2nd International Conference Eco-Innovation in Science, Engineering, and Technology
Volume 2021
http://dx.doi.org/10.11594/nstp.2021.1403

NST PROCEEDINGS

Conference Paper

The Effect of Chitosan and Sorbitol Addition in The Bioplastics Production from Mung Bean Starch

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ABSTRACT

Plastics pollution is a worldwide concern causing many problems in our environment. Plastics were difficult to recycle. Therefore, biodegradable materials such as starch are appealing to replace fossil-based plastics. Starch-based plastics were blended with another natural polymer like chitosan and sorbitol as a plasticizing agent to improve their properties. In this study, the mechanical properties and degradability of the films were evaluated. The mechanical parameter studied were tensile strength, elongation, and young's modulus. A higher ratio of chitosan in the blend would increase the tensile strength and young's modulus. The film consisted of 40% chitosan in polymer blend and 20% sorbitol resulted in 13.33 MPa on tensile strength and 241.98 MPa on young's modulus. On the other hand, the more sorbitol added in polymer blends increased the film elongation and decreased other parameters studied. With 60% sorbitol added into the blends resulted in greater film elongation but low tensile strength. All films blended could degrade in a relatively short time, about 6 to 16 days, with the presence of EM4 microorganisms.

Keywords: Bioplastic, starch, chitosan, sorbitol

Introduction

Nowadays, plastics are widely used in everyday life for packaging or other uses due to their availability and low prices. With the plastics application trends up, it is also accompanied by the increase in plastics waste. From 8.3 billion metric tons of plastics production, the waste produced amounted to 6.3 thousand metric tons and was only 9% recycled (Shafqat et al., 2021). This condition was very harmful to our environment because of the difficulty of plastics waste being degraded naturally.

The alternative to replacing conventional plastic produced from petroleum was using biodegradable material such as starch. Starch is abundant, inexpensive, biodegradable, and has been applied in many areas such as food, packing, and medicine (Liu et al., 2018). One of the starch sources is the mung bean that is easily found in many countries. Mung bean in Indonesia is one of the important legume food crops, ranked after soybeans and peanuts. The production value of mung bean in 2017 was 241,334 tons and in 2018 was 234,718 tons (Nasution et al., 2020). Mung bean has great starch contents that yield starch approximately 50-60% of the total weight. The amylose content is about 40% of the total amount of starch, larger than other legume and cereal starches. Mung bean starch is potentially used for biopolymer with excellent gelling capability and cohesiveness, swelling resistance, high resistance to shear, and high stability. However, its application was still limited due to the characteristics of easy aging, high crystallinity, and low solubility (Li et al., 2011; Zou et al., 2019; Zhang et al., 2019). In the manufacture of plastics film,

How to cite:
Utami, I., Nurmawati, A., Prasyanti, B., & Andrianto, J. (2021). The effect of chitosan and sorbitol addition in the bioplastics production from mung bean starch. *2nd International Conference Eco-Innovation in Science, Engineering, and Technology*. NST Proceedings. pages 14-19. doi: 10.11594/ nstp.2021.1403

starch had a low barrier to water vapor because of the presence of hydrophilic groups even its has a good oxygen barrier (Tapia-Blácido et al., 2011). Therefore, to improve its properties, mung bean starch should be modified with other polymers.

Chitosan is drawing attention as film materials with their unique properties. Chitosan is derived from chitin where can be extracted from crustacean shells such as crabs and shrimp. It has non-toxic properties, is biocompatible, antimicrobial, and biodegradable. Chitosan is compatible with a natural or synthetic polymer in films to improve their mechanical properties (Bourtoom & Chinnan, 2008; Samsi et al., 2019). The material, plasticizing agent, was added to soften the blended films. Glycol and sorbitol are widely used to optimize the mechanical properties of the blends. Sorbitol gave better performance due to less hygroscopic, more resistance to break, less permeable to oxygen, and less elongate (Tapia-Blácido et al., 2011).

This study focused on producing biodegradable plastics from mung bean starch blended with chitosan and sorbitol as a plasticizer. The effect of the addition of additive material to the bioplastic characteristics was investigated. The mechanical properties of the bioplastic are determined by tensile strength, elongation, and young's modulus analysis. With the use of biodegradable materials, this study also investigated the degradation period of the blends.

Material and Methods

Materials

Biodegradable plastics are produced by the synthesis of mung bean starch with chitosan. Sorbitol was also added as a plasticizer. It dissolves using acetic acid and demineralized water. The ratio of mung bean starch and chitosan blended differed from 60:40 to 100:0 (wt/wt). The addition of sorbitol into polymers blend varied from 20% to 60%.

Methods

Bioplastics Preparation

The production of bioplastics film started with weighted the mung bean starch and chitosan based on the ratio. The chitosan dissolved with 5 ml aqueous acetic acid (1%) solution. The mung bean starch was also dissolved in 1% acetic acid as much as 50 ml while stirred and heated up to gelatinization temperature was 75^{o}C. Chitosan solution was mixed with a starch solution to make polymer blends. Sorbitol as a plasticizer was added into the mixture while stirred until homogenous. Then, the mixture was stored at room temperature for 24 hours. The mixture was poured into a glass petri dish with 1.5 mm thickness and dried using an oven at 70^{o}C. The dried film was then peeled off and stored in a dry place.

Mechanical properties test

The mechanical properties test was done by using an autograft machine. Small pieces of film (7 x 2 cm) were pulled until they broke off. The value of force applied in the film was shown on the monitor. From the result, it could be calculated the tensile strength, elongation, and young's modulus.

Biodegradable test

This test was run using EM4 microorganisms that consist of *Lactobacillus sp.*, *Actinomyces sp.*, *Streptomyces sp.*, fungi, and photosynthetic bacteria. Those microorganisms would help the decomposition process of organic material. Small pieces of film (2 x 2 cm) were immersed in 30 ml of EM4 solution. The observation was conducted after 6 days until the film fully degraded.

Results and Discussion

The use of starch in bioplastics obtained a film with low mechanical strength, which was evaluated by the tensile strength and elongation. From the data, the presence of chitosan and sorbitol would improve their mechanical properties. The addition of chitosan would increase the tensile strength of the film (Figure 1). The tensile strength can be calculated with Eq. (1),

$$\sigma = {}^{F}\!/_{A} \quad (1)$$

where σ is tensile strength (MPa), F is force (kN), and A is area (m^2).

The tensile strength depended on the crystallinity structure of the film. Mung bean starch consists of two main components, linear chains of amylose and branched chains of amylopectin. Amylose tends to produce tough gel and strong film, but on the contrary, amylopectin can easily disperse in water and produce soft gel and weak film (Pérez & Bertoft, 2010). On the other hand, chitosan has a linear chain that makes a more compact structure. Chitosan addition on starch increased the intermolecular hydrogen bond between NH^{3+} of the chitosan backbone and OH^- which led to a stronger molecule bond (Xu et al., 2005) and larger energy needed to break the film. The highest tensile strength was 13.33 MPa indicated in the sample with 40% chitosan and decreased along with the addition of starch content.

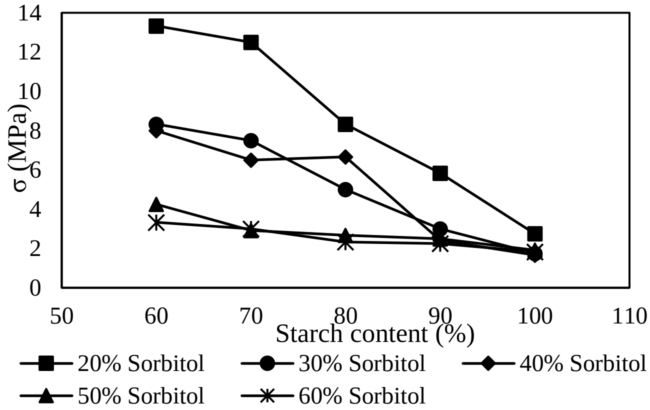


Figure 1 The effect of chitosan and sorbitol addition in tensile strength of the films

Sorbitol addition as a plasticizer also affected the tensile strength of bioplastics. Plasticizing agent addition would weaken the hardness of the blended film due to the increase of the polymeric intermolecular spacing. The hydrogen bond between starch and chitosan was weakened by sorbitol (Maulida et al., 2016; Ooi et al., 2012). As a result, the tensile strength of this blend was decreased with the increase of the sorbitol content. Based on Figure 1, the addition of 20% sorbitol resulted in better tensile strength than other compositions.

The use of plasticizer gave a good result in film elongation. As shown in Figure 2, the film with high sorbitol content gave a higher elongation percent. Elongation represented the change of film length after pull out. It can be evaluated by using Eq. (2),

$$\varepsilon = {}^{\Delta l}\!/_{l_0} \times 100\% \quad (2)$$

Where ε is elongation, Δl is the increase of film length after force added (m), and l_0 is the initial length (m).

Sorbitol would loosen up the molecular structure of the polymeric blends hence the polymer chain segments easier to move (Ooi et al., 2012). The highest elongation percentage in the film blends was 36.27% on film with 100% starch and 60% sorbitol added. This result also showed that sorbitol would increase flexibility but lower the hardness.

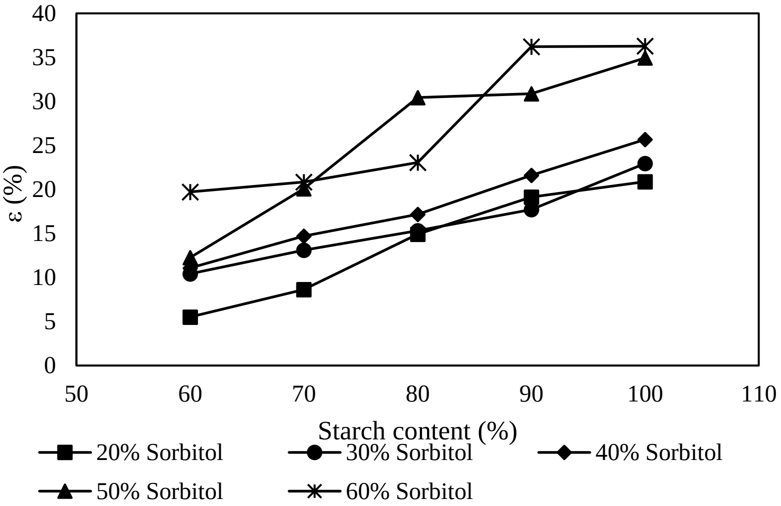


Figure 2. The effect of chitosan and sorbitol addition in elongation of the films

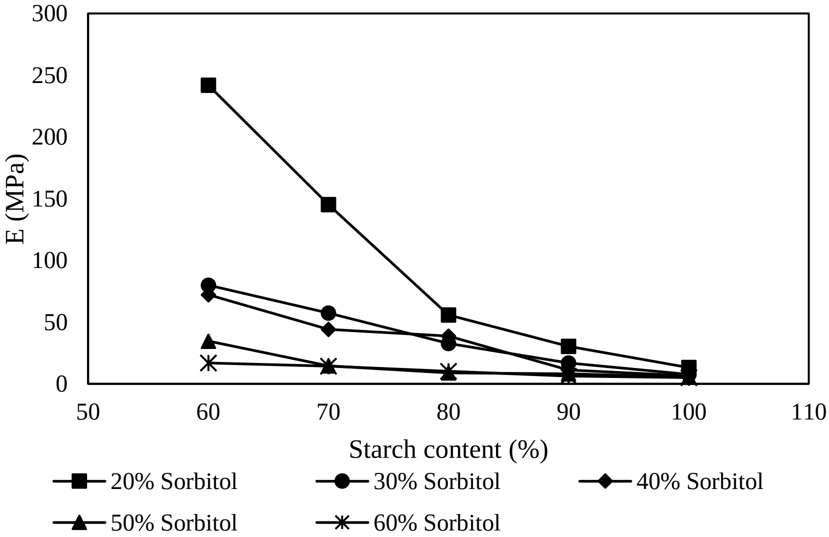


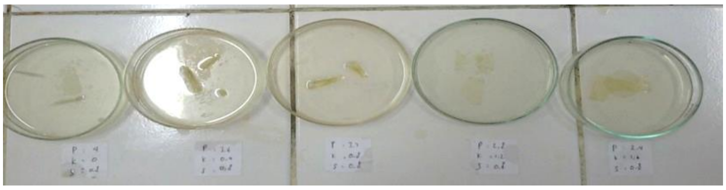
Figure 3. The effect of chitosan and sorbitol addition in young's modulus of the films

Young's modulus (E) is the ratio between tensile strength and elongation of the film. The calculation was based on Eq. (3),

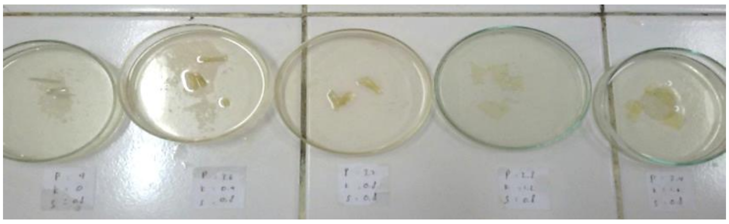
$$E = {}^{\sigma}/_{\varepsilon} \tag{3}$$

Figure 3 showed the greatest young's modulus value was in bioplastics composition of 60% starch: 40% chitosan with 20% sorbitol addition. Generally, young's modulus would decrease along with the higher content of starch in the polymer blends. As explained before, chitosan would enhance the chemical interaction between the polymer molecules and affect the young's modulus.

(a)



(b)



(c)

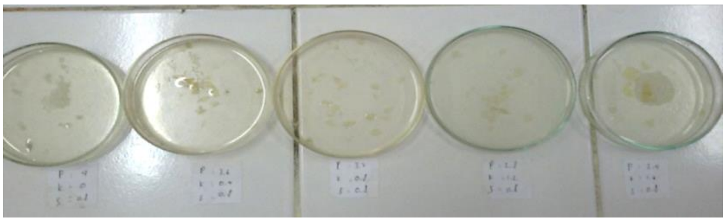


Figure 4. The comparison of bio-degradability test in (a) 6th day, (b) 10th day, and (c) 16th day

The production of bioplastics is intended to develop environmentally friendly materials that are easy to decompose in a relatively short period. The result of the bio-degradability test using EM4 microorganisms is shown in Figure 4. After 6 days, the bioplastics film diminished and faded caused by the molecular structure damage. The bioplastics degraded completely after 16 days of testing. This result indicated that the bioplastics production using mung bean starch combined with chitosan and sorbitol was easier to decompose in a relatively short time than conventional plastics.

Conclusion

Plastics were widely used in many sectors and became an environmental problem due to their waste. Plastics waste was hard to degrade naturally. One of the solutions is the use of natural polymer as the main component in plastic production. The bioplastics could be produced from mung bean starch where has about 50-60% of starch. The addition of other polymers and plasticizing agents would improve the mechanical properties of the film. Chitosan addition in polymer blends would increase the intermolecular strength. This interaction increased the tensile strength of the film and led to young's modulus increment. But in the presence of sorbitol, the tensile strength decreased along with the amount of sorbitol added. However, sorbitol as a plasticizer would increase the elongation of the films. The film composition that showed good mechanical properties in tensile strength and young's modulus was composed of 40% chitosan in polymer blend and 20% sorbitol. The use of natural polymer blends and sorbitol resulted in better degradation performance. Within 16 days, the films degraded with EM4 microorganism activity.

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