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The Effect of Beeswax and Glycerol Addition on the Performance of Bioplastic Film Made of Konjac Glucomannan

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Abstract

In this study, bioplastics made of Konjac glucomannan have been successfully prepared via film casting method. The effects of addition of beeswax content (i.e. of 0%, 0.5%, and 1%,), as well as glycerol content (i.e. 0.5%, 1%, and 1.5%) on the properties of the bioplastics have been investigated. The bioplastics produced have been characterized for their tensile strength, percent elongation, swelling degree, and biodegradability. The results of this study, showed that most of the bioplastic samples have weight loss of about 95% after the drying process as well as the finished film. The addition of beeswax and glycerol concentrations also increased tensile strength and percent elongation of the bioplastics. The highest value of tensile strength occurred at bioplastic film with a concentration of 1.5% beeswax and 1% glycerol (i.e. Sample C3) with a value of approximately 3.5 MPa. Whereas, the highest percent elongation value occurred at bioplastic film with a concentration of 1.5% beeswax and 1% glycerol (i.e. Sample C3) with a value of approximately 23.29%. These tensile and percent elongation values were higher or comparable to other bioplastic samples made from starch of different raw materials reported by literatures. In the other hand, the addition of beeswax and glycerol decreased the degree of swelling. The degree of swelling for all the bioplastic film samples were in the range of 316.77 – 481%.

INTRODUCTION

Synthetic plastics have become an essential part of human daily life due to its versatile use, economical value, and recyclability. Synthetic plastics have been applied in many industrial application, such as food packaging, toys, grocery bags, automotive, etc (Atiwesh et al., 2021; Amin et al., 2019). Nevertheless, synthetic plastic has several drawbacks. Conventional synthetic plastics are produced from petroleum-based raw materials or monomers such as ethylene, propylene, styrene, etc. which are non-renewable resources (Atiwesh et al., 2021). Additionally, these synthetic plastics are also non-biodegradable or difficult to decompose, therefore the use of synthetic materials has a major impact on environmental pollution. Plastic micro-particles and other plastic-derived pollutants are scattered in our environment threatening both humans and animals. Humans are trying to overcome environmental pollution due to plastic waste by making bioplastics. Bioplastics has become a promising alternative to conventional plastics and their uses (Moshood et al., 2022). Also, the use of bioplastic can decrease the emission of greenhouse gas indirectly (Moshood et al., 2022). Bioplastics are type of plastics that are 1) biodegradable; or 2) may or not be degradable but are made from biomaterials or renewable materials/feed stocks. While, "biodegradable" means that these plastics are easy to decompose or compostable materials that are able to be converted almost entirely into benign trash in months (Atiwesh et al., 2021). The bioplastic degradation process is influenced by the type of raw materials used, the concentration, and the environmental conditions of the burying (Zoungranan et al., 2020).

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Starch is one type of promising biomaterials for production of bioplastics due to its biodegradability and renewability (Amin et al., 2019; Garcia et al., 2020). Starch is a natural polymer which composed of amylose (straight structure) and amylopectin (branched structure). It is a product of photosynthesis process and stored in certain parts of the plant as a food reserve. The type of starch depends on the type of plant and where it is stored. It is mainly deposited in roots, tubers, or seeds (Pfister & Zeeman 2016; Garcia et al., 2020). Starch can be obtained by extracting from plants rich in carbohydrates such as sago, rice, cassava, corn, wheat, yam, sweet potatoes, etc. Starch can also be extracted from fruit seeds such as jackfruit seeds, avocado seeds, and durian seeds (Garcia et al., 2020; Cornelia et al., 2013). There are two types of starch that are often used in industry, namely natural starch and modified starch. Natural or conventional starch is starch that naturally produced from the plants and has not undergone changes in physical and chemical properties. It has been decades that modification of starch structures has been implemented to enhance some weak characteristics or properties in starch, e.g. short disintegration time, compression difficulty, low agglutination properties, etc. When the structure of this starch is changed, then the starch is called modified starch. This modification can give higher added values compared to its conventional ones (Garcia et al., 2020).

The process of making bioplastics from starch can be done by a simple casting techniques (Hamid et al., 2022). Bioplastics can also be molded using a hot press or using a molding machine (Vadori et al., 2013). Research on bioplastics is growing very rapidly over the world. Bioplastics in this study were made from a mixture of Konjac glucomannan with addition of glycerol and beeswax as a plasticizer. There have been numerous research studies that have been done to investigate the production of starch-based bioplastics (Özdamar & Murat, 2018; Oluwasina et al., 2021; Ismail et al., 2016; Anugrahwidya et al., 2021; Santana et al., 2018; Abdullah et al., 2019). Nevertheless, literatures that studied specifically about the combination of those three components are still limited. Therefore, it is a good topic for research in the production of bioplastics.

MATERIALS AND METHODS

Sample Preparation

To prepare the bioplastics, several materials were used such as: konjac glucomannan flour, DI water, beeswax, and glycerol. Several tools were also used such as: measuring cup 250 mL, digital scales, stirrer, hot plate, aluminum foil, pipette, beaker glass 1000 mL, mechanical stirrer, oven, 20 x 20 cm mold. Table 1 shows the sample nomenclature with the addition of glycerol and beeswax (wt.%). The ratio of konjac glucomannan flour: DI water for all the samples was 1:25 w/w.

Table 1. Sample nomenclature.

Sample	Glycerol conc. (wt%)	Beeswax conc. (wt%)
A1		0.5
A2	0	1
A3		1.5
B1		0.5
B2	0.5	1
B3		1.5
C1		0.5
C2	1	1
C3		1.5

The preparation of bioplastic film was done by firstly mixing 10 g of Konjac Glucomannan and 250 ml of distilled water and then adding beeswax and glycerol with the ratio (wt%) as mentioned in Table 1. Afterward, the mixture was put in a 1000 ml beaker and stirred for 20 minutes until homogeneous using a mechanical stirrer. After the ingredients are evenly mixed, then heated to a temperature of 70°C and kept stirred for 1 hour 30 minutes until thickened. While waiting for the stirring process, the mold is placed in the oven. After the mixing is complete, the solution is poured into hot molds and then dried in the oven. The hot mixture was poured into the hot mold in order to maintain the temperature of the beeswax in the mixture when it touches the mold so that there was no clumping of beeswax due to high temperature gradient.

Sample Characterization

The characterization of the material is carried out by three types of testing of the material

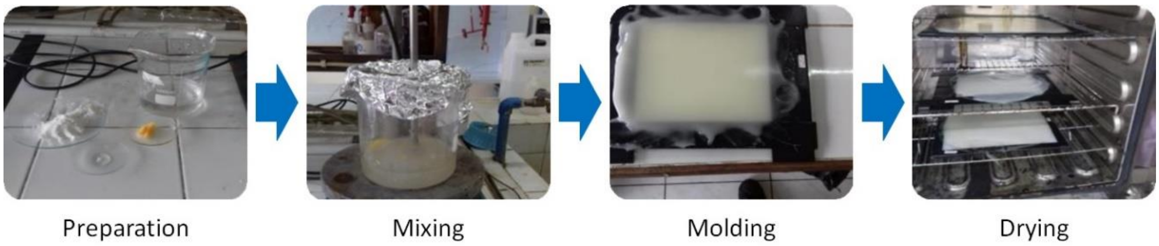


Figure 1. Schematic step of the bioplastic film preparation.

including the swelling test, tensile test, and biodegradation test. From the test results will be analyzed and used to determine the characterization of the film.

Swelling Test

The swelling test was carried out using the ASTM D570 standard. ASTM D570 is a standard used to make water absorption tests of plastics. To perform the swelling test, the first sample was prepared at a size of 2 cm x 2 cm. Then the sample was conditioned in an oven at 50°C for 24 hours. The sample was then soaked for 2 hours and then weighed the obtained final mass, from this data get the degree of swell by using the Eq. (1).

$$W_m = \frac{m_2 - m_1}{m_1} \times 100\ \% \quad (1)$$

Where m_1 is the initial sample mass and m_2 is the final sample mass.

Tensile Test

The tensile test was carried out using based on the ASTM D882 standard by using a Tenso lab equipment. For the test, a rectangular sample with size of 2.5 x 10 cm was used.

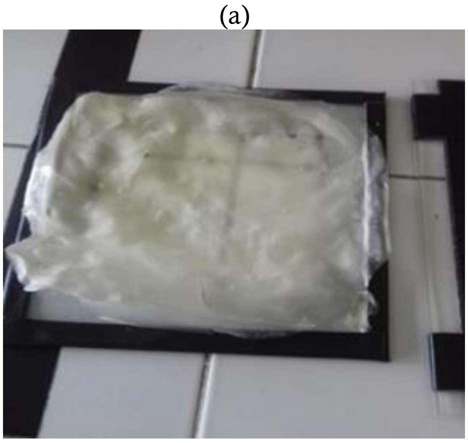
Biodegradation Test

This test determine the biodegradability of the bioplastic film sample by utilizing Effective Microorganism or EM4 bacteria, which is a type of composting microorganism that is commercially available in the market at an affordable price. The test was carried by placing a sample of the film in a container and then adding 10 ml of Effective Microorganism or EM4 bacteria and left to degrade.

RESULTS AND DISCUSSION

Figure 2 shows the photographs of the bioplastic samples before and after the drying process. During the preparation of bioplastic samples, the mass of the samples was weighed before and after the drying process, as shown in Table 2. It is noted that the weight loss percentage of the bioplastic film was within 95 – 96 wt%. The dried samples were then further characterized, such as: tensile test, and biodegradation test, swelling test.

(a)



(b)

Figure 2. Photographs of the bioplastic sample (a) wet (b) dry.

Tensile Test

The tensile test was carried out based on the ASTM D882 standard with a rectangular sample with a size of 2.5 x 10. Whereas, the average thickness of the bioplastic films was about 0.4 mm. The tensile test was conducted in Textile

Table 2. Sample of mass in drying process.

Sample	Wet sample (g)	Dried sample (g)	wt% loss
A1	171.56	7.54	95.61
A2	177.54	6.78	96.18
A3	180.65	7.78	95.69
B1	168.90	6.43	96.19
B2	175.87	6.76	96.16
B3	177.60	5.99	96.63
C1	157.84	5.84	96.30
C2	176.90	7.77	95.61
C3	175.65	7.81	95.55

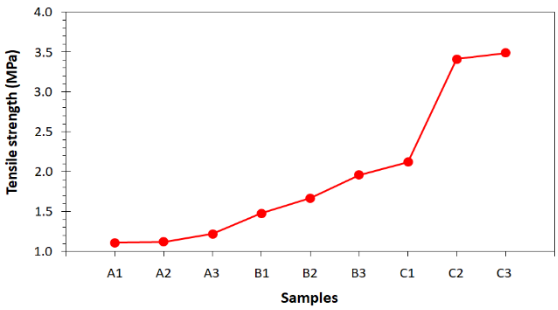


Figure 3. Tensile strength of the bioplastic samples.

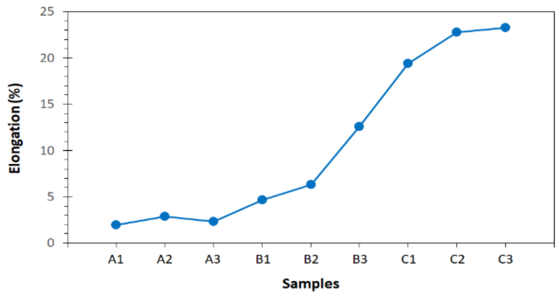


Figure 4. Percentage elongation of the bioplastic samples.

Evaluation Laboratory of Universitas Islam Indonesia by using a Tenso lab equipment. From this test, several physical and mechanical properties were obtained, i.e. tensile strength, elongation, and the value of the thickness of the bioplastic. Figure 3 shows the result of tensile test of all bioplastic film samples. As shown in the figure, the highest tensile value occurred at bioplastic film with a concentration of 1.5% beeswax and 1% glycerol (i.e. Sample C3) with a value of approximately 3.5 MPa, while the smallest tensile value occurred at bioplastic film with a concentration of 0.5% beeswax and without glycerol (i.e. Sample C1) with a value of approximately 1.11 MPa. In the other hand, the percentage elongation properties of the bioplastic film samples were plotted in Figure 4. As shown in the figure, the highest elongation value occurred at bioplastic film with a concentration of 1.5% beeswax and 1% glycerol (i.e. Sample C3) with a value of approximately 23.29%, while the smallest elongation value occurred at bioplastic film with a concentration of 0.5% beeswax and without glycerol (i.e. Sample C1) with a value of approximately 2.00%. These values of tensile strength and percent elongation were comparable to other bioplastics made from starch and other different raw materials as reported in the literatures. The highest tensile strength of bioplastic prepared in this study (i.e. 3.5 MPa) was higher than that of corn starch-based bioplastics reported by S. Gujar, et al (Gujar et al., 2014), which was about (1.46 MPa). The percent elongation of current bioplastics also higher than that of bioplastics reported by Oluwasina et al. (2019). Also comparable of even higher than other literatures with different starch-based raw materials (Gabriel et al., 2021), yam-starch based (Behera et al., 2022), durian seed-based (Cornelia et al., 2013) and jack fruit-based (Santana et al., 2018), etc.

Swelling Test

In carrying out the swelling test, the sample was prepared at a size of 2 cm x 2 cm. Then the sample was conditioned in an oven at 50°C for 24 hours. The sample was then soaked for 2 hours. Table 3 shows the swelling test results of the bioplastic samples. Based on the table, there was a decrease in the degree of swelling with the increase of concentration of beeswax. The addition of beeswax is compatible with the starch-based glucomannan biopolymer, as it helps to reduce the degree of swelling. This is because beeswax has hydrophobic properties. Hydrophobic properties are properties where the material does not have an affinity for water, so that bioplastics containing beeswax are expected to easily repel water and

Table 3. Swelling test results of the bioplastic samples

Sample	Weight of sample		Swelling percentage (%)
	Before (g)	After (g)	
A1	0.33	1.922	481.45
A2	0.27	3.27	475.33
A3	0.49	2.67	445.32
B1	1.11	5.82	424.33
B2	0.61	2.80	360.44
B3	0.8	3.59	349.67
C1	0.5	2.20	340.45
C2	0.48	2.02	321.28
C3	0.7	2.91	316.77

hinder the swelling process. The ability of bioplastic to hinder the swelling process due to moisture/water absorption is good for durability of the bioplastics. The minimum swelling degree value of bioplastics produced in this study was 316.77 % (i.e. Sample C3). If compared with other bioplastics made from durian seed with a value of 200% (Cornelia et al., 2013), the swelling degree value of the bioplastic produced in this study is still relatively high.

Biodegradation Test

To further analyze the biodegradability properties of bioplastic sample, a biodegradation test was carried out by the help of effective microorganisms or EM4 bacteria, in the form of a composting bacteria. The biodegradation test was carried out in aerobic process (i.e. open air). The test was carried out by first immersing the prepared bioplastic sample in EM4 liquid for 2 hours. The next step was to dry the sample in an open space at ambient temperature for 7 days. The physical appearances of bioplastic film samples before and after the biodegradation test can be seen in Table 4. As noticed in Table 4, the appearances of bioplastic film samples that have been aerated for 7 days have changed in color and physical shape. In general, the color of the bioplastic film samples changed from initial bright yellow color to black and brown. Also, the shape of the sample shriveled and become irregular. Additionally, for samples A1 to A3, in which the samples did not contain glycerol, the degradation process was almost complete. In the other hand, samples containing glycerol (B and C samples) still leave a white appearance on some parts of the surface. Nevertheless, the biodegradability performance of the bioplastics film produced in this study were quite good. According to ASTM 5336 standard, it would take time of 60 days for the bioplastics to be 100% biodegraded. Therefore, all bioplastic samples produced in this study can be categorized as biodegradable plastics.

CONCLUSION

Bioplastic films made from a mixture of Konjac glucomannan with glycerol and the addition of beeswax as a plasticizer have been successfully prepared via film casting method. The prepared bioplastic has also been characterized for their tensile strength, percent elongation, swelling degree, and biodegradability. From all the tests, it can be concluded that the addition of beeswax and glycerol concentrations increased the tensile strength and elongation of the bioplastics. Most of the bioplastic samples have weight loss of about 95% after the drying process as well as the finished film. The higher the concentration of beeswax and glycerol causes a decrease in the degree of swelling. The value of the degree of swelling of the sample test is between 316.77 – 481%. The addition of beeswax slightly decreases the rate of biodegradation. The highest value of tensile strength occurred at bioplastic film with a concentration of 1.5% beeswax and 1% glycerol (i.e. Sample C3) with a value of approximately 3.5 MPa. Whereas, the highest elongation value occurred at bioplastic film with a concentration of 1.5% beeswax and 1% glycerol (i.e. Sample C3) with a value of approximately 23.29%.

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Table 4. Biodegradation test results of bioplastic film samples

Sample	Glycerol (wt%)	Beeswax (wt%)	Before	After
A1		0.5		
A2	0	1		
A3		1.5		
B1		0.5		
B2	0.5	1		
B3		1.5		
C1		0.5		
C2	1	1		
C3		1.5		

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