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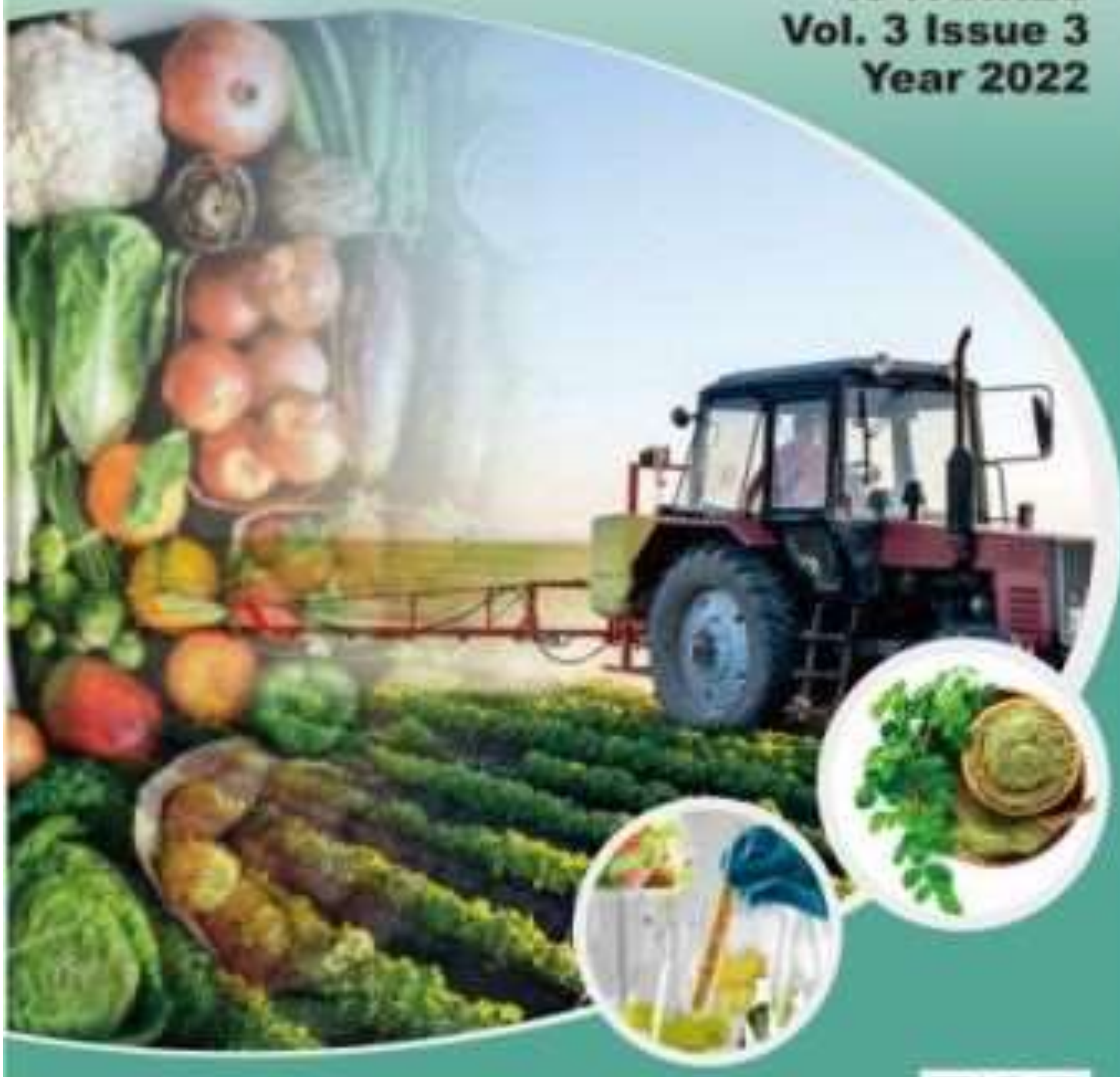

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*Original Paper*

# The Characterization of Biodegradable Plastics from Cassava Starch with Varried Addition of Robusta Coffee Skin (*Coffea canefora*) and Glycerol

*Andrew Setiawan Rusdianto[1*], Maghfirah Usman[1], Triana Lindriati[1], Eka Ruriani[1], Nidya Shara Mahardika[1]*
1) *Department of Agroindustrial Technology, Faculty of Agricultural Technology, University of Jember, Indonesia*
*) *Corresponding Author: andrew.ftp@unej.ac.id*

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***Abstract*— One of the solutions to the plastic pollution crisis is biodegradable plastic. The most efficient raw material for making biodegradable plastic is cassava starch, but it has a weakness in that natural fibers are generally added as reinforcement and natural filler. In this study, Robusta coffee skin fiber was used as a reinforcement for biodegradable plastic. To obtain the right variation of coffee skin composition, this study applied a completely randomized design (CRD) with two factors. The parameters observed in this study were thickness, water absorption, biodegradation, tensile strength, elongation, and modulus of elasticity. Data were analyzed using descriptive statistics and ANOVA test, coupled with the effectiveness index test was carried out. The results showed a thickness value of 0.703 – 1.007 mm. The value of water absorption is between 3.437 – 13.512 %. The resulting biodegradation value is between 32.914 – 68.971%. The tensile strength value is 19,056 – 46,507% and it is directly proportional to the modulus of elasticity, which is produced between 2.557 – 16.442 Mpa. The effectiveness index test demonstrated that the best treatments were obtained from the addition of 15% coffee skin with 20% glycerol, 10% glycerol with 20% coffee skin, and 5% glycerol with 20% coffee skin.**

***Keywords—biodegradable plastic, cassava starch, robusta coffee skin, glycerol***

## I. Introduction

Indonesia has been grappling with plastic pollution, with an estimated increase in plastic flow by 30% between 2017 and 2025. One of the measures to reduce plastic waste is making biodegradable plastic [1]. The raw material for biodegradable plastics mostly is made from cassava starch because it is very affordable and completely degradable. Biodegradable plastic made from cassava starch has a brittle texture because it contains a high amount of amylopectin reaching 60,15%. To make biodegradable plastics from starch, natural fibers are required as fillers and reinforcement. Robusta coffee skin contains 35,6% fiber, so it can be used as a reinforcing material to make biodegradable plastics.

## II. Method

### A. Tools and Materials

The tools used in this research included 40 and 60 mesh sieves, glass beaker (Herma), blender (Philip), analytical balance, stopwatch (Xiaomi), hotplate magnetic stirrer (IKA C-MAG HS 7), Thickness gauge (Mitutoyo type 1012x), universal testing machine (HT-2402), and oven.

The materials were cassava starch, dried Robusta coffee skin obtained from coffee farmers in Kalibaru district of Banyuwangi regency, aquadest, and glycerol.

### B. Research Design

This research applied a completely randomized design (CRD) with two factors. The first factor was the addition of glycerol with 3 levels: 20% (G1), 30% (G2), and 40% (G3) relative to the weight of cassava starch. The second factor was the addition of Robusta coffee skin flour with 4 levels: 0% (A0), 5% (A1), 10% (A2), and 15% (A3) relative to the weight of cassava starch.

## III. Research Implementation

### A. The Process of Making Robusta Coffee Skin Flour

The first step in making Robusta coffee skin flour (*Coffea canefora*) was reducing the size of dry coffee skin using a blender. After the coffee skin became smooth, it was sieved using a 40 and 60 mesh sieve because the cellulose passed through a 40 mesh sieve and was retained in 60 mesh. Eventually, the Robusta coffee skin flour was finished [14].

### B. The Process of Making Biodegradable Plastic

The first step in making biodegradable plastic was mixing 20 grams of cassava starch with 20 ml of distilled water. The next step was mixing the cassava starch and glycerol according to the treatment until it became homogeneous. The mixture was then printed using an aluminum mold. After that, the mixture was dried using the oven for 120 minutes at 90ºC. The last step was cooling the mixture at room temperature for 24 hours, before removing the plastic from the mold properly.

*C. Procedure Analysis*

The observation parameters were thickness, hygroscopicity, biodegradation, tensile strength, elongation, and modulus of elasticity. Data analysis was carried out by descriptive statistics and ANOVA test, coupled with effectiveness index test.

## IV. RESULTS AND DISCUSSION

Generally, the main raw material for making biodegradable plastics is cassava starch. The following sections document the effects of adding coffee skin to reinforce biodegradable plastic and glycerol as a plasticizer on the physical and mechanical properties of biodegradable plastic.

*A. Thickness Test*

The results showed that biodegradable plastics had different thicknesses. Thickness was measured at three different points on the plastic sample [15]. The addition of coffee skin and glycerol affected the thickness of biodegradable plastic. Coffee skin also characterized the plastic texture (Fig. 1). The ANOVA test results showed that coffee skin, glycerol, and their interactions affected the thickness of biodegradable plastic. The results of measuring the thickness of biodegradable plastic are shown in Fig. 2.

Fig. 1. Biodegradable plastic thickness test

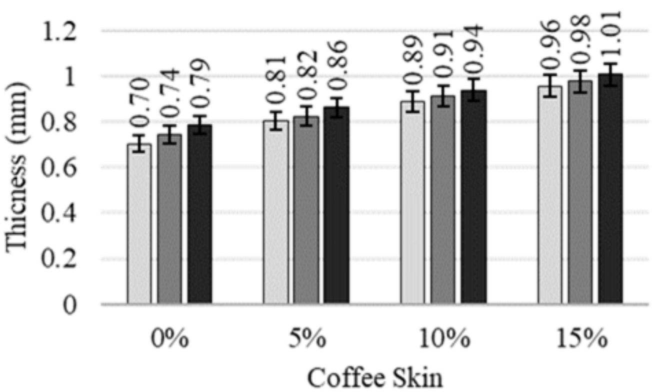


Fig. 2. Biodegradable plastic thickness test value, (glycerol 20%), (glycerol 30%), and (glycerol 40%)

The more components used with the same mold size can increase the total solids and polymers making up the matrix, which therefore increases the thickness of biodegradable plastic [2].

*B. Water Absorbtion Test*

This analysis was aimed to determine the ability of biodegradable plastics to retain and absorb water. The results of the ANOVA test showed that coffee skin, glycerol, and their interactions affected the water absorption of biodegradable plastics. The results of the water absorption test are shown in Fig. 3.

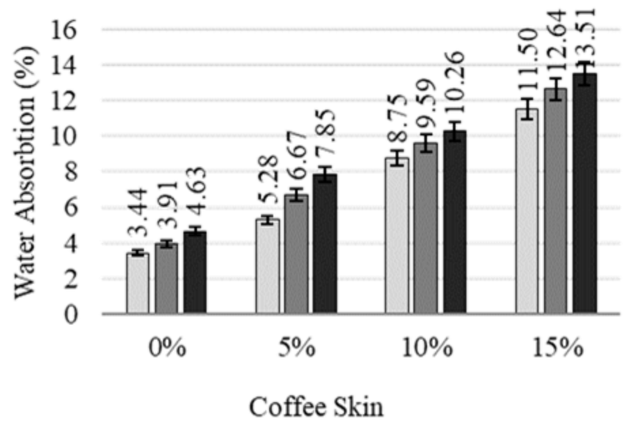


Fig. 3. Biodegradable plastic water absorption value, (glycerol 20%), (glycerol 30%), and (glycerol 40%)

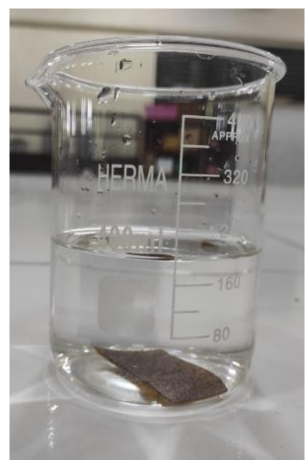

Fig. 4. Biodegradable plastic water absorption test

Glycerol can easily absorb water because it has enough $OH^-$ groups so that it can easily bind water through hydrogen interactions [3]. The function of adding cellulose to biodegradable plastic is to reduce the hydrophilic nature of starch because cellulose is insoluble in water [4]. The research results contradict the existing literature, in that the present study showed that the more cellulose (from coffee skin) was added, the more water the plastic absorbed. The discrepancy in the function of cellulose in this study was because cellulose and starch had unequal mesh sizes so during the mixing process the plastic dough was not homogeneous. The application of cellulose with different mesh sizes was thought to create cavities in the bonds formed. This caused the plastic to absorb water more easily. The bond between starch and cellulose was not strong due to the difference in size between starch and cellulose so the mixture became homogeneous [4].

## C. Biodegradation Test

The biodegradation test was carried out using the soil burial test. This was performed by burying the plastic in the humus soil for some time. The weight before and after the burial was measured and compared. In this study, plastic was buried for 15 days. In general, the research results document a biodegradation value aligned with SNI. based on SNI 7188.7:2016, the biodegradability value of bioplastics is 52.82% in 10 days [5]. The ANOVA test results showed that coffee skin, glycerol, and their interaction affected the biodegradation of biodegradable plastics. The test results are shown in Fig. 5.

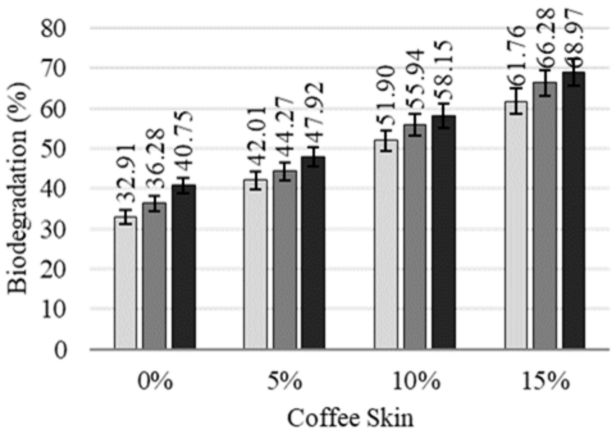


Fig. 5. The results of the plastic biodegradation test, (glycerol 20%), (glycerol 30%), and (glycerol 40%)

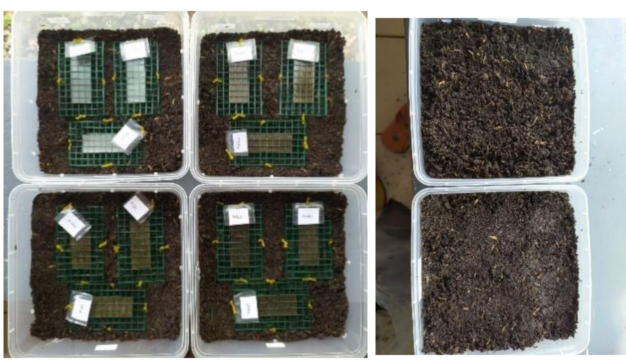

Fig. 6. *The results of the plastic biodegradation test*

Glycerol easily absorbs water which can cause the plastic to break down easily so that the plastic is degraded faster [6]. The addition of cellulose can make plastic more resistant to water [4]. The addition of cellulose in this research makes the plastic easier to absorb water because the plastic dough is not homogeneous so this can also cause the plastic to degrade faster.

## D. Tensile Test

The test aimed to determine the magnitude of the maximum pulling force of biodegradable plastic. ANOVA test results showed that coffee skin, glycerol, and their interactions affected the tensile strength of biodegradable plastics. The test results are presented in Fig. 7.

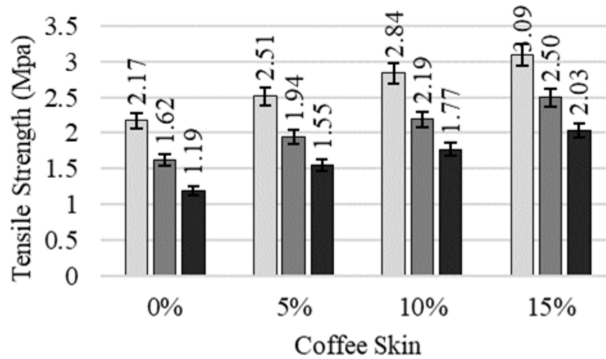


Fig. 7. The tensile test results of biodegradable plastic, (glycerol 20%), (glycerol 30%), and (glycerol 40%)

Fig. 8. The tensile test of biodegradable plastic

Glycerol can weaken the tensile strength of plastic because glycerol can cause the formation of empty spaces by breaking the polysaccharide bonds [7]. The addition of cellulose material during the production of biodegradable plastic can increase its tensile strength because cellulose has straight and long polymer chains that can make bioplastics strong [8]. The increased tensile strength due to the addition of cellulose can form a network of strong hydrogen bonds that occur between the starch and cellulose matrix [9]. The tensile strength of bioplastics based on SNI 7188.7:2016 is 24.7 – 302 Mpa [6]. The results show that the tensile strength of biodegradable plastic has yet to comply with the standard. This is because the cellulose is not reduced in size so the mixture is not homogeneous. Cellulose can make plastics strong because cellulose has long and straight polymer chains, but there is a possibility that the mixture between starch and cellulose is not homogeneous. This can be caused by the different sizes between starch and cellulose, which can generate the bonds between starch and cellulose. Although cellulose is not strong, it affects the tensile strength of plastics [4].

## E. The Elongation Test of Biodegradable Plastic

The test was aimed at identifying the elongation of biodegradable plastic. The results of the ANOVA test showed that coffee skin, glycerol, and their interaction affected the elongation of biodegradable plastics. The test results are shown in Fig. 9.

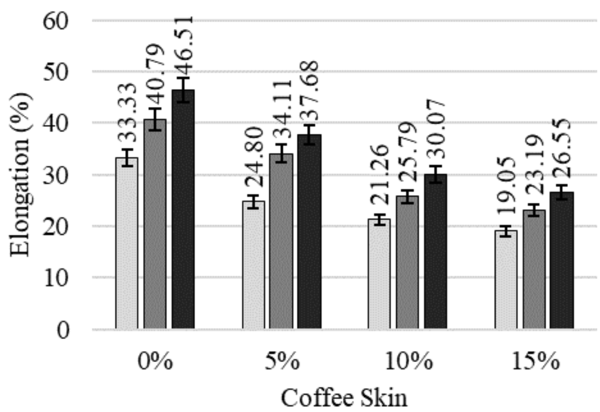


Fig. 9. The elongation test of biodegradable plastic, (glycerol 20%), (glycerol 30%), dan (glycerol 40%)

The value of tensile strength and elongation is inversely proportional. This is because glycerol can weaken the tensile strength of a plastic which can reduce intermolecular interactions so that it can expand the space for movement of the polymer chain and cause more glycerol to be added while increasing elongation [10]. The addition of cellulose to the plastic increases the brittleness and stiffness of the plastic and decreases the elongation [7][16]. In general, the research results have corroborated that the elongation test result has satisfied the required value based on SNI 7188.7:2016 which ranges from 21 to 220% [6].

*F. The modulus of elasticity of biodegradable plastic*

The modulus of elasticity was used to measure the stiffness of biodegradable plastics. The elastic modulus measurement was obtained by comparing the results of the tensile test and elongation test. The ANOVA test results showed that coffee skin, glycerol, and their interaction affected the elasticity of biodegradable plastics. The test results are displayed in Fig. 10.

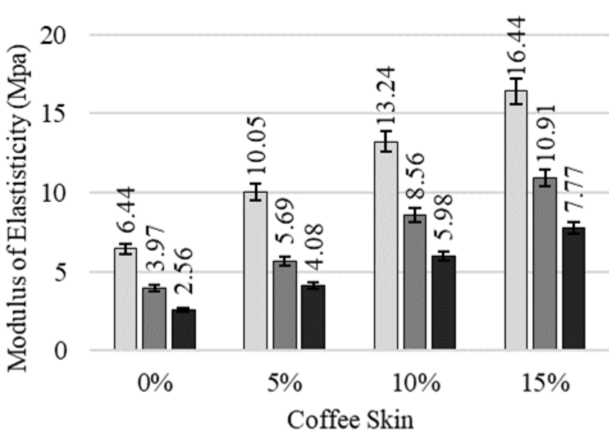


Fig. 10. The elasticity test of biodegradable plastic (glycerol 20%), (glycerol 30%), and (glycerol 40%)

The greater value of the modulus of elasticity, the smaller the strain that occurs, implying that the material becomes stiffer [11]. The addition of cellulose can increase the value of elasticity modulus in plastics due to the hard and strong character of cellulose [4]. The addition of glycerol can reduce the modulus of elasticity so that the plastic will be more flexible. This is because glycerol can reduce the intermolecular forces which can result in the OH group on glycerol which will form intermolecular bonds with polymer chains to be reduced [12]. The value of tensile strength is directly proportional to the value of the modulus of elasticity. The results showed that the value of the modulus of elasticity did not match the required value in SNI. The required value of the modulus of elasticity based on SNI 7188.7:2016 is between 117 – 137 Mpa [13].

## CONCLUSION

The addition of coffee skin and glycerol has a significant effect on the physical and mechanical properties of biodegradable plastic. The effectiveness index test demonstrates that the best biodegradable plastic is characterized by a thickness of 0.956mm, 11.497% water absorption, 61.761% biodegradation, tensile strength value of 3.095 Mpa, 19.055% elongation, and modulus of elasticity of 16.442 Mpa. The highest biodegradation value, 61.761%, was identified after the addition of 15% coffee husk and 20% glycerol. The best treatments based on the results of the effectiveness index test were the addition of 15% coffee skin and 20% glycerol, 10% glycerol and 20% coffee skin, and 5% glycerol and 20% coffee skin.

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