HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

December 2023. 11(6)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 810-820

The Influence of Adding Glycerol and Spirulina on The Characteristics of Starch-Based Bioplastics Film from Potato Peel Waste

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Article History
Received: 06-11-2023
Revised: 18-11-2023
Published: 20-12-2023

Keywords: bioplastic film, potato peel, starch, glycerol, spirulina

Abstract

The development of bioplastic films is one of the efforts to reduce plastic waste. The polymer used as the basic material for making bioplastic films is starch. Potato peel waste can be repurposed by extracting its starch content. This research has the purpose to investigate the influence of adding glycerol and spirulina on the characteristics of bioplastic films made from potato peel starch, and to ascertain the optimum composition of raw materials. Bioplastics were produced by casting method from potato peel starch with variations of glycerol and spirulina. The bioplastic composition in this research includes K0 (0 ml glycerol and 0 grams spirulina), K1 (2.5 ml glycerol and 0.3 grams spirulina), K2 (1.25 ml glycerol and 0.3 grams spirulina), K3 (2.5 ml glycerol and 0.15 grams spirulina), and K4 (1.25 ml glycerol and 0.15 grams spirulina). The characteristics of bioplastic films include thickness testing, tensile strength, elongation at break, and degradation. The results from the characterization of bioplastic films indicate that the addition of glycerol and spirulina is inversely proportional to the tensile strength produced, meaning it decreases. However, the addition of glycerol and spirulina is directly proportional to the percentage of elongation produced, meaning it increases. The addition of spirulina has an impact on the degradation time of bioplastic films. The optimal raw material ratio in this research is found in sample K4, with a tensile strength value of 23.038 MPa, elongation at break of 4.385%, thickness of 0.1367 mm, and complete degradation occurring on the sixth day.

How to Cite: Ni'mah, K., Hakim, M., Julia Putri, L., & Rahmawati, F. (2023). The Influence of Adding Glycerol and Spirulina on The Characteristics of Starch-Based Bioplastics Film from Potato Peel Waste. Hydrogen: Jurnal Kependidikan Kimia, 11(6), 810-820. doi:https://doi.org/10.33394/hjkk.v11i6.9549

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INTRODUCTION

Plastic is one of the polymers derived from petroleum and is non-renewable. Based on its function, plastic is used for packaging due to its economic, flexible, and air, water, and heat-resistant properties. The drawback of plastic is its difficulty to degrade, leading to waste accumulation that can harm the environment. Efforts under the *Reduce, Reuse, Recycle* (3R) initiative have been made to mitigate the negative impact of plastic use. Bioplastic is one application of the "*reduce*" aspect, as it aims to reduce the use of petroleum-based plastics. The raw material for bioplastic originates from biomass, which falls under the category of *renewable energy* sources (Rahmawati et al., 2023), thereby contributing to a reduction in dependence on fossil fuels. Biomass is non-fosil organic material obtained from plants, animals and microorganism (Zainuddin et al., 2017).

Organic materials such as polysaccharides, proteins, lipids, or specific substances produced by microalgae can be used as materials for making bioplastics (Ayu & Ningsih, 2020). Commonly used polysaccharides for bioplastic production include starch and cellulose (Rendón-Villalobos et al., 2022). Starch can be sourced from corn, cassava, potatoes, sweet potatoes, and others. Meanwhile, cellulose can be obtained from the lontar fruit, which produces cellulose diacetate (Batu et al., 2023).

Starch is widely utilized as a primary material in the production of biodegradable plastics due to its renewability, ready availability, and cost-effectiveness (Alves et al., 2015). Natural starch appears in the form of small granules. Starch granules are insoluble in water at room temperature and in some organic solvents (Sakinah & Kurniawansyah, 2018), necessitating the application of heat for dissolution. When heated with water at a specific temperature, starch granules undergo swelling due to water absorption, and certain starch components such as amylose will leach out and dissolve, this process is referred to as gelatinization (Moorthy et al., 2017). The gelatinization temperature varies for different types of starch; for example, potato starch undergoes gelatinization at temperatures between 56 and 67°C, corn starch at temperatures between 62 and 72°C, and rice and sorghum starch at temperatures between 68 and 78°C (Niba, 2005). Bioplastic films made from starch as a base material exhibit high biodegradability (rapid decomposition) in soil (Nandiyanto et al., 2020). One of the materials containing starch is potatoes.

Potatoes are one of the staple foods and are widely used as the primary ingredient in various food products. Potato production in Indonesia increased by 4.21% in 2022, reaching 1.42 million tons (Sadya, 2023). This indicates that the demand or consumption of potatoes in Indonesia is also on the rise, resulting waste in the form of potato peels. Food waste, such as inedible parts like peels or seeds, holds potential as raw material in the production of bioplastics (Listyarini et al., 2020). Efforts that can be made to reduce this waste are by reusing potato peels by extracting them into starch. Based on research by Arapoglou *et al*. (2010), 40 grams of potato peels contain about 52.14% starch. The starch content in potato peels is higher compared to durian seed starch at 18.46%, cassava starch at 15-20%, and jackfruit seed starch at 34.68% per 100 grams (Dermawan et al., 2020).

Bioplastic films made with starch as the *biobased* component have a weakness in that they are rigid and brittle. The development of other materials serving as plasticizers and fillers has been carried out to enhance the mechanical properties and biodegradability of bioplastic. As stated by Boey *et al*. (2022), parameters such as the type of filler, filler percentage, and raw material ratio can significantly enhance the mechanical properties of bioplastics. Research has been conducted by Genalda & Udjiana (2021) using biobased starch from potato peels with the addition of sorbitol as a plasticizer and calcium silicate as a filler. The highest tensile strength value obtained from the research is 2.61 MPa. Meanwhile, research conducted by Hayati *et al*. (2020) used spirulina as a filler and alginate as the biobased component. The produced plastic film exhibits the highest tensile strength of 5.26 MPa and an elongation at break of 58.23%.

Research on bioplastics from potato peel starch as a biobased, glycerol as a plasticizer and spirulina as a filler has never been carried out, so this combination of raw materials is a novelty for this research. Glycerol is used to enhance the elasticity of the bioplastic film and spirulina is used to improve the degradation properties of the bioplastic film. Spirulina has a high protein content, approximately 55-70% (Christwardana & Nur, 2013). Additionally, spirulina exhibits antimicrobial activity (Winahyu et al., 2020), which can inhibit bacterial growth.

Based on the description above, this research has the purpose to investigate the influence of adding glycerol and spirulina on the characteristics of bioplastic films made from potato peel starch, and to ascertain the optimum composition of raw materials. These characteristics include tensile strength, elongation at break, thickness, and degradation.

METHOD

Equipment and Materials

The equipment used in this research includes analytical balances, measuring glass, beaker glass, stirring rods, hot plate, molds (33 x 23 cm), thermometers, heaters, blenders, filter cloths and sieves. The materials used in this research include potato peel starch, distilled water, glycerol, spirulina and soil for degradation testing.

Extraction of starch

In this research, the process of potato peel starch production follows the method established by Nurlaila & Purnomo (2020) with modifications to the starch drying temperature. Potato peels were cleaned to remove impurities, then blended at a ratio of 2:1 between potato peels and distilled water. The resulting *slurry* was filtered using a cloth filter to separate the filtrate from the residue. The filtrate was allowed to settle for 24 hours. The starch precipitate obtained was subsequently washed again using distilled water until it became white and clean. The starch precipitate was then dried at 40°C for 8 hours. Once dried, the potato peel starch was finely ground and sieved. The results of the potato peel starch in this research are presented in Figure 1.

Figure 1. Starch of potato peels

Production of bioplastic film

The production of bioplastics in this research refers to the process conducted by Jabbar (2017) with several modifications, including variations in filler type, raw material ratio, mixing temperature and duration, as well as mold size. Bioplastic was created by dissolving raw materials in 220 ml of distilled water. The composition of potato peel starch used was 12 grams with variations of glycerol (0, 1.25, and 2.5 ml) and spirulina (0, 0.15, and 0.3 grams). Afterward, the solution was stirred and heated to 65°C for 1 hour to form a homogenous solution. The bioplastic solution was poured into a mold (33 x 23 cm) and dried at a temperature of 45-55°C for 30 hours. Once dried, the potato peel starch bioplastic film samples were removed from the mold and stored in a dry container for testing. The process flowchart for making potato peel starch bioplastic is presented in Figure 2.

Testing of mechanical properties

Testing of bioplastic film samples was conducted at the Center for Standardization and Service of Leather, Rubber, and Plastic Industries. This testing included *tensile strength*, *elongation*, and *thickness*.

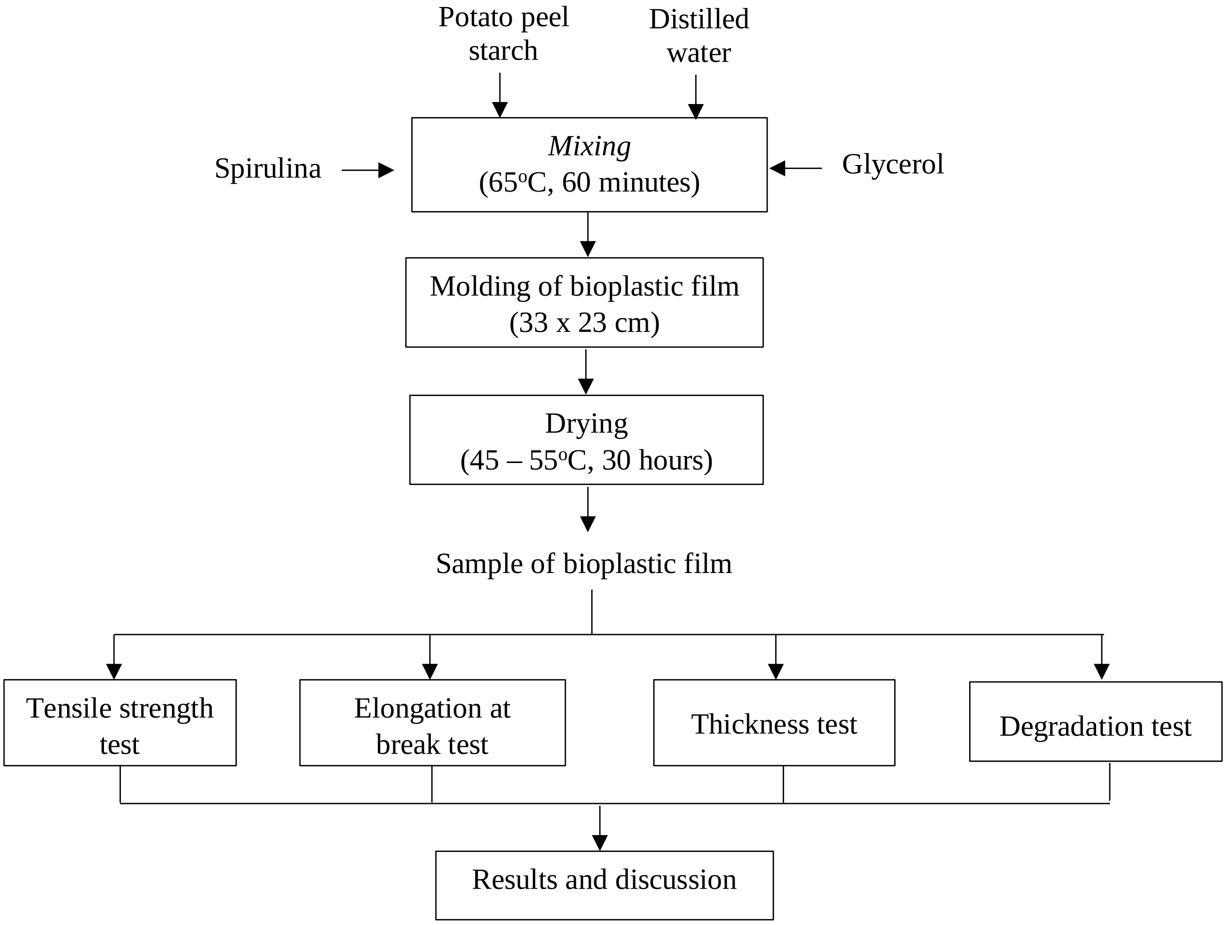


Figure 2. Flowchart of manufacturing bioplastic film

Degradation testing

Degradation testing is conducted to determine whether a material can degrade effectively in the environment. In this research, the degradation test for bioplastic follows the procedure outlined by Saputra & Supriyo (2020) using the *soil burial test* method. Bioplastic film samples, cut into 8 x 2 cm pieces, are weighed and then placed in containers filled with soil. The observation of bioplastic degradation is conducted over a period of 7 days. The level of bioplastic degradation can be calculated using the following formula.

$$\%\mathrm{m} = \frac{\mathrm{m_{first}} - \mathrm{m_{end}}}{\mathrm{m_{first}}} \times 100\%$$

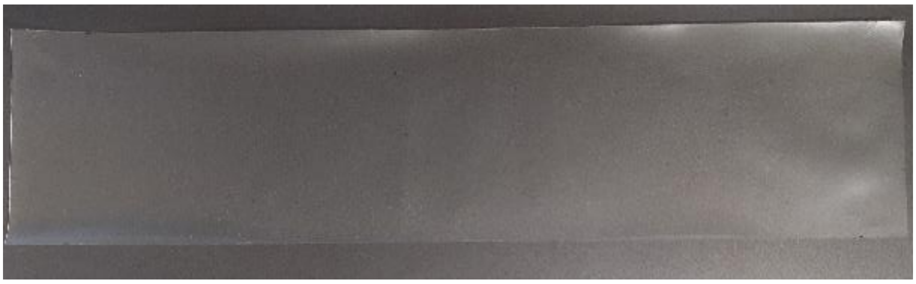
Notation

m_{first} = Mass before being buried in the soil (grams)

m_{end} = Mass before being buried in the soil (grams)

RESULTS AND DISCUSSION

The production of potato peel starch-based bioplastic films has been carried out, resulting in thin and transparent plastic, as shown in Figure 3. The composition in bioplastic has an impact on its morphology, where the untreated variable produces rigid bioplastic. In contrast, bioplastic with the addition of glycerol and spirulina produces more elastic bioplastic. This is consistent with the outcomes of a research conducted by (Layudha et al., 2015), where the addition of glycerol has an effect on the morphological quality of bioplastic.



(a)

(b)

Figure 3. Bioplastic film (a) untreated; (b) with the addition of glycerol & spirulina

Tensile strength

The tensile strength of bioplastic films was tested using the ASTM D 882-18 method. This test aims to determine the level of strength that can be achieved by potato peel starch bioplastic film before breaking or tearing. The equipment used was the Zwick Roell tensile tester with sample dimensions of 25 x 6 cm. The tensile strength values of potato peel starch bioplastic films can be seen in Figure 4.

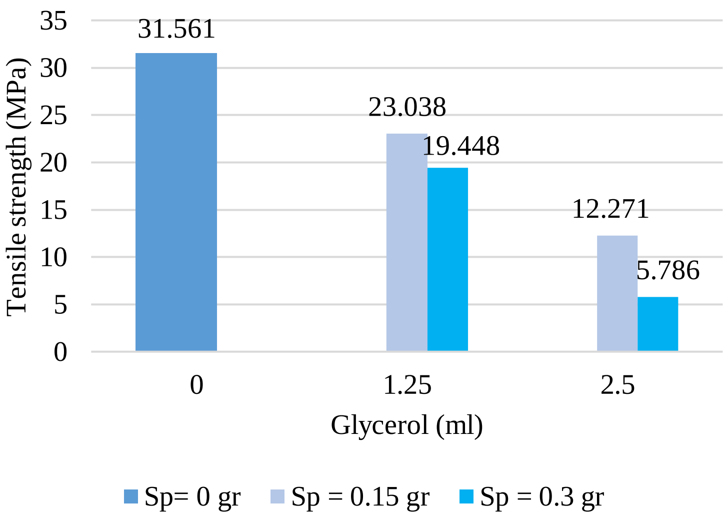


Figure 4. Tensile strength values of bioplastic film from potato peels starch

The results presented in Figure 4 indicate that the untreated variable has the highest tensile strength value, which is 31.561 MPa. Meanwhile, the lowest tensile strength is 5.786 MPa in the variation with 2.5 ml of glycerol and 0.3 grams of spirulina. The results obtained in this research are consistent with the research conducted (Merino et al., 2021), where the highest addition of glycerol, 30 grams, resulted in bioplastic film with the lowest tensile strength, which is 1.7 Mpa. The variable that influences tensile strength is the *plasticizer*. As stated by Nuriyah *et al*. (2018), a high addition of plasticizer will decrease the tensile strength of bioplastic.

Excessive *plasticizer* volume leads to a reduction in hydrogen bonds within the polymer chains, weakening the intermolecular forces between neighboring polymer chain segments, thereby reducing the strength of the bioplastic film (Nandika et al., 2021). The tensile strength value of bioplastics based on Indonesian National Standard 7188.8:2016 is 24.7 – 302 MPa. The bioplastic film sample that meets the SNI requirements has a tensile strength of 31.561 MPa in the untreated variable.

Elongation at break

Elongation is the maximum change in length when a bioplastic film is stretched until it breaks, which is expressed as a percentage of its original length (Harahap & Bukit, 2020). The method and equipment used in this test are the same as those used in the tensile strength test. The values for the elongation at break test are presented in Figure 5.

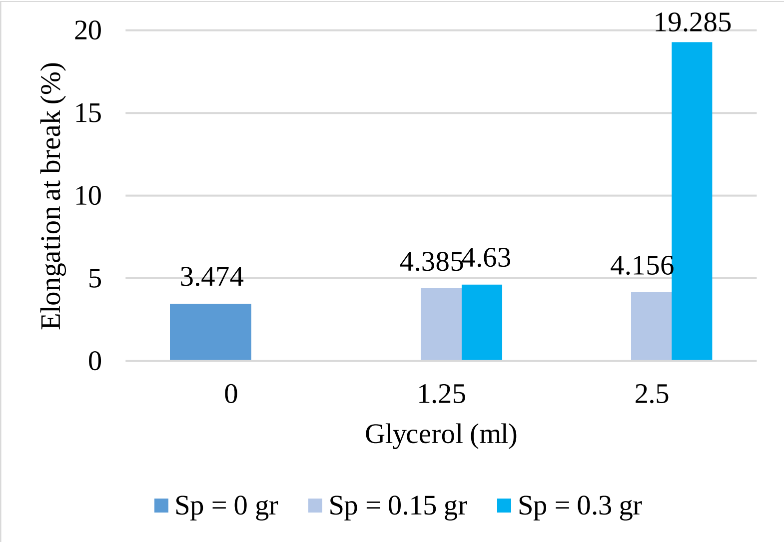


Figure 5. Elongation at break results of bioplastic film from potato peel starch

Based on the results presented in Figure 5, the elongation at break values for all samples range from 3.474% to 19.285%. The elongation at break of the bioplastic film increases proportionally with the addition of the plasticizer glycerol. This is consistent with a research by Setyaningrum *et al*. (2020), which states that the higher the glycerol added, the higher the elongation at break value produced. The addition of glycerol volume leads to a reduction in intermolecular forces along the polymer molecules, making the bioplastic more elastic and increasing its elongation at break (Darni et al., 2017).

The highest elongation at break value is found in the variation with 2.5 ml of glycerol and 0.3 grams of spirulina, which is 19.285%. Similar elongation at break values were obtained in the production of bioplastics from jackfruit seed starch with the highest glycerol addition of 30%, which yielded the highest elongation at break value of 15.76% (Lubis et al., 2018). The lowest elongation at break result in this study was 3.474% in the variation of untreated bioplastic film. According to the Indonesian National Standard (SNI), the percentage of elongation at break for bioplastic should be between 21% and 220%. Therefore, the percentage of elongation at break for bioplastic in this research does not meet the SNI requirements.

Thickness

The thickness of the bioplastic film was measured using *a thickness* gauge with the ASTM D 6988-13 method. The influence of varying glycerol and spirulina on the thickness of the bioplastic film is presented in Figure 6.

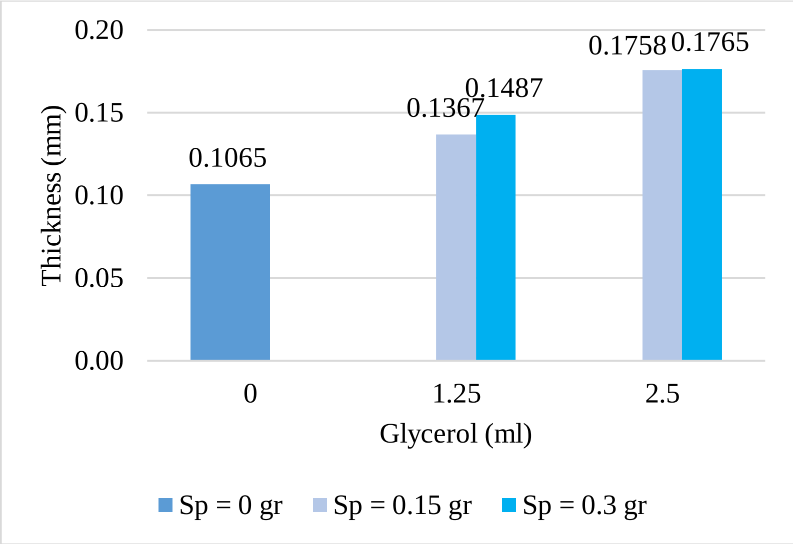


Figure 6. Thickness values of bioplastic film from potato peels starch

Based on Figure 6, the greater the amount of glycerol and spirulina added to the bioplastic, the higher the thickness value of the bioplastic. From the results obtained in Figure 6, the thickness of the bioplastic film increased by 0.03 mm with each addition of glycerol volume. The highest thickness was obtained from the variation of 2.5 ml glycerol and 0.3 grams of spirulina, which is 0.1765 mm. The increase in thickness value is influenced by the mass of solids dissolved in the bioplastic film production (Zaky et al., 2021). The thickness value of bioplastics in the research Susilawati *et al*. (2019) also provided the highest value, which is 0.332 mm in the variation of 2% chitosan and 20% gelatin, representing the composition with the highest solid mass among the other samples.

Degradation test

Degradation testing is one of the parameters that indicate whether the produced bioplastic film is environmentally friendly or not. This test aims to determine the time required for bioplastic to degrade by the microorganism in a particular environment (Budiman et al., 2018), such as being buried in the soil. The results of the degradation test of potato peel starch bioplastic films are presented in Figure 7.

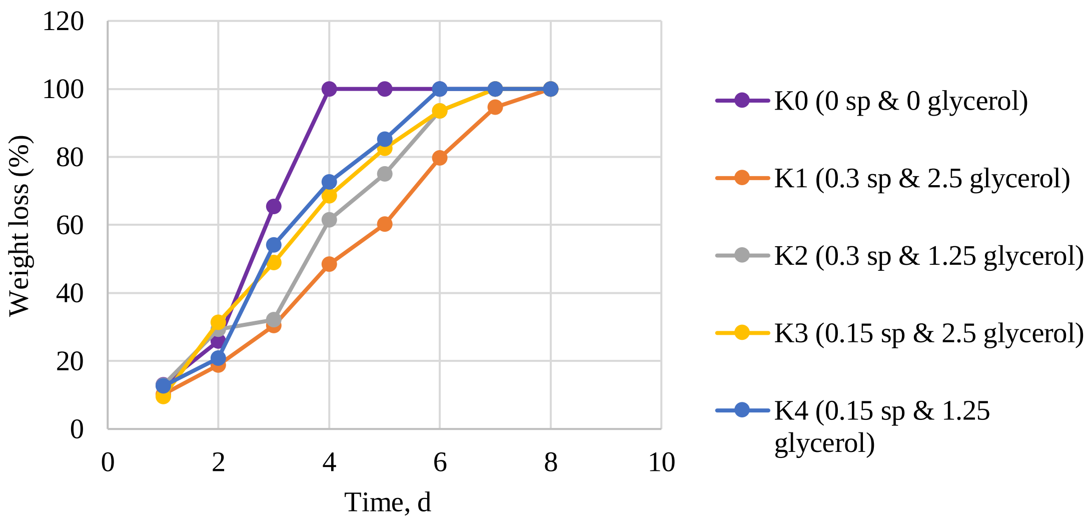


Figure 7. Degradation test values of bioplastic film from potato peels starch

Based on Figure 7, all samples of bioplastic films made from potato peel starch degraded within 4 to 8 days. The untreated sample (K0) degraded by 65.47% on the third day and completely degraded on the fourth day. This represents the fastest degradation time compared to the other samples. This occurred because bioplastic is derived from natural polymers and lacks additives that serve as antimicrobials, making it susceptible to faster degradation (Dwi Hartatik et al., 2014). These results are consistent with the research conducted by Nafilah & Sedyadi (2019) where untreated bioplastic degraded more rapidly than bioplastic with the addition of glycerol and sorbitol. The research conducted by Tan *et al*. (2022) also yielded similar results, indicating that starch-based bioplastics lose their weight more rapidly compared to bioplastics reinforced with chitosan. Chitosan contains antimicroba substances that act as preservatives (Sholihatunnisa et al., 2015).

On the sixth day, samples K1 and K2 degraded by 79.69% and 93.57%, respectively. Meanwhile, sample K3 degraded by 93.43%, and K4 degraded completely on the sixth day. In samples K1, K2, K3, and K4, spirulina was added to the bioplastic film. This occurred because spirulina contains phenolic compounds (Hayati et al., 2020) where these compounds act as antimicrobials (Detha & Datta, 2016). According to SNI 7188.7:2016, bioplastic degradation should be >60% within one week. Referring to the SNI, all bioplastic film samples in this research comply with the SNI in terms of degradation.

CONCLUSION

Based on the results of the conducted research, it can be concluded that the addition of variations in glycerol and spirulina has an impact on the mechanical properties of potato peel starch-based bioplastic films. The characterization results of the bioplastic films in this research yielded tensile strength values ranging from 5.786 to 31.561 MPa, elongation at break values ranging from 3.474 to 19.285%, thickness values ranging from 0.1065 to 0.1765 mm, and degradation times from the fourth to the eighth day. Sample K4 (1.25 ml glycerol and 0.15 grams spirulina) represents the optimum composition obtained in this research.

RECOMMENDATIONS

The recommendations in this research include the necessity of testing the starch content of the potato peel product. Additionally, Scanning Electron Microscopy (SEM) analysis is also required to determine the homogeneity level of the bioplastic film produced.

ACKNOWLEDGEMENTS

Gratitude is extended to Mr. Muhammad Fahmi Hakim, in his capacity as the supervising lecturer, for his invaluable guidance, directives, and input during the entire research process.

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