Journal of Engineering Science and Technology
Vol. 18, No. 1 (2023) 235 - 243

PHYSICAL RESISTANCE OF CORN STARCH BASED BIOPLASTIC AT VARIOUS STORAGE TEMPERATURE

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Abstract

Bioplastic is an alternative to the use of conventional plastics because bioplastics are easily biodegradable and environmentally friendly. Bioplastics are expected to have the function of protecting products in storage especially for food. This study aims to analyse the effect of different storage temperature on mechanical properties of bioplastic. The use of corn starch as matrix on bioplastic shows great potential. Corn starch-based bioplastic was added nanofiber cellulose (NFC) 3% and glycerol 30%. Bioplastics were tested at 3 different storage temperatures which were at room temperature (20-25 ℃), cold temperature (5-10 ℃) and freezing temperature (-5-10 ℃). The aspects studied were tensile strength value, elongation at break using ASTM D882-02, water vapor permeability of bioplastic and morphological properties using scanning electron microscopy. Mechanical characteristics (tensile strength and elongation at break), permeability, and morphology of bioplastics were not significant at various storage temperatures. The highest value of tensile strength is 17.44 MPa on day 1 at freezing temperature (-5-10 ℃). Meanwhile, the highest value of elongation at break is 2.59 % on day 3 at cold temperature (5-10 ℃). The highest value of water vapor permeability bioplastic is 48.5 gram/m^2.hour at room temperature (20-25 ℃). Morphology of bioplastic based on scanning electron microscopy show there were no morphological changes and damage such as holes, tears or wrinkles on 3 different storage temperatures.

Keyword: Biodegradable, Bioplastic, Corn starch, Nanofiber cellulose, Storage temperature.

1. Introduction

Currently, the use of plastic is increasing from various sectors, both the industrial sector and the household sector. Plastics are often used as food and beverage packaging materials, components and containers for electronic equipment, furniture and others [1]. In Indonesia, the annual record of plastic use reaches 5.045.714 tons until 2021 [2]. Plastics are usually produced from petroleum derivatives such as polyethylene which are difficult to decompose and become an environmental problem. Hence, there is an alternative to using plastic with bioplastic that is easily biodegradable.

Bioplastics are attracting research attention currently and many developments have been carried out in bioplastics because they are considered bioplastics to reduce environmental pollution. Biodegradable plastics can decompose by the activity of microorganisms to produce CO_2 and H_2O as final product [3]. Bioplastics can made from starch, chitosan, cellulose, extracted from protein from renewable biomass [4]. The use of starch as matrix in bioplastics is often used because starch is considered easy to obtain and often applied as packaging [5]. Starch has advantages when used bioplastic raw material, namely permeability low oxygen. However, starch has a tendency to absorb air from air due to its hydrophilic nature. So that low mechanical properties and transmission rate high water vapor [6]. To outgrow the low mechanical properties of starch-based bioplastics, it is necessary to add other components that can increase the mechanical strength of bioplastics.

The manufacture of bioplastics required reinforcement such as fillers that can improve the mechanical properties of bioplastics. The use of nanofiber cellulose in bioplastic modification is currently being carried out. Nanofibers have advantages due to their large surface area, high modulus of elasticity, porous structure and high chemical reactivity [7].

Several studies have been conducted in the manufacture of starch-based bioplastics with cellulose nanofiber fillers, such as Syafri et al [8] making tapioca flour-based bioplastics with cellulose nanofiber fillers from hemp fiber, which resulted in the highest tensile strength and crystallinity index of 12.84 MPa and 30.76%, respectively. Xu et al [9] made amylose (AM) based bioplastic from barley flour and nanofiber cellulose (CNF) from sugar beet pulp. The admixture of CNF into the AM matrix significantly increased the crystallinity, mechanical properties and permeability, while glycerol increased the elongation at break, especially with AM plasticization.

Bioplastics like packaging conventional plastics are expected to have function of protecting the product in storage including in cold-freeze conditions. Therefore, bioplastics are required to have good physical and mechanical properties against various storage temperatures so that can protect the product. Asgar [10] has conducted research on the effect of storage temperature at 5 °C, 10 °C, 15 °C and room temperature and the type of packaging on physical and chemical quality of carrot which produces temperature of 5 °C was the storage temperature that could maintain changes in the characteristics of the carrot.

Meanwhile, Iflah [11] conducted a study to determine the cold storage characteristics of agricultural products from climacteric products (tomatoes) and non-climacteric products (peppers) packaged in fruit bags made of bioplastic compared to HDPE. Packaged products were stored at three levels of storage temperature (5, 10 and 15 ºC) for 21 days. The results showed that bioplastic packaging could delay the climacteric phase of tomatoes until the 21st day of storage, longer than HDPE packaging. Bioplastic packaging is not suitable for low temperature storage (5-10 ºC). Tomatoes and peppers packed with bioplastic gave better colour change and hardness during storage at 15 ºC.

Bioplastics are expected resistant to damage so that it does not break when deformation occurs. This research is aim to study the characteristics of corn starch as bioplastic material and nanofiber cellulose as filler and evaluate the characteristics mechanics, water vapor permeability and morphology bioplastics produced in 3 different storage temperatures which were at room temperature (20-25 ℃), cold temperature (5-10 ℃) and freezing temperature (-5-10 ℃).

2. Material and Method

2.1. Materials

Oil palm mesocarp fiber used in this study were supplied by Palm Oil Mill (PKS) Tanjung Sementok, Aceh Tamiang, Aceh, Indonesia and for isolated nanofiber cellulose used nitric acid (HNO_3), sodium nitrite ($NaNO_2$), sodium hydroxide (NaOH), sodium sulfite (Na_2SO_3), sodium hypochlorite (NaOCl), hydrogen peroxide (H_2O_2), sulfuric acid (HCl) and hydrochloric acid (HCl). All chemical used was laboratory grade. Chemical-ultrasonic processes and isolated nanofiber cellulose were executed at Organic Chemical Laboratory in Department of Chemical Engineering, Universitas Sumatera Utara, Indonesia. Analytical grade glycerol, food grade corn starch was used for bioplastic preparation.

2.2. Extraction of nanofiber cellulose

Oil palm mesocarp fibers are washed thoroughly and then dried in the sun for 1-2 days. Then, oil palm mesocarp fibers were delignified using 1 L of 3.5% HNO_3 solution and 10 mg $NaNO_2$ at 90 °C for 2 hours, then sample was digested using 750 ml of 2% NaOH solution and Na_2SO_3 for 1 hour at 50 °C. Sample was washed and filtered then bleached with 250 ml of 1.75% NaOCl for 30 minutes at boiling temperature. Then reacted with 500 ml of 17.5% NaOH solution for 30 minutes at 80 °C to obtain alpha-cellulose. After washing and filtering, the alpha-cellulose was bleached using 10% H_2O_2 solution. To obtain cellulose nanofibers using a chemical-ultrasonic process with ultrasonic waves and chemical solutions using a mixture of 5% HCl and 5% H_2SO_4 at a temperature of 60 °C for 0.5 hours [12].

2.3. Preparation of bioplastic

10 grams of corn starch as matrix was stirred in 75 mL aquadest and heated for 15 min at 60 ℃. Nanofiber cellulose (NFC) with 3 wt% of matrix was dissolved by 25 mL aquadest and added in corn starch solution. The blended solution was followed by glycerol 30 wt% of matrix and heated at 75 ℃. The mixture solution was casted on glass plates and dried. Bioplastics were tested at 3 different storage temperatures which were at room temperature (20-25 ℃), cold temperature (5-10 ℃) and freezing temperature (-5-10 ℃). Each bioplastic was stored at 3 different storage temperatures for 5 days. Bioplastic changes are observed every day. After 5 days, the bioplastic will be tested for mechanical properties, permeability and morphology characteristics. The overall preparation of bioplastic can be seen on Fig. 1.

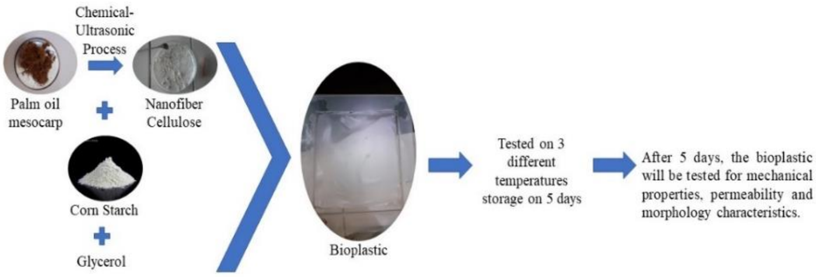


Fig. 1. Overall methodology.

2.4. Mechanical properties and characterization

Tensile test and elongation at break test were performed by Instron Universal Testing Machine based on the ASTM D882-02 in Polymer Laboratory, Chemical Engineering, Universitas Sumatera Utara. Tensile test and elongation at break test were carried out with the specimen size according to ASTM standards and the dimensions used are in accordance with the size of the tool. Figure 2 shows the geometry and dimension tensile strength test specimen of bioplastic. 3 specimens were analysed for each treatment.

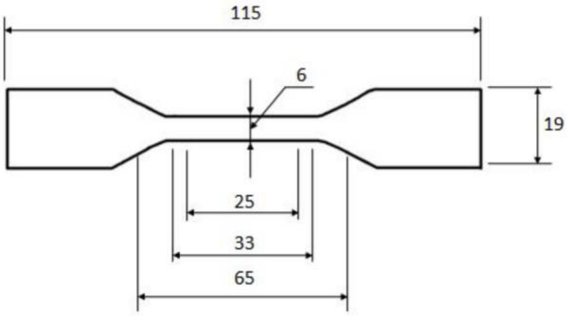


Fig. 2. Geometry and dimension tensile strength test specimen of bioplastic (unit in mm) [13].

Scanning Electron Microscope (SEM) Morphological investigations were performed on bioplastic films of corn starch by using SEM machine model (HITACHI TM 3000) in Research Laboratory, Universitas Sumatera Utara. SEM images were produced with magnification of 250 times.

2.5. Water vapor permeability test

Bioplastic film (1×2 cm) was placed in on the mouth of a porcelain dish with a diameter of 7 cm and a depth of 2 cm filled with 10 grams of silica gel. Glue the edges of the film and porcelain dishes together with glue. Put the porcelain cup into a container containing 40% NaCl (w/v). The film changes were calculated every 1 hour until the weight was constant. Water vapor permeability was calculated by Eq. (1).

$$WVP = \frac{linear\ slope\ for\ the\ change\ in\ weight\ of\ a\ jar\ (g/hour)}{Surface\ area\ (m^2)} \tag{1}$$

3. Results and Discussion

3.1. Effect of storage at various temperatures on tensile strength and elongation at break corn starch based bioplastic

Figure 3 shows the effect of storage at various temperature on tensile strength corn starch-based bioplastic with NFC as filler. Meanwhile, on Fig. 4 showed the effect of storage at various temperature on elongation at break value on bioplastic. This test was carried out after being determined based on the value of the best tensile strength on the addition of 3% cellulose nanofiber and 30% glycerol, then the samples were stored at 3 storage temperature conditions, namely room temperature (20-25 °C), cold temperature (5-10 °C) and freezing temperature (-5-10 °C).

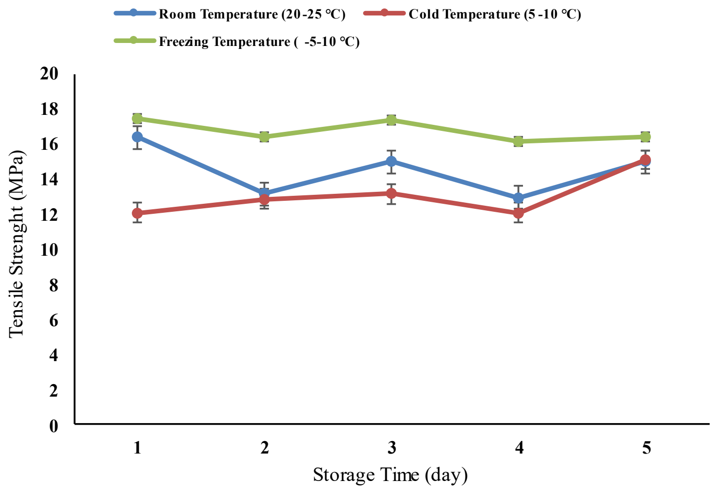


Fig. 3. The effect of storage at various temperature on tensile strength corn starch-based bioplastic with NFC as filler.

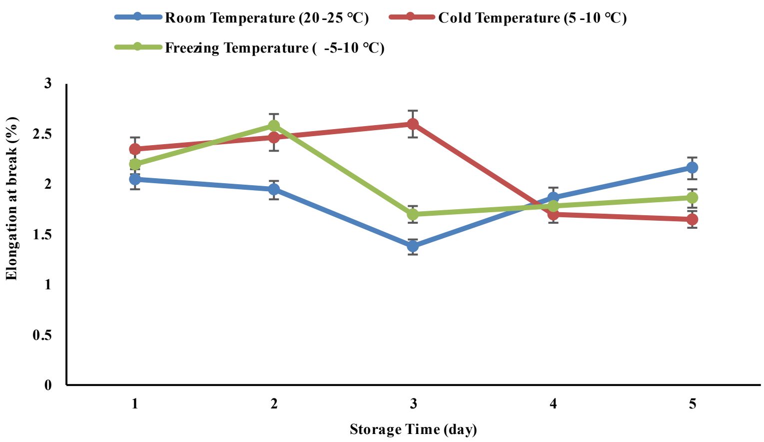


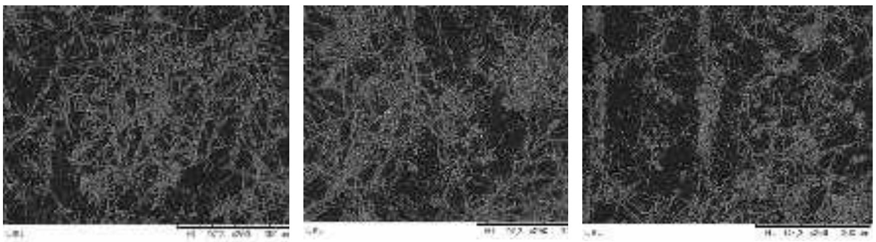
Fig. 4. The effect of storage at various temperature on elongation at break corn starch-based bioplastic with NFC as filler.

Based on Figs. 3 and 4, it can be seen that the tensile strength and elongation at break values at 3 storage temperatures tend to be constant. The highest value of tensile strength is 17.44 MPa on day 1 at freezing temperature (-5-10 ℃). Meanwhile, the highest value of elongation at break is 2.59 % on day 3 at cold temperature (5-10 ℃). There was no significant change from day 1 to day 5. This shows that that storage at low temperatures either cold or freezing temperatures does not because bonds formed between filler, starch and glycerol become easily broken/weak. Cold and freezing do not make the density between molecules are stretched or expanded [14].

This condition was also reported by Waryat [14] that the tensile strength value of bioplastics made from TPS/LLDPE and TPS/HDPE tended to be constant from day 0 to day 5 under storage conditions at room temperature, cold temperature and freezing temperature. Pranta [15] stated that low temperature storage did not show a significant change in mechanical properties compared to high temperature. In addition to temperature, the short storage time does not cause significant changes/damage to the mechanical properties of bioplastics.

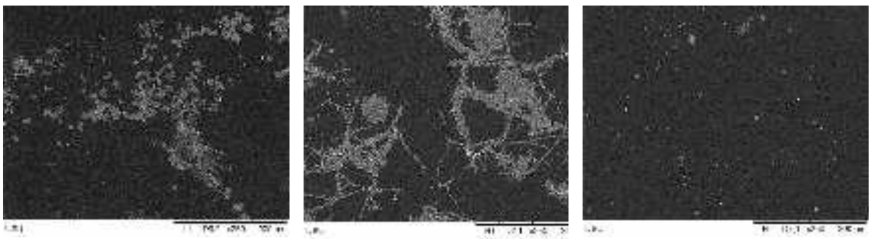
3.2. Morphological characteristics of corn starch based bioplastic filled with cellulose nanofiber palm fruit fiber at various storage temperatures

Figure 5 shows the morphological characterization of the bioplastic surface at 3 different storage temperatures using a scanning electron microscope (SEM).



(a)

Room temperature (20-25 ℃) **Cold temperature (5-10 ℃)** **Freezing temperature (-5-10 ℃)**



(b)

Room temperature (20-25 ℃) **Cold temperature (5-10 ℃)** **Freezing temperature (-5-10 ℃)**

Fig. 5. Morphology of surface bioplastic at various storage temperature using scanning electron microscope (SEM) with magnification 250× (a) Before storage (0 day) and (b) after day-5.

It can be seen in 3 specimens with different temperatures at 0 day showing uneven surface morphology. Meanwhile, on day 5, each specimen with 3 storage temperatures showed better surface, no damage occurred. This shows that storage at low temperatures can inhibit or slow down the reaction rate of microorganisms, so that at low temperatures it will slow down and slow down the growth of microorganisms. The use of low temperatures cannot kill microorganisms, only inhibit the microorganisms [16].

3.3. Water vapor permeability of bioplastic

Figure 6 shows the effect of different storage temperatures on the value of water vapor permeability on bioplastics. Water vapor permeability is calculated through the water vapor transmission rate (WVTR).

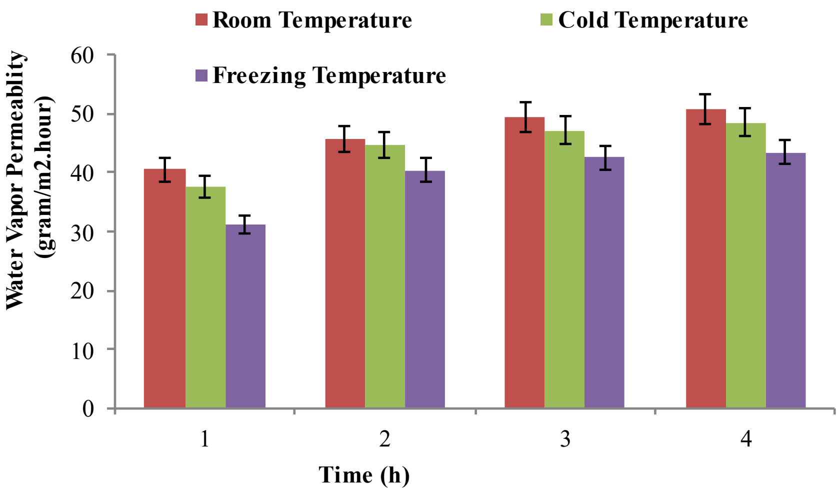


Fig. 6. The effect of storage at various temperature on water vapor permeability of bioplastic.

The permeability value of a packaging material needs to be known because it can be used to estimate the shelf life of packaged products. In addition, the permeability value can be used to determine what packaging is suitable for a particular product. In Fig. 6, it can be seen that the water vapor permeability value of the specimen at room temperature storage is 40.62 gram/m^2.h, 45.75 gram/m^2.h, 49.50 gram/m^2.h and 50.62 gram/m^2.h and cold temperature storage, the water vapor permeability value is 35.50 gram/m^2.h, 44,62 gram/m^2.h, 47,12 gram/m^2.h and 48.50 gram/m^2.h. Meanwhile the water vapor permeability value at freezing temperature is 31.25 gram/m^2.h, 40.37 gram/m^2.h, 42.50 gram/m^2.h and 43.50 gram/m^2.h.

Based on Fig. 6, the value of water vapor permeability of bioplastic tends to increase with time. Nanofiber cellulose as filler increases the O-H bending interaction between NFC members so that the glycerol and starch molecules freely interact with water molecules. In addition, glycerol which acts as plasticizer is hydrophilic so that the transfer of water vapor from the environment to the surface of bioplastic becomes faster. Small molecules in glycerol will more easily enter the amorphous network of starch so that there is more space and opportunity for water to be adsorbed and water transfer in the film [17].

The value of water vapor permeability at room temperature is higher than at cold temperature (5-10 ºC) and freezing temperature (-5-10 ℃). Meanwhile, the value of water vapor permeability at freezing temperature (-5-10 ℃) tends to be lower than at cold temperature (5-10 ºC) and room temperature (20-25 ℃) because rate of evaporation of water depends on the temperature so that the rate of evaporation increases as the temperature increases. At low temperatures, evaporation of water occurs very slowly or low rate [18].

4. Conclusion

Storage temperature has an influence on the quality of bioplastic resistance based on the results of the water vapor permeability test. The highest value of water vapor permeability bioplastic is 48.5 gram/m^2.hour at room temperature (20-25 ℃). The highest value of tensile strength is 17.44 MPa on day 1 at freezing temperature (-5-10 ℃). Meanwhile, the highest value of elongation at break is 2.59 % on day 3 at cold temperature (5-10 ℃).

Based on mechanical properties of bioplastic, there was no significant change from day 1 to day 5. This shows that storage at low temperatures either cold or freezing temperatures does not because bonds formed between filler, starch and glycerol become easily broken/weak.

Cold and freezing do not make the density between molecules are stretched or expanded Morphology of bioplastic based on scanning electron microscopy show there were no morphological changes and damage such as holes, tears or wrinkles on 3 different storage temperatures.

Storage time is quite short so it has not shown significant results. further research should be carried out by increasing the storage time so that significant results are obtained.

Acknowledgement

This research was financially supported by Ministry of Research and Technology and the Higher Education Republic of Indonesia on “Hibah Penelitian Dasar Unggulan Perguruan Tinggi” research grant 2019-2021.

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