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Edible Film Biocomposite based on Cassava Starch/Soy Lecithin Reinforced by Sugarcane Bagasse Fiber: Mechanical, Morphological and Moisture Properties

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Abstract. Edible film biocomposite (EFB) is a kind of materials able to substitute the non-biodegradable plastics. This idea is one of the breakthroughs in reducing plastic waste which is not environmentally friendly. EFB is an environmentally-safe and biocompostable material. This research explores and fabricate EFB from tapioca starch, soy lecithin and sugarcane bagasse fiber (SBF). The SBF was varied by 1, 2, and 3% (from dry starch) into the cassava starch/soy lecithin matrix. The production of EFB was solution casting. A tensile machine and Scanning Electron Microscope (SEM) observed the tensile properties and fracture surface characteristics. The results present that the highest value of tensile strength is in EFB (2% SBF) of 0.823 MPa. The tensile modulus shows a similar trend in values for this EFB of 0.523 MPa. In addition, the fracture surface provides information that a rough surface indicates a good bond between the matrix and the fiber. These two observations confirm that the matrix has successfully transferred the tensile load to the reinforcement. Meanwhile, the results of resistance to moisture resistance also experienced an increasing trend of around 4% from unreinforced specimens.

Keywords : Edible film biocomposite, Biocomposite, Cassava starch/soy lecithin, Sugarcane bagasse fiber, Tensile strength

1 Introduction

In Indonesia, synthetic plastic waste is a problem that has not been solved to date. This plastic waste is a source of social problems due to their impact on the environment such as flooding, air pollution, and causing environmental damage [1]. One alternative to reduce the

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use of synthetic plastics is environmentally friendly plastic (edible film) which is easily degraded by nature. However, edible film has several weaknesses including low moisture resistance and tensile mechanical properties. The extension of other biopolymers to starch-based edible films can improve mechanical, thermal and moisture resistance properties [2-3]. The combination of two or more materials consisting of a biopolymer matrix and natural fiber which able to improve the material properties, is called an edible film biocomposite [4].

Generally, edible film biocomposite matrices are made from starch, protein, chitosan and polylactic acid [5]. Of these matrices, starch and protein are alternatives in the development of edible films because they have good flexibility and formability compared to other biopolymers [6]. In addition, these two materials are more easily degraded in a relatively short time. Starch is a polysaccharide consisting of glucose and amylopectin, which is capable of making sheets, meanwhile, soy lecithin is a protein obtained from soybean fat, which is biodegradable with good tensile and physical characteristic so that it can be used as a biodegradable resin for the development of edible film biocomposite [7].

The combination of cassava starch and soy lecithin can be used as an edible film matrix. However, the edible film still has weaknesses in its mechanical properties. The addition of cellulose fibers is a way to improve these mechanical properties [3]. Several studies reported that cellulose natural fibers have a reinforcing function in starch-based biopolymer matrices. For example, in research conducted by Asrofi (2018) on the combination of yam starch and water hyacinth fiber. They reported the addition of 1% cellulose fiber increased tensile strength by 200% [8]. Other researchers also reported that the addition of cellulose fiber to biopolymers increased moisture resistance properties [9].

Meanwhile, research on edible films based on cassava starch and soybean lecithin has been carried out by Adjouman (2018) [10]. They reported that addition of glycerol and soybean lecithin decreased tensile properties and increased elongation break. This is due to a decrease in intermolecular interactions between polymer chains. Other researchers also reported that soy lecithin is suitable for use as an emulsifier [10].

Thus, this research has the objective of developing an edible film biocomposite based on cassava starch/soy lecithin reinforced by sugarcane bagasse fiber. To the best of the author's knowledge, no studies have published this object. Characterization of edible film biocomposite using tensile test, fracture morphology analysis by SEM and moisture absorption test.

2 Materials and methods

2.1 Materials

Cassava starch (tapioca flour) brand 99 super was purchased from a local shop in Jember, Indonesia. Granular soy lecithin (710 calories; 58.4 gr total fat, 8.2 gr total carbohydrates) was purchased from Matahari Sdn. Bhd. Selangor, Malaysia. Sugarcane bagasse was obtained from a sugarcane ice seller located in Jember, Indonesia (Google Map Coordinates: -8.169104916691335, 113.70225526116143). All chemical materials (98% NaOH and Aquadest) were supplied by Materials Testing Laboratory, Mechanical Engineering Department, University of Jember, Indonesia.

2.2 Preparation of sugarcane bagasse fiber (sbf)

Sugarcane bagasse fiber (SBF) was washed thoroughly using water, then followed by an alkalization process of 10% NaOH for 4 hours. The SBF was rinsed using aquadest until it reached a neutral pH. In the final process, it was dried in an oven for 20 hours at 50 ℃ to form paper.

2.3 Production of edible film biocomposite (efb)

Cassava starch, soy lecithin, glycerol and distilled water were dissolved in aquadest using a hot plate magnetic stirrer at 400 rpm for 10 minutes. SBF was added to the mixture with variations of 1, 2, and 3% (from the starch dry weight) to produce EFB. The EFB was coded as SPL (Sample), namely SPL1%, SPL2%, SPL3% for the addition of sugarcane bagasse fiber into the matrix of 1%, 2%, and 3%, respectively. The EFB mixture in the form of a solution was stirred at a temperature of 65 - 75 ℃ for 25 minutes at 200 rpm to form a hydrogel. Then, the hydrogel was poured into a rectangular glass mould (10 cm long and 5 cm wide) and dried in an oven at 40 °C for 24 hours as reported by previous research [11]. After drying, the EFB specimens were cut to form tensile test sizes according to ASTM D882 standards.

2.4 Tensile test

Prior to the tensile test, the specimen must be shaped and sized in accordance to ASTM D882 standard [12]. The tensile test of EFB was carried out using a Wang TA Type SF093A tensile testing machine at room temperature with a tensile speed of 3 mm/minute. Before the tensile test, the specimens were measured for width and thickness at 5 different points for each and averaged. Tensile testing was carried out on all specimen variations with 3 repetitions, then the average value was taken to get the results as reported by previous study [13].

2.5 Fracture morphology observations

Scanning Electron Microscope (SEM) was operated to observe the fracture morphology of the EFB specimen after tensile test. The type of SEM machine used was the Hitachi model TM 3030. Observations were made at a voltage of 1 kV with a magnification of 5000 X.

2.6 Moisture absorption test

The moisture absorption test was conducted to determine the moisture resistance. The test was done in a closed chamber filled with water at 78% humidity and room temperature. The EFB sample was cut to a size of 2 cm x 2 cm, then dried for 2 hours in a drying oven to constant weight. After that, the samples were weighed to determine the initial weight (Wo) before testing. The final sample weight (Wt) was obtained after the sample was tested in a moisture chamber. The final weight was recorded hourly. The calculation of the percentage of moisture absorption using the formula as according to previous study [14]:

$$Moisture\ Absorption = \frac{W_t - W_o}{W_o} x100\% \qquad (1)$$

3 Results and discussions

3.1 Tensile properties

Tensile strength is the limit of the ability of a material to withstand the tensile loads obtained by the product or material before failure or fracture occurs [15]. The mechanical properties of the composite depend on the interfacial bond between the matrix and filler [16]. Modifying the filler/fiber surface improves tensile strength, moisture resistance and thermal stability. The results of the tensile test in this study are shown in Figure 1. These results indicate an increase in tensile strength in line with the increase in fibre percentage. The highest yield was shown in the addition of 2% fiber with a value of 0.829 MPa. This is because the interaction mechanism of the matrix polymer chains becomes limited when cellulose fibers are added to the matrix. According to previous research, the interaction of fibers in the matrix forms hydrogen bonds which can improve mechanical properties [3].

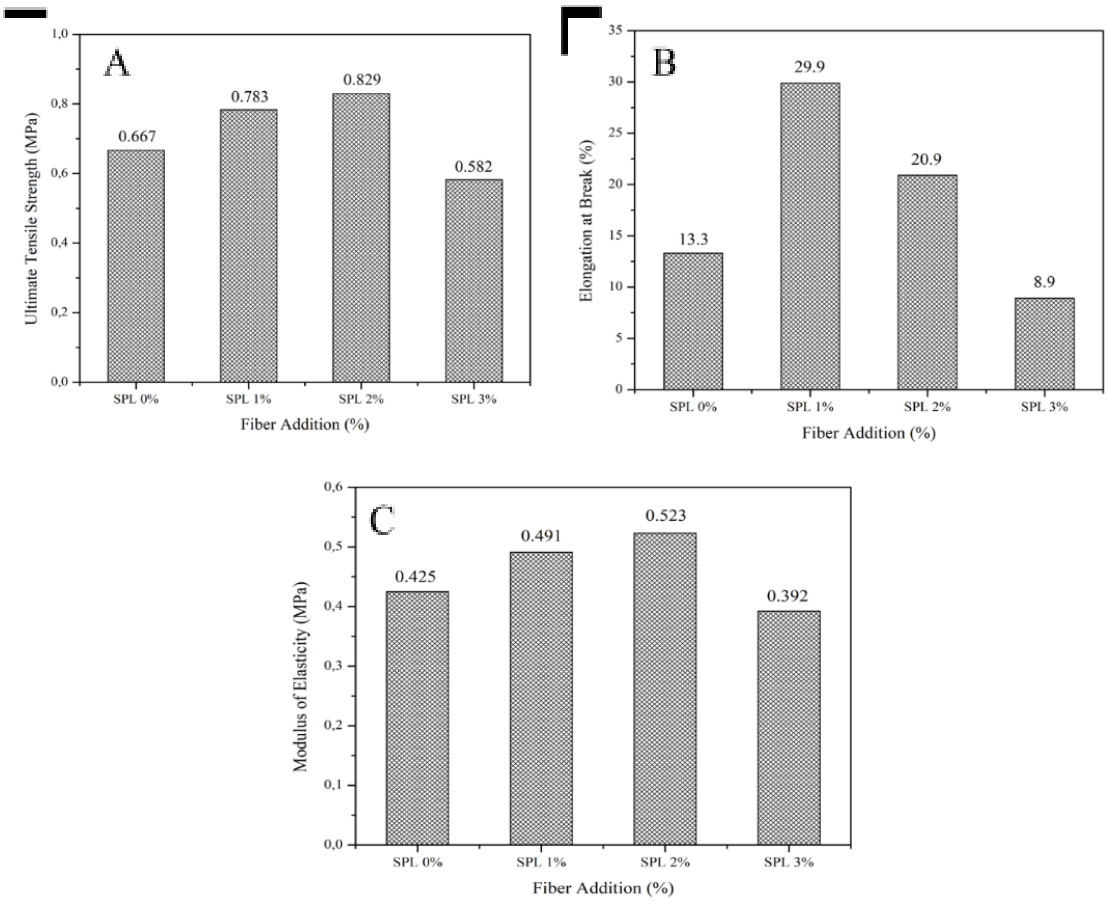

Fig. 1. Tensile properties of EFB: (a) tensile strength, (b) elongation at break and (c) modulus of elasticity

A different phenomenon was shown by EFB with the addition of 3% fiber. In this biocomposite the tensile strength value decreased to 0.582 MPa. This case due to poor and bad interfacial bonding which induces microspaces between filler and matrix causing microcracks [7]. According to previous researchers, the decrease in the tensile strength of EFB was caused by agglomeration in the matrix and poor surface bonding between the matrices, where the matrix has the same hydrophilic properties as the fiber. With an increasing number of fibers, the fiber also produces free OH bonding due to its hydrophilic nature [3, 17].

Meanwhile, the elongation at break graph is shown in Figure 1b. The addition of bagasse fiber mass reduced the toughness of the edible film biocomposite. As seen in the figure, the EFB decreased with each addition of 2% and 3% bagasse fiber. This is due to the addition of filler material to the matrix resulting in material stiffness which causes the material to be less ductile [8]. Another reason is that the presence of fiber in the matrix makes the movement of the polymer chains less flexible so that the biocomposite material is rather stiff [2, 3]. The modulus of elasticity is shown in Figure 1c. The value of the elastic modulus increased with the addition of 1% and 2% bagasse fiber with a value of 0.491 MPa to 0.523 MPa. This is due to the strong bond between the matrix and fiber interfaces. According to previous study, the homogeneous distribution of the fibers and the high interfacial surface area between the fibers and the matrix which might lead to an increase in the elastic modulus. On the addition of 3% bagasse fiber in the matrix, the modulus of elasticity decreased to 0.392 MPa due to fiber agglomeration in the matrix [18]. Several factors that cause an increase or decrease in the modulus of elasticity are film fabrication, for example temperature, homogeneity, and time

3.2 Fracture morphology

SEM observation was carried out to determine the microstructure of the fracture of the edible film reinforced by bagasse fiber. The samples observed were EFB with 2% and 3% fiber reinforcement due to the highest and lowest tensile strength results. Figure 2 shows morphological observations with SEM. As seen in Figure 2a, the sample with the highest tensile strength shows a homogeneous smooth surface and a compact structure. The addition of fiber causes the formation of a more heterogeneous surface, where the filler is covered with a starch matrix. In addition, a rough surface is also seen due to tensile loads and this shows that the matrix successfully transfers all the load to the filler because a good bond is formed [2].

In the observation of the EFB sample with the addition of 3% fiber (Figure 2b) it showed that the particle density increased, resulting in interactions between filler particles which could result in the formation of defects in the matrix which affected the film structure. It can be seen that the surface of the sample has gaps and porosity or empty space on the edible film sample. This is because the fibers are not uniform and not evenly distributed (agglomeration) thereby reducing the tensile strength [19].

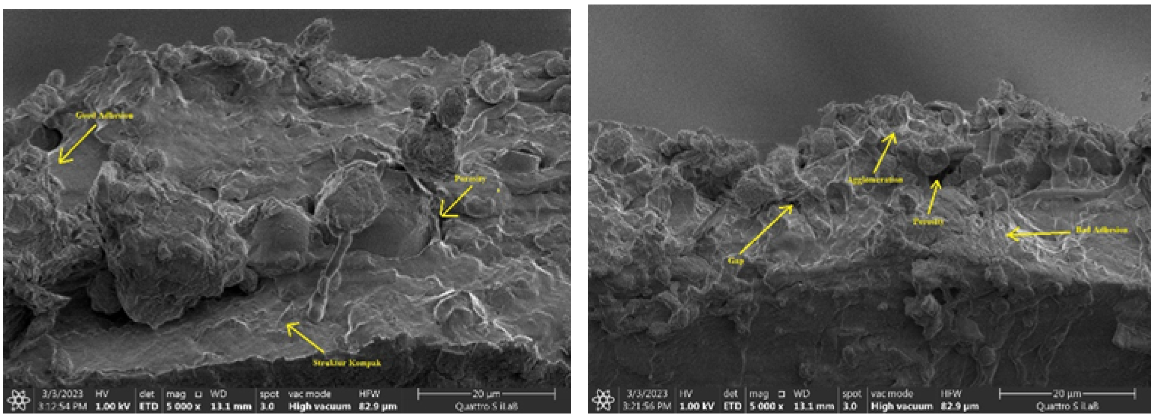

Fig. 2. SEM Observation to determine the fracture morphology after tensile test of EFB: (a) 2% and (b) 3% fiber in matrix

3.3 Moisture resistance

Figure 3 shows the results of the moisture absorption test of all EFB samples. It can be seen that, as the addition of sugarcane bagasse fiber into the matrix display a decrease in moisture absorption. The lowest percentage decrease in moisture absorption is located in the sample with the addition of 2% fiber with a value of 45% (at 3 hours). This is due to the good bond between the matrix and the fiber so that water vapor is prevented from entering the matrix [8]. A good bond between the matrix and the fibers reduces the gaps in the biocomposite material. This phenomenon has been proven by previous research that the bond between matrix and fiber is good as a barrier for moisture to enter the biocomposite [20].

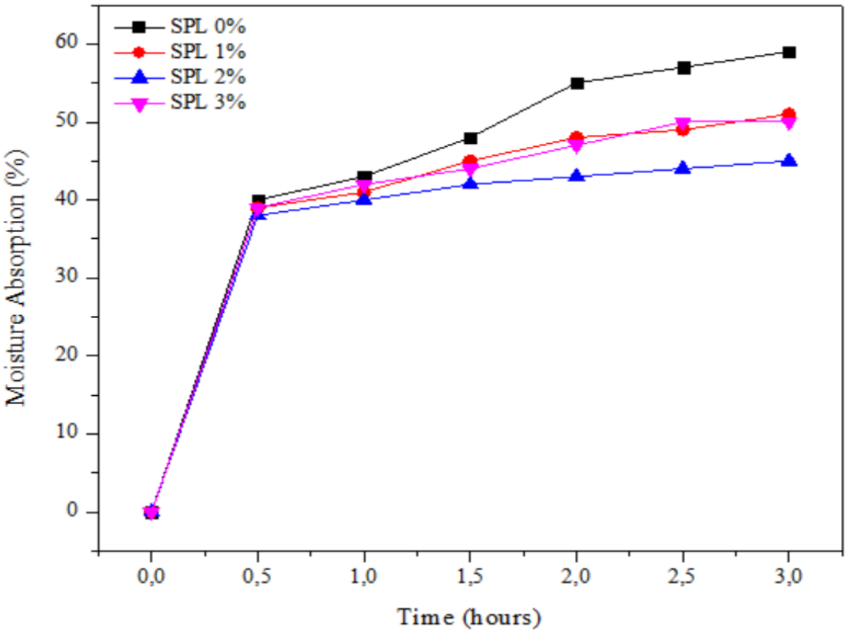

Fig. 3. Moisture absorption of all samples tested

The phenomenon is different when the EFB sample is added with 3% fiber. In this sample there was an increase in moisture absorption due to the poor distribution of fibers in the matrix [3, 14]. This proves that this sample has a low moisture resistance compared to other samples.

4 Conclusions

Edible Film Biocomposite (EFB) based on Soy Lecithin/Cassava Starch reinforced by SBF was successfully made through a solution casting process. The addition of the mass fraction of cellulose fibers affects the value of the tensile strength of the sample. The highest tensile strength value is found in the 2% variation with a tensile strength result of 0.829 MPa. This is evidenced by the good bond between matrix and fiber through SEM observations. In addition, the increasing of fiber content into the matrix also improve the moisture resistance. For future research, it is necessary to pay attention to the composition and fabrication process of EFB

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