OPTIMUM VOLUME RATIO OF SORBITOL AND GLYCEROL AS PLASTICIZER ON BIOPLASTIC FROM TAPIOCA STARCH

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Abstrak

Permintaan plastik di seluruh dunia terus meningkat, hampir setiap produk menggunakan plastik sebagai kemasan. Karena sifatnya yang tidak dapat terbiodegradasi, mereka menyebabkan dampak negatif berbahaya pada lingkungan. Maka, dibutuhkan alternatif untuk mengelola limbah plastik di bumi dengan menemukan alternatif ramah lingkungan untuk plastik. Alternatif ramah lingkungan ini adalah bioplastik, yang dibuang ke lingkungan dan dapat dengan mudah terdegradasi dengan aksi enzimatik dari mikroorganisme. Saat ini bioplastik berbasis pati mendominasi 66% dari pasar bioplastik global. Bioplastik berbasis pati dibuat oleh pati gelatinisasi. Untuk tepung tapioka, nama umum untuk pati diekstraksi dari singkong, suhu gelatinisasi cukup rendah, hanya sekitar 52-64^{o}C. Untuk mendapatkan bioplastik berbasis pati fleksibel, sorbitol dan gliserol ditambahkan sebagai plasticizer. Tujuan dari penelitian ini adalah untuk menentukan komposisi rasio volume plasticizer dan tepung tapioka yang optimal untuk menghasilkan bioplastik dengan karakteristik yang baik. Hasil yang diperoleh berupa lembaran bioplastik putih transparan. Setelah sifat mekanik diuji, hasil yang paling optimal diperoleh pada 10 gram tepung tapioka dan rasio volume sorbitol dan gliserol (7:3.5) ml atau 2:1. Dengan nilai uji kuat tarik 1.2 MPa, uji perpanjangan 50%, 39.22% uji penyerapan air dan uji biodegradasi menunjukkan bahwa sampel 100% terdegradasi dalam waktu 18 hari.

Kata kunci: bioplastik, tepung tapioka, sorbitol, gliserol

Abstract

Plastic demand worldwide continues to increase, almost every product uses plastic as packaging. Due to non-biodegradable nature they cause hazardous negative impact on the environment. Thus, it takes an alternative for managing plastic waste on earth by finding eco-friendly alternative to plastics. This ecofriendly alternative is bioplastics, which are disposed in environment and can easily degrade through the enzymatic actions of microorganisms. Today starch based bioplastic dominates 66% of the global bioplastics market. Starch based bioplastic is made by gelatinizing starch. For tapioca starch, a common name for starch extracted from cassava, gelatinization temperature is quite low, only about 52-64^{o}C. To obtain a flexible starch based bioplastic, sorbitol and glycerol are added as plasticizers. The purpose of this study was to determine the optimum composition of the volume ratio of plasticizers and tapioca starch to produce bioplastics with good characteristics. The results obtained are in the form of transparent bioplastic sheets. After the mechanical properties were tested the most optimum results were obtained at 10 grams of tapioca starch and volume ratio of sorbitol and glycerol is (7:3.5) ml or 2:1. With the value of 1.2 MPa tensile strength test, 50% elongation test, 39.22%

water absorption test and biodegradation test showed that the sample was 100% degraded within 18 days.

Keywords: bioplastic, tapioca starch, sorbitol, glycerol

1. INTRODUCTION

Plastics used today are synthetic polymers of petroleum are limited in number and not renewable (Setiawan et al., 2012). Due to non-biodegradable, disposal of plastic wastes are major cause of environment pollution (Rajeswari, 2014).

Thus it takes an alternative plastic material from materials that are easily to get and available in nature that is bioplastic. Bioplastics are disposed in environment and can easily degrade through the enzymatic actions of microorganisms which give rise to carbon dioxide, methane, water, biomass, humic matter and various other natural substances which can bereadily eliminated (Kuta et al., 2004).

As potential alternative raw materials for plastics, starch has drawn a great deal of attention. The appeal of starch comes from its biodegradability, renewable sources, low cost, and ease of handling (Zuo et al., 2015). Starch synthesized by plant cells is formed by two types of polymers: amylopectin and amylose. Amylopectin consists of linear chains of glucose units linked by α-1,4 glycosidic bonds and is highly branched at the α-1.6 positions by small glucose chains at intervals of 10 nm along the molecule's axis it constitutes between 70 to 85% of common starch. Amylose is essentially a linear chain of α-1.4 glucans with limited branching points at the α-1,6 positions and constitutes between 15-30% of common starch (Alcázar-Alay and Meireles, 2015).

When the starch is placed in contact with an excess of water and subjected to heating, occurs gelatinization. This process is the first step to film development. During the gelatinization process occur a phase transition and the collapse (disruption) of the molecular order within the starch granule structure over a temperature range that depends on the characteristic of the starch source. The weaker hydrogen bonds in amylose and amylopectin chains are broken, and the starch granules begin to swell, increasing the solution viscosity (Luchese et al., 2017).

Cassava flour is one of the most commonly used biopolymers as food packaging material because it is nontoxic, biodegradable, biocompatible, low cost, renewable and abundantly available in nature. For tapioca starch, a common name for starch extracted from cassava, gelatinization temperature is quite low, only about 52-64°C (Mulyono et al., 2015).

To obtain a flexible starch based bioplastic, plasticizers are added to reduce brittleness, impart exibility, and improve toughness, reducing crystallinity, lowering glass transition and melting temperatures. Plasticization reduces the relative number of polymer–polymer contacts thereby decreasing the rigidity of the three-dimensional structure thereby allowing deformation without rupture. Consequently, plasticizers improve processability, exibility, durability and in some cases reduce the cost of polymers (Mekonnen et al., 2013).

Glycerol and sorbitol are plasticizers to reduce fragility, increase the flexibility and durability of films, especially if stored at low temperatures. According to Mchugh and Krochta (1994) in (Hidayati et al., 2015), polyols such as sorbitol and glycerol are plasticizers that function to reduce internal hydrogen bonds so that they will increase intermolecular distances. This research aims to know the effect of additions sorbitol and glycerol for bioplastic film quality from tapioca starch and determine the optimum volume ratio of plasticizer to produce good quality of bioplastic films.

2. METHOD

The research method used is Completely Randomized Design that is arranged in factorial (CDR-factorial) The research method used in this study is a Complete Random Design (RAL) consisting of 3 treatments and 3 replications so 9 experimental units were obtained.

2.1 Research Variable

Dependent variable is tensile strength, elongation, water absorption and biodegradability. Amount of tapioca starch (8, 10 and 12 g) and volume ratio of sorbitol and glycerol (3.5ml:7ml), (3.5ml:3.5ml), (7ml:3.5ml) as independent variable. And as a control variable are temperature at 65°C, time of mixture 30 minutes, speed of mixture at 300 rpm and amount of aquadest 100 ml.

2.2 Materials and Tools

The material used in making bioplastic film is tapioca starch from Kleco local market in Surakarta. Sorbitol, glycerol and aquadest from CV. Agung Jaya, Surakarta. The tools used in making bioplastic films are measuring glass, beaker glasses, thermometer, glass stirrer, petri dishes, bowls porcelain, desiccator, analytic balance, tissue, heater, magnetic strirrer, stopwatch, mold and stationery.

2.3 Procedure

Weigh tapioca starch 8 gram, then dissolve with 100 ml aquadest and gelatinize at 300 rpm and 60°C for 10 minutes. And repeat the step for tapioca starch 8, 10 and 12 gram. Mix Sorbitol and glycerol with certain ratio volume of sorbitol and glycerol [(3.5ml:7ml), (3.5ml:3.5ml), (7ml:3.5ml)]. After tapioca starch solution gelatinized, put plasticizer solution into the same of beaker glass with gelatinized solution. Mix both solution at 65°C and 300 rpm in a hot plate for 30 minutes. After 30 minutes of mixturing process, then put the solution into the mold that has been prepare from a ceramic. Then store in a week. A week later then do the testing of mechanical properties (tensile strength and elongation), biodegradability and water absorption.

2.4 Data Analysis

Data obtained from observations will be analyzed statistically by using Analysis of Variance (Anova). If the data is normally distributed on a normality test then proceed with Least Significant Differences (LSD) at the level of 10%.

2.4.1 Tensile Strength Test

Tensile strength test was measured by Creep Testing Machine. Before the measurement is carried out, a sheet of film is prepared with the size according to the specimen that is available. Tensile strength is determined based on load. Tensile strength is measured by the formula:

$$\sigma = \frac{F}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where,

σ = tensile strength (MPa)

F = Load (N)

A = area of specimen (m^2)

2.4.2 Elongation Test

Tensile strength test was measured by Creep Testing Machine. Before the measurement is carried out, a sheet of film is prepared with the size according to the specimen that is available. Percentage of elongation is calculated when the film is broken or torn. Before drawing is withdrawn, the length of the film is measured to the limit of the handle called the initial length (lo), while the length of the film after withdrawal is called the length after break (lt) and is calculated as the percent elongation by the formula:

$$\varepsilon = \frac{l_t - l_o}{l_o} \times 100\% \quad \ldots\ldots (2)$$

where,

ε = elongation (%)

l_o = initial length of specimen (m)

l_t = length after break of specimen (m)

2.4.3 Water Absorption Test

Samples were cut into small pieces measuring 2 cm × 2 cm, and the pieces were vacuum-dried at 50°C for 24 hours. The dried pieces were weighed immediately and then the specimens were soaked in distilled water at room temperature. After 24 hours, the specimens were removed from distilled water, blotted dry with filter paper, and then weighed again. Data were recorded as averages of three specimens. Water absorption of the plastic was calculated as follows (Zuo et al., 2015):

$$\text{Water absorption} = \frac{w_2 - w_1}{w_1} \times 100\% \quad \ldots\ldots (3)$$

where,

w_2 = mass of the sample after water absorption (g)

w_1 = mass of the dry sample (g)

2.4.4 Biodegradability Test

Biodegradability test is done by soil burial test method according to Hidayati et al., 2015, by cutting plastic film with size 2 cm × 2 cm. Samples placed and planted in pots that have been filled with soil, the sample is left exposed to open air without being covered with glass. Observation of samples is carried out in a span of two weeks until the sample is completely degraded or bioplastic sheets are no longer visible or fused with soil.

3. RESULT AND DISCUSSION

3.1 Tensile Strength Test

The mechanical properties of biodegradable plastics are influenced by the amount of content of the plastic constituent components, namely starch and plasticizer. Plastics made from starch only have elastic properties while the tensile strength is low. The addition of biodegradable plastic plasticizers can have better properties. The tensile strength test results can be seen in the graph below.

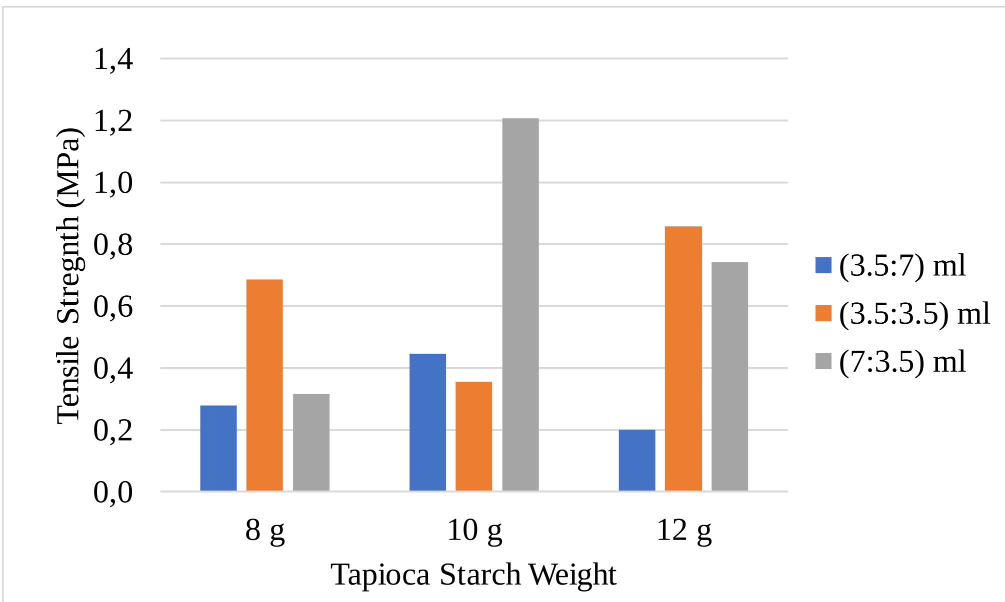

Figure 1. Relationship between tapioca starch and ratio of plasticizer to tensile strength test

From the figure 1, the best tensile strength result is 1.2 MPa from the composition of tapioca starch 10 grams with the volume ratio of plasticizer (7:3.5) ml or 2:1. From the graph it can be seen that at all of the volume ratio of plasticizers are show fluctuation result as the more starch used. From the graphic above it can be conclude that the more sorbitol used the higher the tensile strength. This because of glycerol has the ability to reduce internal hydrogen bonds in intermolecular bonds. So that the addition of the glycerol ratio to increase plastic elasticity while the value of tensile strength is getting lower.

And if it compared with other journal as controls, Journal of Teknik according to Kumoro and Purbasari, (2014) on biodegradable plastic from tapioca, the value of tensile strength with the addition of glycerol 0% is 34 MPa. Good quality biodegradable plastic was obtained when 15% weight of glycerol is added with tensile strength 20.65 MPa . And for these research, the value of tensile strength is still too far from the Journal of Teknik, Kumoro and Purbasari (2014) .

Based on the analysis of LSD, there is no difference in the real tensile strength test value for the variation of starch weight and variation volume of ratio of plasticizer.

3.2 Elongation Test

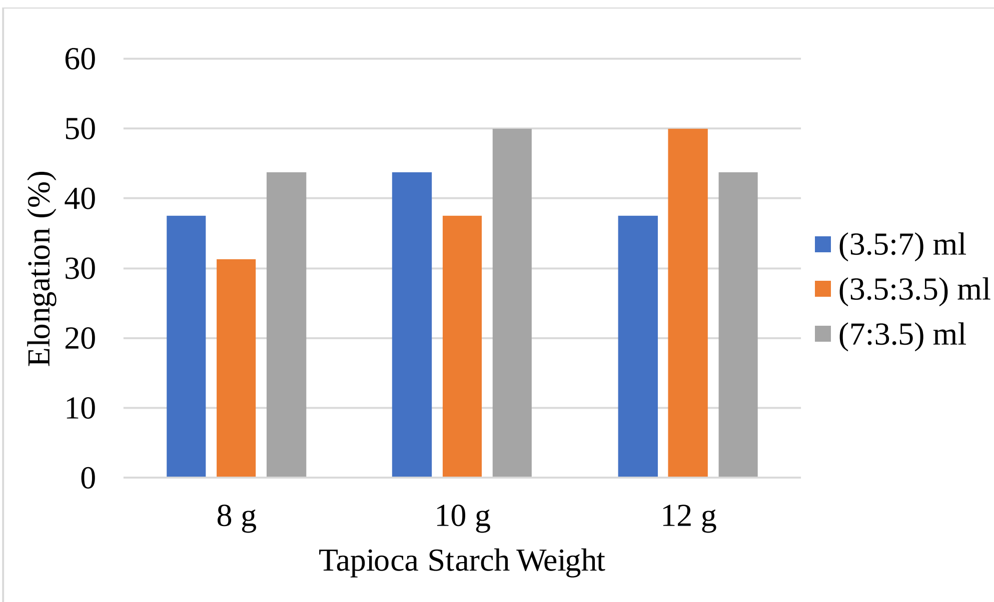

Figure 2. Relationship between tapioca starch and ratio of plasticizer to elongation test

From the figure 2, the best elongation result is 50% from the composition of tapioca starch 10 grams with the volume ratio of plasticizer (7:3.5) ml or 2:1 and tapioca starch 12 gram with the volume ratio of plasticizer (3.5:3.5) ml or 1:1. From the graph it can be seen that at all of the volume ratio of plasticizers are show fluctuation result as the more starch used. From the graphic above it can be conclude that the less tapioca starch used has lower the elongation. The fluctuation in the results of the elongation test may be due to the lack of the observed observation scale.

As a plasticizer, sorbitol has entered into the starch molecule then decreases interaction between starch molecules (cohesion) with forming hydrogen bonds between hydroxyl groups in starch molecules with sorbitol molecules so causing increased biodegradable flexibility film and increase the percent elongation value (Laohakunjit & Noomhorm, 2004).

Based on the analysis of LSD, there is no difference in the real elongation test value for the variation of starch weight and variation volume of ratio of plasticizer.

3.3 Water Absorption Test

The absorption properties of a molecule are related to the nature of the constituent material. The materials used in this study were tapioca starch and glycerol, both of which have hydrophilic properties. This water absorption test is used to determine the amount of water that can be absorbed by biodegradable plastic. The water absorption test results can be seen in the graph below.

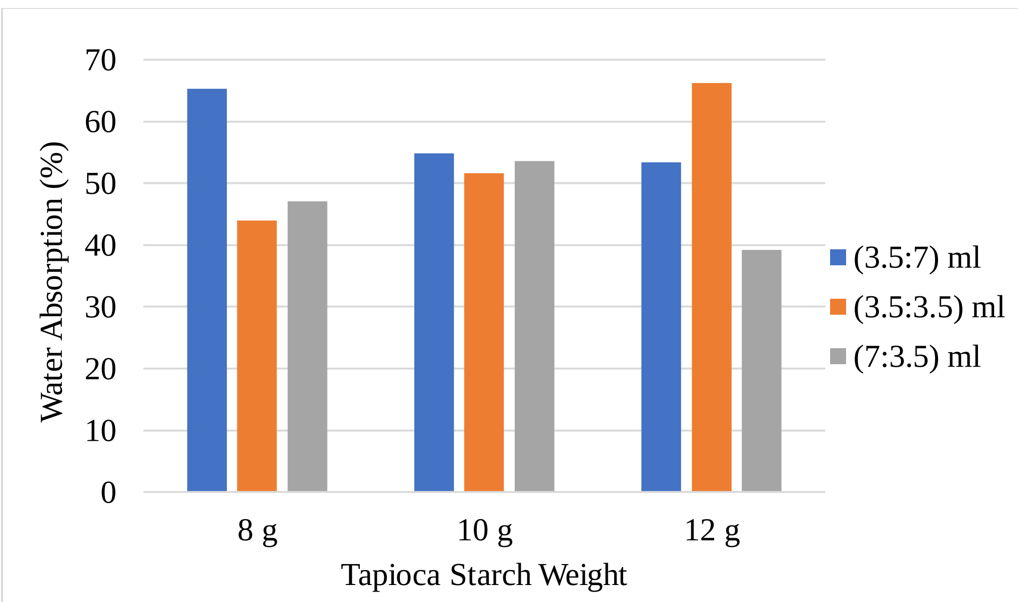

Figure 3. Relationship between tapioca starch and ratio of plasticizer to water absorption test

From the figure 3, for volume ratio of plasticizer (3.5:7) ml or 1:2 show that the more tapioca starch used the value of water absorption is decrease. Vice versa, volume ratio of plasticizer (3.5:3.5) ml or 1:1 show that the more tapioca starch used the value of water absorption is increase. While the ratio of volume of plasticizer (7:3.5) ml or 2:1 the more tapioca starch used show fluctuation value of water absorption.

The highest value of water absorption is 66.23% from the composition of tapioca starch 12 grams with the volume ratio of plasticizers (1:1) and the lowest value of water absorption is 39.22% from the composition of tapioca starch 12 grams with the volume ratio of plasticizers (2:1). The best results from the water absorption test are not the highest but the lowest because large water absorption then the plastic less able to protect products from water that can cause products quickly damaged or reduced quality (Laohakunjit and Noomhorm, 2004).

In general, the more concentration of plasticizer is added, the more water is absorbed, so the lower the resistance of biodegradable plastic. This is because the addition of plasticizers, especially glycerol, adds to the empty space in the plastic.

Based on the analysis of LSD, there is no difference in the real water absorption test value for the variation of starch weight and variation volume of ratio of plasticizer.

3.4 Biodegradability Test

From the 9 samples buried in the soil, all samples left no residue in about 18 days, which means that all samples were completely degraded on soils. Before this biodegradation test all samples were not overgrown with fungi, this was because the samples were stored in a dry and closed place so that hygroscopic samples did not absorb much moisture from the air so that microorganisms did not appear in the sample.

From the results of the research that has been done can be compared with the existing Standard Nasional Indonesia (SNI 7188.7:2016), that for the biodegrability already in accordance with the minimum SNI criteria. Where microbial growth on the product surface > 60% for one week by using test method of ASTM G21 that degraded 100% within 28 days, while in this research 100% degraded within 18 days.

4. CONCLUSION

From the result of this study, the optimum volume ratio of sorbitol and glycerol as plasticizer on bioplastic from tapioca starch is (2:1) or 7:3.5 ml at 10 grams of tapioca starch. With the value of 1.2 MPa tensile strength test, 50% elongation test, 39.22% water absorption test and biodegradation test showed that the sample was 100% degraded within 18 days.

5. SUGGESTION

For further research it is recommended to use the mechanical tests device by using the latest microtensile test machine and increase the volume ratio of plasticizers to be bioplastic with good quality as packaging.

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