuber Starch Bioplastics (Chemical Engineering, Medan, 2014), pp. 1-3.

15. W. Setiani, T. Sudiarti and L. Rahmidar, Preparation and Characterization of Edible Film from Polyblend Starch Breadfruit-Chitosan (Valensi, Bandung, 2013), pp.100-109.
16. I. M. D. Pradipta and L. J. Mawarani, Manufacture and Characterization of Polymers Environmentally Friendly Based on Porang Tuber Glucomannan (Journal of Science and Pomits Art, 2012), pp. 1-6.
17. E. P. D. Putra and H. Saputra, Characterization of Biodegradable Plastic from Starch Waste Banana Peel Muli with Plasticizer Sorbitol (Journal of agricultural Technology Andalas, Padang, 2020), pp. 29-36.
18. R. Krisnadi, Y. Handarni and K. Udyani, Effect of Plasticizer Type on Biodegradable Plastic Characteristics of Rice Bran (National Seminar on Applied Science and Technology, Surabaya, 2019), pp. 125-130.
19. E. Maneking, H. F. Sangian, and S. H. J. Tongkukut, Manufacture and Characterization of Biomass-Based Bioplastics with Glycerol Plasticizer (Journal MIPA, Manado, 2020), pp. 23-27.
20. N. Hasanah and A. Mahyudin, Effect of Glycerol Mass Variations on the Mechanical Properties of Plastic Film of Taro Tubers Affecting Nano Betel Nut Fiber (Journal Physics of Unand, Padang, 2022), pp. 195-199.
21. L. Nowicki and M. Markowski, Kinetic Analysis of Thermografimetric Data Collected from Bigger Samples (PAN, Poland, 2012), pp. 85-94.
22. M. Yamada, S, Moimitsu, E. Hosono and T. Yamada, Preparation of Bioplastic Using Soy Protein (Elsevier, Okayama, 2020), pp. 1077-1083.
23. M. B. Satriawan and I. Illing, FT-IR Bioplastic Test from Sago Pulp Waste with The Addition of Variations in Gelatin Concentration (Journal of Dynamics, Palopo, 2017), pp. 1-13.
24. M. Afif, N. Wijayati and S. Mursiti, Manufacture and Characterization of Bioplastics from Avocado Seed Starch-Chitosan with a Sorbitol Plasticizer (Indonesian Journal of Chemical Science, Semarang, 2018), pp. 102-109.
25. H. Setiawan, R. Faizal and A. Amrullah, Determination of Optimum Conditions for Modification of Sorbitol PVA Plasticizer Concentration in Biodegradable Plastic Synthesis Based on Sorghum Starch and Chitosan Shrimp Shell Waste (SAINTEKNOL, Semarang, 2015), pp. 29-38.