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MANGO (*Mangifera indica* L.) LEAVES WASTE/POLYVINYL ACETATE BIOCOMPOSITE FOR BUILDING MATERIALS APPLICATION

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ABSTRACT

A leaves waste biocomposite was produced via a simple mixing and hot-pressing process. Using mango (*Mangifera indica* L.) leaves waste as a filler and polyvinyl acetate (PVAc) as a binder, the biocomposite was synthesized at pressure and temperature of 3 metric tons and 40°C, respectively, for 20 minutes. The weight fraction of leaves waste varied obtaining a composite having maximum compressive strength, i.e., 37.82 MPa for leaves waste fraction of 0.62 (w/w). This strength is comparable to several stones such as sandstone stone, limestone, clay brick, aspen wood, and pinewood usually used as building materials. Therefore, the biocomposite is acceptable for building materials application.

Key words: Mango leaves waste, polyvinyl acetate, biocomposite, compressive strength

INTRODUCTION

The composite research is one of the emerging studies currently done due to its utilization and applications in several fields relating such as in electricity, magnetism and mechanical properties (Kumagai & Sasaki, 2009; Taghvaei *et al.*, 2010; Zeng *et al.*, 2012; Ko *et al.*, 2014; Wang *et al.*, 2014). Also, particularly the mechanical composite research has been done for a large number of applications, such as automotive and building industries (Holbery & Houston, 2006; Masturi *et al.*, 2010; Rêgo *et al.*, 2015). One of the raw materials that enable to be used for a mechanical composite is solid waste, especially leaves waste. Some works using the solid waste as have been done, such as Hadiyawarman *et al*. (2008) making the solid waste for composite using epoxy resin as a matrix. Kumagai and Sasaki (2009) produced silica composite from agricultural waste. Then, Masturi *et al.* (2010) also developed leaves waste composites using polyurethane.

On the other hand, mango leaves is a kind of crop waste that is rich in resources (Pan *et al.*, 2018), and currently not used for any commercial application. Therefore, the leaves of the mango only become an environmental problem. Previous studies have shown that mango leaves are rich in flavonoids (Berardini *et al.*, 2005), such as quercetin, gallic acid, gallotannins, and iriflophenones (Barreto *et al.*, 2008; Zang *et al.*, 2014; Fernández-Ponce *et al.*, 2015). This flavonoid content is the reason for the enormous potential of mango leaf in large applications of many industries.

Therefore, in this work, we have developed a leaves waste biocomposite using the phenolic or flavonoid compounds of the fiber and minerals in mango leaves associated and bound with PVAc into matrix. The PVAc was used since its binding properties make up strong mechanical properties of composite and has been widely used in several composites engineering, such as in-home waste

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composite (Masturi *et al.*, 2011a), conducting composite (Eraldemir *et al.*, 2008), and silver-iron photocatalytic composite (Ghanbari *et al.*, 2016).

MATERIALS AND METHODS

Materials

The Mango (*Mangifera indica* L.) leaves waste was collected from Central Java province of Indonesia. Commercial polyvinyl acetate (PVAc) was purchased from Bratachem, Semarang, Indonesia. All the chemical were pure analytical reagents from Merk.

Sample preparation

The Mango (*Mangifera indica* L.) leaves waste was cleaned using water, then dried at room temperature (50-60°C) for 20 minutes. The dried mango leaves were pulverized using a crusher-machine.

Synthesis of biocomposite

The powder of mango (*Mangifera indica* L.) leaves was mixed with several weights of PVAc. The PVAc-solid waste mixture then was hot-pressed at pressure and temperature of 4 metric ton and 80°C respectively on a mold of 4 cm in diameter. Finally, the sample was released from the mold to measure its compressive strength.

A compressive strength characterization was performed to test the mechanical strength of composite produced by cutting the sample in the small cubic form (ASTM C0109M-02). This measurement used Torsee Tokyo Testing Machine MFG Ltd. equipped with Load Cell with a relation (Masturi *et al.*, 2010):

$$\sigma = \frac{4P}{\pi D^2}$$

With P is a maximum force loaded making a composite crushed, and D is the composite diameter.

RESULTS AND DISCUSSION

The strength of composite produced varies as the weight fraction of leaves waste with the maximum strength attains 37.82 MPa for leaves weight fraction of 0.62 (w/w) (Figure 1). The variation of strength was commonly governed by surface interaction, especially van der Waals interaction between the atoms of the leaves waste and polyvinyl acetate. In a certain amount, the interaction in atomic-scale significantly increases the strength.

The improvement of biocomposite was governed by interaction-pairs of leaves waste and its polymer. Using the effective interaction, the strength change can be explained using the interaction appearing between the polymer and the leaves waste, where the optimum interaction occurs when all of the polymer surfaces interact with the leaves waste particles surfaces, and it makes the composite strength maximum (Tan *et al.*, 2007; Masturi *et al.*, 2011a; 2016). Even, with polyvinyl

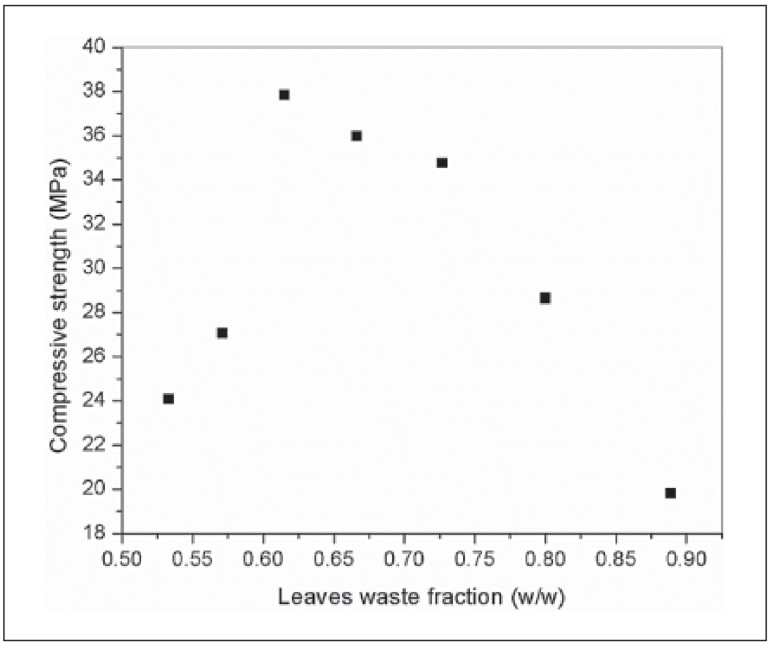

Fig. 1. Compressive strength as leaves waste fraction (w/w) with the optimum fraction is 0.62 (w/w) for compressive strength of 37.82 MPa.

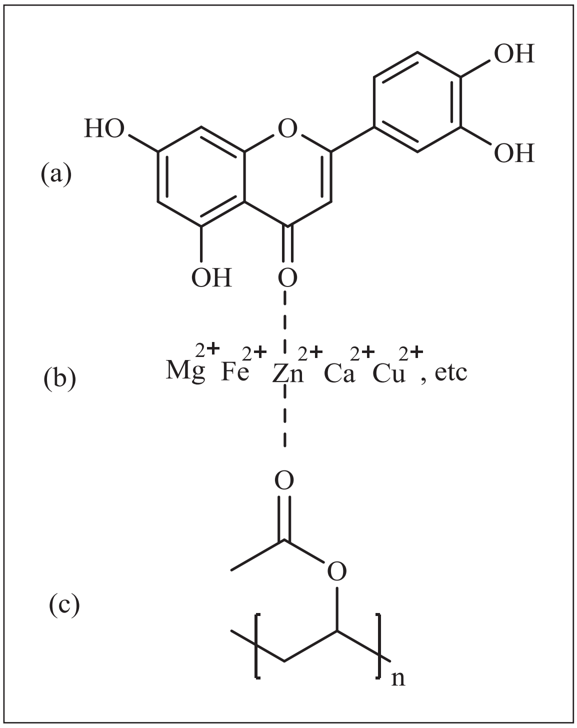

Fig. 2. Illustration of Van der Waals interaction (represented by a dashed line) between (a) quercetin as the main of flavonoid in mango leaves (Wu *et al.*, 2010), (b) mineral in mango leaves (Okwu & Ezenagu, 2008), and (c) PVAc's carbonyl group.

acetate having carbonyl group the interaction especially occurs between its oxygen and some atoms of leaves consisting of oxygen, hydrogen and some metals (Figure 2), however in this work the measurement of composition and amount of the atoms, molecules, and ions contained in the leaves waste has not been addressed. This interaction that is usually called van der Waals interaction mainly governs the composite strength (Volkov *et al.*, 1990; Singh & Bansal, 2015; Liu *et al.*, 2010).

The attainment of strength to 37.82 MPa, then decreases due to leaves addition is fulfilling the pair-interaction between polymer leaves surface. For the initial fraction with a smaller amount of leaves, the interaction has not reached yet maximum since the amount of PVAc is still more significant. Then the addition of leaves wastes up to 0.62 (w/w) affects the improvement of pair-interaction of the latter waste with the PVAc so that the surface of polymer correctly interacts with the leave particles surface, wherein this condition the fraction of 0.62 was called as an optimum fraction. Further, the leaves addition, excluding the optimum fraction presents the new unpaired surface governing the decreasing of the strength (Masturi *et al.*, 2011b; Wang *et al.*, 2015).

The strength of composite produced is very comparable to some materials mainly used in building materials application, such as sandstone stone (43 MPa), limestone (40 MPa), clay brick (20 MPa), aspen wood (36 MPa) and pinewood (41 MPa) (Brencich & Sterpi, 2006; Green *et al.*, 2002; Nazir *et al.*, 2013; Abouhussien *et al.*, 2015). It means the composite is very potential to be used in a building application.

CONCLUSION

We successfully made leaves waste biocomposite using polyvinyl acetate matrix with the maximum strength attaining 37.82 MPa for 0.62 mango leaves waste-fraction (w/w). This strength is comparable to some building materials used widely in building fields, such as sandstone stone, limestone, clay brick, aspen wood, and pinewood. It showed that the biocomposite produced has potential to be used as building materials application.

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