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The Glycerol Effect on Mechanical Behaviour of Biodegradable Plastic from the *Walur* (*Amorphophallus paenifolius* Var. *sylvestris*)

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ABSTRACT

Bioplastic material development by utilizing indigenous commodity is a trend to overcome the environment damage by plastic and as a sustainable resource. As a home of broad biodiversity, Indonesia has more species of *Amorphophallus* that are still unexplored. One of species among them that is possible to explore as bioplastic material is Walur. The aim of this work is to study the behaviour of bioplastics with the Walur corm as a raw material and glycerol as a plasticizer. Glycerol portion is varied in 7 levels and in a range of 6% to 30%. The result showed that glycerol has significantly affected the tensile strength, elongation and modulus elasticity of the Walur plastics. Glycerol could decrease both, elongation and elasticity of Walur plastic despite increasing effect on elongation behaviour.

INTRODUCTION

Various efforts from recycling to energy conversion have been made to overcome the pollution problem of plastic waste . However, it is not enough in degrading the plastic pollution level (Burange et al. 2015). Dominating petroleum based plastics, nowadays in the packaging industry, need to propagate an alternative of biodegradable plastic development. Utilization of native Indonesian commodities as plastics raw material is expected to be an option to mitigate the petroleum plastics hazards. The potential of biodegradable raw materials obtained from renewable resources has been intensively investigated in recent years (Wahyudi et al. 2013).

Indonesia is a home of broad biodiversity, including *Amorphophallus* species that has a potential for bio-plastic material. There are four species of *Amorphophallus* usually found in Indonesia, i.e., *Amorphophallus variabillis, Amorphophallus paeoniifolius* var. *hortensis, Amorphophallus paeoniifolius* var. *sylvestris* and *Amorphophallus muellery blume* with local name as Iles-iles, Suweg, Walur and Porang respectively (Ibrahim et al. 2013). During the last few years, a few attempts have been made on the development and exploiting of konjac glukomannan and its derivatives, especially for nutritional use as well as medicinal use. Also, the exploitation of *Amorphophallus konjac* in aspects of both, processing (Widjanarko et al. 2014) and product development has been paid a great attention in recent years. Widjanarko et al. (2011) found that *Amorphophallus mueleery blume* succeed in order to bind the food bar components and improve food bar breaking force. However, utilization of *Amorphophallus* for bio-plastic material still lack an adequate attention.

The Walur (*Amorphophallus paenifolius* var. *sylvestris)* is a potential source of bio-plastic material. This species is found in Java almost not cultivated, whereas it is commonly found wild in the forest boundary or in marginal land (Kurniawan et al. 2011).

Some previous studies used starch as the material to produce biodegradable plastics such as Chung et al. (2010), De Melo et al. (2011), Mbey at al. (2012), Slavutsky et al. (2012) and Lopez et al. (2015). However, using starch from *Amorphophallus* spp. is relatively rare. Recently, starch has become useful as a biodegradable packaging component in the film (Shen et al. 2010), particularly from underutilized agricultural commodity. Starch as a renewable resource is annually renewable within the limits determined by agricultural capacity and needs for food and fuel (Rhee at al. 2004). Exploring of either needs, food or fuel commodities will advantage in both aspects, agricultural land cultivation and low cost of production. Such efforts to initiate economically conserve the underutilized commodity in Indonesia will maintain the local plant species to strive (Lutfi et al. 2016).

MATERIALS AND METHODS

Fresh corm of Walur were collected from Klangon village, Saradan, Madiun regency, East Java (Fig. 1). First, Walur corm were peeled and washed, and then sliced to make easier to crush. Furthermore, wet sliced walur corm were crushed and then extracted. Sedimentation needs 24 hours to decant solid phase from liquid. After decanting, the solid residue was then dried using an oven at 50°C for 48 h. The dried Walur starch was then ground by using hammer mill and lastly sieved through 200 mesh to get uniform size. NaCl was used to help the cleaning stage, glycerol was used as plasticizer, and 1% acetic acid and distilled water were employed to allow a fine reaction.

Fig. 1: a. Corm of Walur b. Walur Starch

This study used a completely randomized design single factor of glycerol portion. Seven levels of glycerol i.e., 6%, 10%, 14%, 18%, 22%, 26% and 30% were tried to find the best performance of Walur plastics. Each treatment was done by 3 replications. The data obtained were analyzed by using analysis of variance and then compared using Duncan's Multiple Range Test (DMRT). The Walur starch was mixed with the ratio of particular treatment in distilled water at 80°C by a magnetic stirrer at hot plate, operated at 150 rpm for 10 minutes. After the mixture is completely thick and homogenous, blended materials were poured onto a flat glass surface of 10 cm × 15 cm, which has been bordered on both sides with a duct tape to adjust uniformity of plastic thickness. Lastly, they were put in the oven to dry, at a temperature of 70°C for 3 hours. The sheet was then removed from the glass mould to get the final product of Walur plastic. Measuring parameters that were observed and analyzed in this study include, the mechanical properties (Dang et al. 2015) such as tensile strength, elongation, and modulus of elasticity (Muscat et al. 2012, Tapia-Blacido et al. 2011).

RESULTS AND DISCUSSION

Walur thermoplastic is shown in Fig. 2. Walur thermoplastics produced were characteristically transparent and light brown in colour. The average thickness is 0.052mm. The moisture content of plastic varies from 2.095% to 11.205% that is shown in Fig. 3 and it is significantly different by statistical test.

The difference of moisture content among treatments is because of the variance of additional glycerol in each treatment. Increasing glycerol portion in the mixture is directly proportional to moisture content. It is because glycerol is not only able to bind water during the mixing process, but also the hydrophilic behaviour of glycerol. Hence, the moisture of a plastic produced has been increased as the glycerol portion was higher (Shi et al. 2007).

Tensile strength: Mechanical properties of Walur plastic were evaluated in terms of tensile strength, elongation and modulus elasticity. Tensile strength property of a plastic was used to describe the strength of Walur made plastic. The tensile strength testing of the developed plastic will provide information about the suitability for its application.

The increase in glycerol portion was found to significantly affect the tensile strength of the Walur plastic. The tensile strength of Walur plastic varies between 0.010 and 0.038 MPa (Fig. 4), with the strongest plastic obtained from the additional glycerol of 6% i.e., 0.0309 MPa. The increase in glycerol portion affects the lower tensile strength. Glycerol can decrease the tensile strength by weak intermolecu-

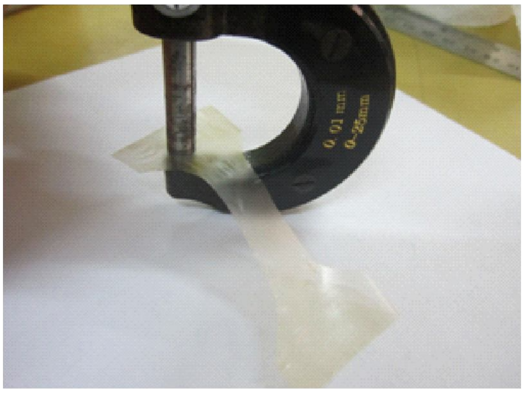

Fig. 2: Specimen of Walur plastic.

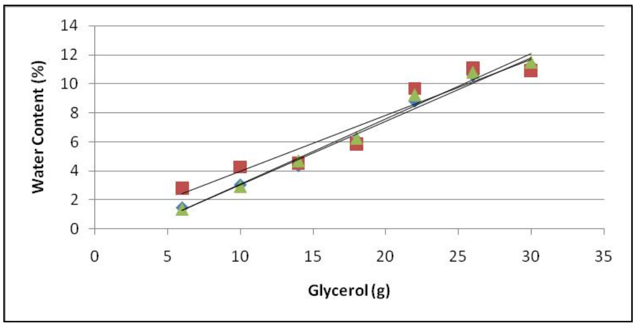

Fig. 3: Effect of glycerol precentage to water content of Walur plastic.

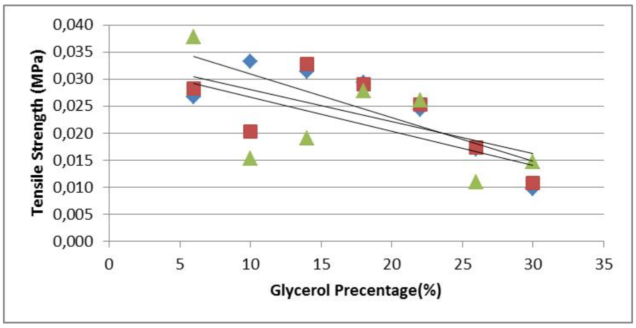

Fig. 4: Effect of glycerol precentage to tensile strength of Walur plastic.

lar forces in their chains (Krochta et al. 2008), as well as the mechanical resistance. Rodriguez et al. (2006) described that the tensile strength weakening by glycerol is because of the disruption of molecular cohesiveness of starch as well as lowering of intermolecular interaction in the film. The high tensile strength at the low glycerol percentage is the effect of strong hydrogen bonds between starch-starch intermolecular interaction over starch-glycerol attraction. Glycerol has the ability to weaken the intramolecular attraction between the starch chains and to raise the formation of hydrogen bonds between glycerol and starch molecules. Thus, it reduces the tensile strength of Walur plastic by subsequently diminishing the hydrogen bonds between the starch chains.

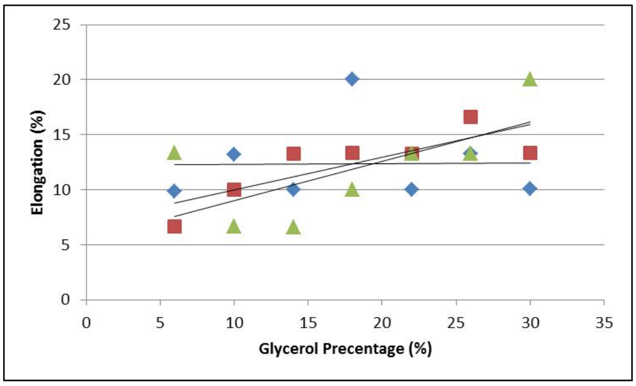

Fig. 5: Effect of glycerol precentage to elongation of Walur plastic.

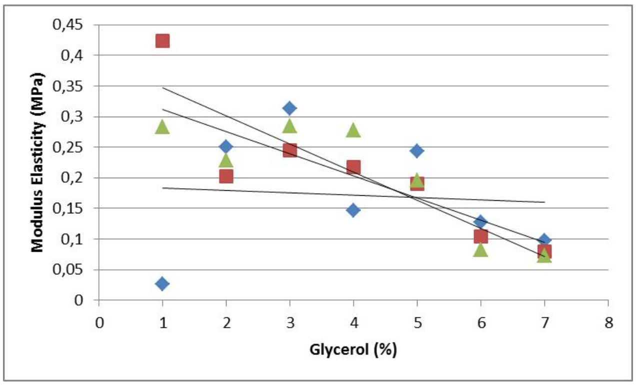

Fig. 6: Effect of glycerol precentage to modulus elasticity of Walur plastic.

Elongation: Elongation property is the percentage increase in length, that occurs before it breaks under tension. The overall results of Walur plastic's elongation are in the range of 6.59% to 20%. Generally, the increase in the glycerol portion was significantly affecting the higher elongation (Fig. 5), despite in the group of low level glycerol addition (6%, 10% and 14%) the elongation obtained was not significantly affected. Higher portion of glycerol addition contrasts the increase in elongation value.

Glycerol as plasticizer serves to reduce the stiffness and improve the flexibility of the plastics through both functions increasing the mobility of the polymer bonding and improving the water holding capacity (De Roza et al. 2012). The experiment found that the water content is increasing linearly with glycerol addition in the mixture. Because the water is also a plasticizer, elongation of Walur plastic has highly correlated with the water content. As water content is directly proportional to glycerol, higher concentration of glycerol results in more flexible film.

Modulus of elasticity: Modulus of elasticity is found by comparing the tensile strength and elongation data measured for a particular treatment. It is an important behaviour of bio-plastics in which the bio-plastics are either compressed or stretched. Statistical analysis showed that glycerol has significant difference on the modulus of elasticity of Walur plastic. Results of Walur plastic's modulus of elasticity for all the treatments in this experiment are shown in Fig. 6. Generally, higher glycerol portion significantly decreases the modulus of elasticity. The most elastic film is 60.19 MPa found in the 6% of glycerol mixture, while the lowest value elasticity is 15.23 MPa found in treatment of 30% glycerol. As modulus of elasticity is directly affecting the elongation and tensile strength, higher percentage of glycerol added improved the mobility of the molecule bonding in the mixture.

CONCLUSIONS

Walur yam starch has worked as an alternative material of biodegradable plastics. The result showed that glycerol has significantly affected the tensile strength, elongation, and modulus of elasticity of the Walur plastic. Generally, glycerol gives an effect not only to decrease the elongation, but also the modulus of elasticity of Walur plastic. Inversely, it is increasing the effect on elongation behaviour.

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