



## Studies on Tensile Strength, Fracture Surface and Biodegradation of Biocomposite From Polyvinyl Alcohol (PVA) Filled by Sugarcane Bagasse Fiber

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**Abstract.** Synthetic plastic is a material that is difficult to decompose in the environment and causes serious problems in long term such as an increase in the volume of waste. To reduce plastic waste, biodegradable composite (biocomposite) is expected to overcome this problem. Natural cellulose fiber can be used as a filler in biopolymer matrix based biocomposite. This study aims to determine the tensile properties, fracture morphology, and biodegradation rate of biocomposite from Polyvinyl Alcohol (PVA) and sugarcane bagasse fiber. The test of biocomposite samples was carried out with a tensile test, scanning electron microscopy (SEM), and soil burial test. The results show that the highest tensile strength and modulus elasticity was in PVA pure film for 2.15 MPa and 3.468 MPa, respectively. The addition of cellulose fiber from sugarcane bagasse in the PVA matrix did not have a strengthening effect on the tensile strength of the biocomposite. This is due to the presence of porosity, agglomeration, and poor bonding between the matrix and fiber according to the SEM observation. The biodegradation rate showed that all biocomposite samples were degraded in the soil and had weight loss above 40% after 15 days of burial in the soil. From the data above, this biocomposite is very possible to be used as an environmentally friendly food packaging.

**Keywords:** Biocomposite; Polyvinyl alcohol matrix; Sugarcane bagasse cellulose fiber; Tensile Strength; Biodegradation in soil.

### 1. Introduction

Many plastics are made from non-biodegradable chemical products which are difficult to decompose in the environment and cause serious problems in long term [1]. To reduce plastic waste, biodegradable composite is one of the solutions to replace non-biodegradable plastics. Biodegradable composite is generally produced from natural polymers namely polysaccharides, proteins, lipids, cellulose, or a combination of other components [2-4]. The addition of fillers to the

biopolymer matrix can improve the properties of the biodegradable composite [5]. Some candidates for natural cellulose fibers as fillers are banana leaf fiber, coconut shell, water hyacinth, kenaf, bamboo, and some non-wood fiber including biomass waste [6-7].

Biodegradable composite or biocomposite is a material formed by matrix and reinforcement (filler). The combination of matrix biopolymer with natural cellulose fibers can produce environmentally friendly packaging products [4]. The addition of cellulose fibers into the biopolymer matrix can increase the tensile strength of the biocomposite. This is because the semicrystalline structure of cellulose can bind well to the biopolymer matrix [8]. From these examples, researchers generally modify the fiber surface only to the alkalizing stage. This can result in the lignin and hemicellulose content remaining in the natural fiber. To obtain a high cellulose content, several researchers have modified the surface of natural fibers with chemical treatments such as alkalization and bleaching [4, 9]. However, it should be noted that very strong or excessive chemical treatment also causes changes in the crystal structure of cellulose. It can also reduce the bond between the matrix and the fiber and resulting in low mechanical properties [10].

Several biocomposites based on biopolymer matrix and cellulose natural fibers have been studied by several previous researchers. For example, PVA is filled with waste fiber areca [11], black oat [12], rice husk [13], and durian peels fiber [14]. They reported that the improvement in mechanical properties was due to the good hydrogen bonding between the matrix and fibers, the strengthening of the crystallization degree, and the even distribution of the fibers in the matrix [14]. However, the addition of cellulose does not always improve the mechanical properties of the biocomposite. Previous researchers reported that the addition of fibers to the matrix decreased the mechanical properties. This is due to poor hydrogen bonding between the matrix and fiber and a large number of agglomeration formations. The mechanism of interaction between PVA and cellulose in the hydroxyl group of cellulose and PVA matrix is hydrogen bonding [15].

Therefore, the modification of the fiber surface to the bleaching stage needs to be investigated further. In this study, sugarcane bagasse fiber was processed by alkalization and bleaching and continued with acid hydrolysis. The resulting fiber is made as a filler in a Polyvinyl Alcohol (PVA) biopolymer matrix. The characterizations were the tensile test, scanning electron microscopy (SEM), and biodegradation in the soil.

## 2. Experimental

### 2.1. Materials

Polyvinyl alcohol (PVA) with a viscosity of 49.2 cps (alcoholysis degree of 87.58 % mol) was purchased by Chang Chun Petrochemical Co., Ltd. Sugarcane bagasse was obtained from sugarcane

bagasse ice seller located in Jember, Indonesia. The cellulose content of sugarcane bagasse was 46%. All chemicals reagent (NaOH, NaClO<sub>2</sub>, and distilled water) were supplied by Material Testing Laboratory, University of Jember.

## 2.2. Methods

PVA was dissolved in distilled water using a hot plate and magnetic stirrer for 120 min at room temperature to form a gel. Sugarcane bagasse fibers were dried to constant weight under the sun for 5 days. Then, it was processed by alkalization with 15% NaOH solution to remove lignin and impurities. The alkalized fiber was neutralized with distilled water to pH 7. The sugarcane bagasse fiber was then bleached using a 10% NaClO<sub>2</sub> solution. After the bleaching process, the fibers were neutralized with distilled water to pH 7.

The biocomposite was prepared by the solution casting method. First, 10 grams PVA was dissolved in 100 ml of hot distilled water at 90 °C for 1 h. After completely dissolved in become PVA solution, it was mixed by adding bleached sugarcane bagasse fiber at variations of 0%, 8%, 9%, 10%, and 11% from the total weight percent of PVA, and 2 mL of glycerin was added as a plasticizer. The solution was mixed with the hot plate magnetic stirrer at 150 rpm for 15 min at a temperature of 60 °C. After mixing, the solution was allowed to stand at room temperature for 5 min to remove air bubbles. Then, the biocomposite solution was dried in a drying oven at 60 °C for 20 h.

The dried biocomposite sample was cut according to ASTM D882 standard for tensile test. The tensile test was carried out 5 times for each sample with HT-2402 computerized universal testing machine to obtain the average tensile strength. The test was conducted in room temperature with 5 mm/min of tensile speed. Scanning electron microscopy (SEM) was performed to observe the fractured surface of the biocomposite after tensile test. SEM was operated under 10 kV and at room temperature. The biodegradation test of biocomposite was carried out in soil (pH 6) (soil burial test). The biodegradation samples were cut in a size 2 cm x 2 cm. There are 3 samples for each variation when soil burial test. The samples were buried 10 cm deep from the soil surface at open environment.

## 3. Results and Discussions

### 3.1. Tensile Strength

PVA as a matrix and sugarcane bagasse as a fiber with mass fraction variation (0%, 8%, 9%, 10%, and 11%) has been made through solution casting. This study obtained biodegradable composite (biocomposite) in sheet form. [Figure 1](#) displays tensile strength, modulus elasticity, and elongation at break. The addition of fiber mass fraction affected tensile strength ([Figure 1a](#)), based

on the result 0% variation was achieved as the highest tensile strength for 2,15 MPa.

Different phenomena are shown by biocomposites with the addition of sugarcane bagasse fiber. The addition of bagasse fiber into the PVA matrix decreased the tensile strength of the biocomposite. For example, with the addition of 8% bagasse fiber, the tensile strength value decreased to 1.85 MPa compared to pure PVA specimens. This is also similar to the addition of fiber by 9%, 10%, and 11%. This is due to some porosity that appears on each part of the fault and the bad adhesion bonding between the matrix and fiber [15-16]. In addition to the two reasons above, the phenomenon is due to the cellulose fiber of the sugarcane not completely moistened by the PVA matrix during the fabrication process.

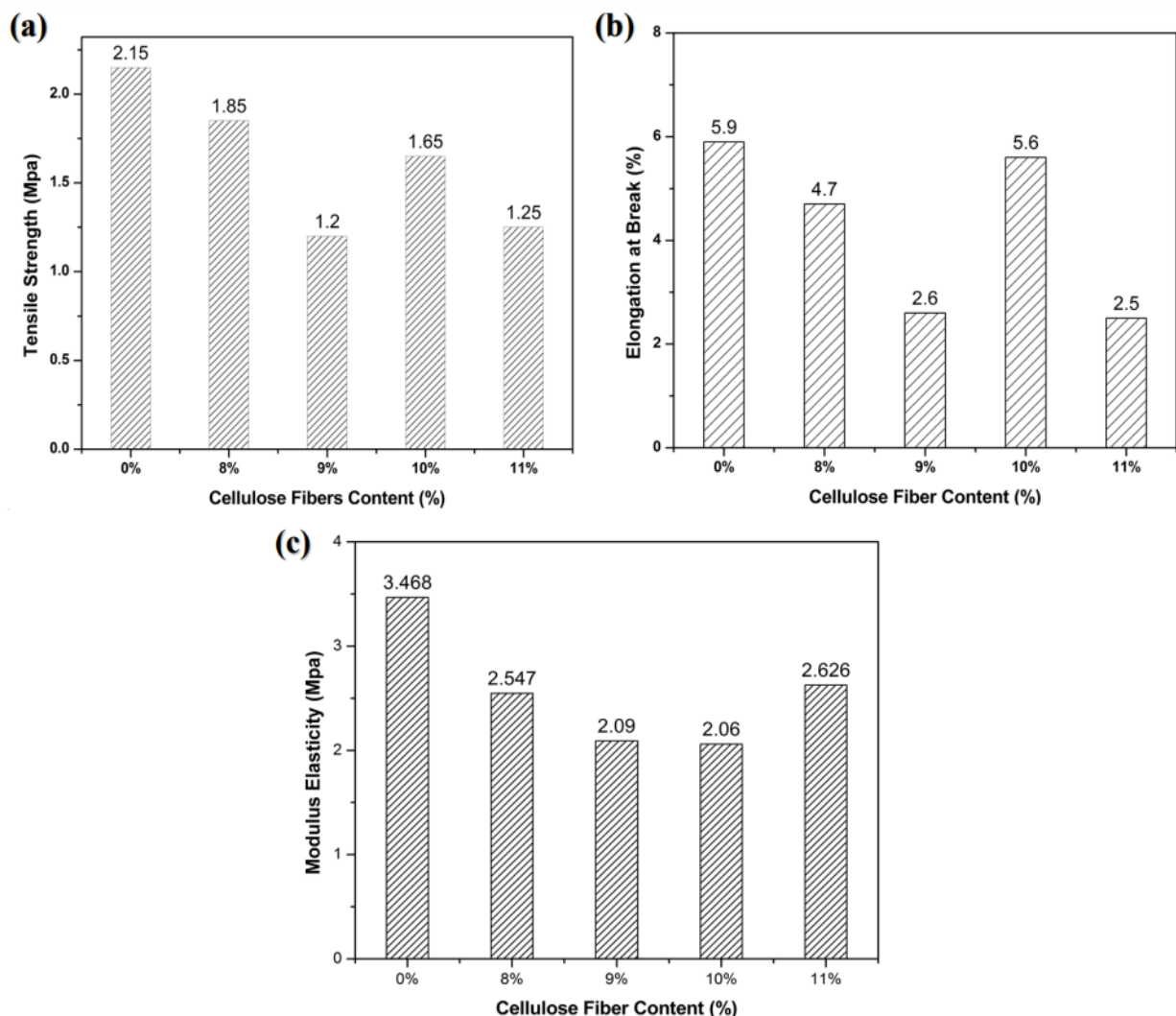


Figure 1. Tensile properties of all biocomposite tested: (a) tensile strength, (b) elongation at break, and (c) modulus elasticity

The addition of sugarcane bagasse fiber affected elongation at break. Figure 1b shows that the highest elongation at break PVA filled 0% sugarcane bagasse fiber based biocomposite for 5.9%.

But, with the addition of 9% fiber in PVA matrix, there was a decrease with a value of 2.6%. However, at PVA/10% fiber biocomposite sample there was an increase and 11% decrease again. According to previous research, they explained that the elongation value continues to decrease along with the addition of variations in the ratio of lignin to PVA, causing low ductility [17].

Figure 1c shows the modulus elasticity of all biocomposite samples tested. Based on the results, the highest value of elastic modulus lies in pure PVA film (Biocomposite with 0% fiber). The addition of fiber into the PVA matrix had no significant effect on the modulus of elasticity. This result is in agreement with the tensile strength trend (Figure 1a). This is due to the porosity of the fracture surface. In addition, fiber agglomeration may also be the cause of the decrease in the modulus of elasticity. This phenomenon is similar to that reported by previous researchers [18-19].

### 3.2. Fracture Morphology

Figure 2 displays the fracture morphology of biocomposite based PVA and cellulose from sugarcane bagasse. Figure 2a and 2b display a fracture morphology of 8% fiber filled PVA matrix with different magnification.

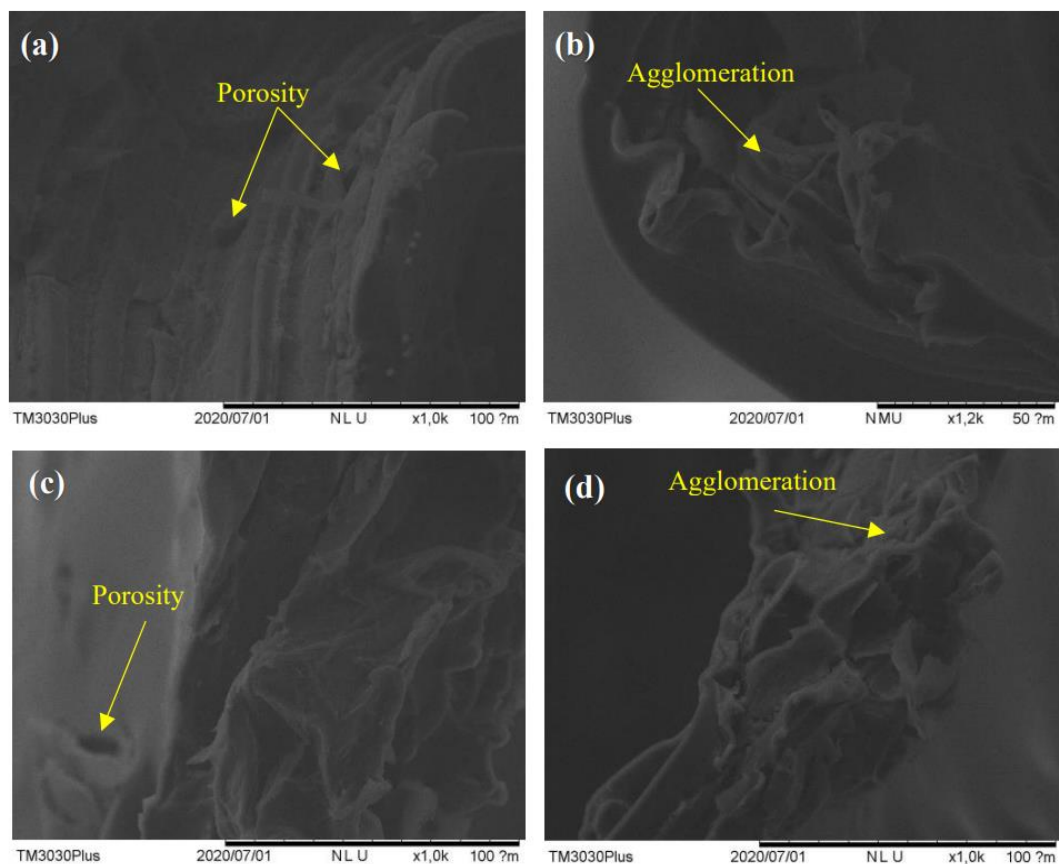


Figure 2. Fracture morphology of biocomposite by SEM: 8% fiber in matrix with magnification (a) 1000x and (b) 1200x; 11% fiber in matrix with magnification (c) 1000x and (d) 1200x

This sample has several morphological appearances such as porosity, bad adhesion bonding between matrix and fiber [15]. This is because the mixing process during fabrication is less homogeneous, resulting in some of these phenomena [19]. This is confirmed by the tensile test results wherein, the tensile strength value of 8% fiber in PVA matrix biocomposite is lower than that of pure PVA film. A similar phenomenon was also shown by the sample with the addition of 10% fiber into the PVA matrix (Figures 2c and 2d) with different magnifications. As seen in the picture, there is a phenomenon of gaps and agglomeration of fibers in the matrix. This causes the mechanical properties of the biocomposite to be low. A similar case was also reported by previous studies which stated that the fibers did not always bind well to the matrix and the distribution of the fibers was uniform [15, 20].

### 3.3. Biodegradation in Soil

The biodegradability test was carried out to determine the effect of adding sugarcane bagasse cellulose fiber to PVA matrix based biocomposites within a certain time, to get the percentage of weight reduction and sample damage. Figure 3 shows the biodegradation rate of PVA-based biocomposite samples with the addition of sugarcane bagasse cellulose fibers at 0%, 8%, 9%, 10%, and 11%. In the figure, it can be seen that all biocomposite samples experienced an increase in the rate of weight loss with increasing time. For the addition of 0% fiber into the PVA matrix and its biocomposite, the sample experienced an increase in percentage loss continuously. The increase in the value of the biodegradation rate in the sample was due to several factors including humidity and the number of microorganisms in the soil [21].

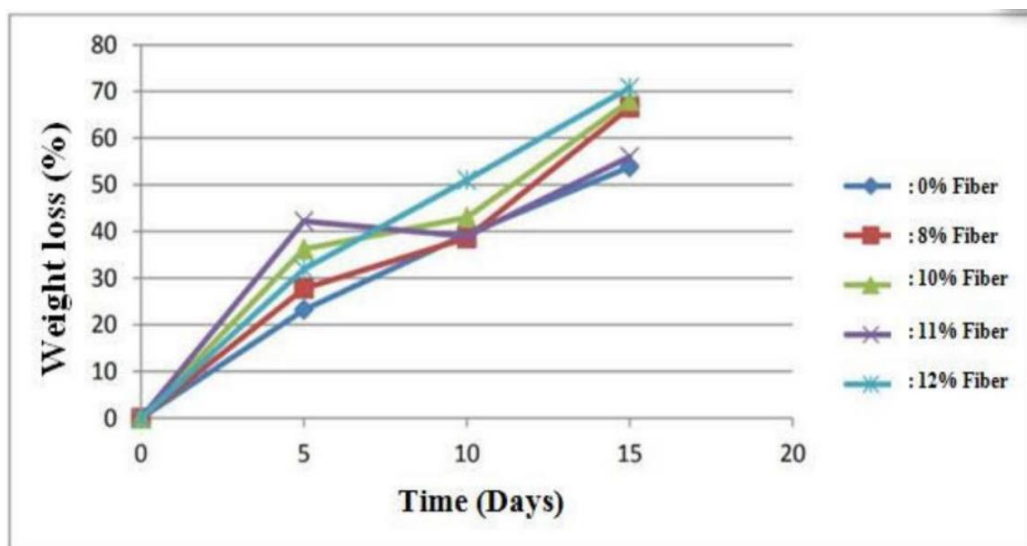


Figure 3. Biodegradation rate of all biocomposite samples after burial test

The lowest percentage rate of weight loss after burial in the soil was found in pure PVA samples. A different phenomenon was shown by the composite sample with the addition of cellulose fiber into the PVA matrix. As seen in the graph, the percentage of weight loss after burial was higher than that of pure PVA. This may be due to a large number of porosities and voids in the sample. This phenomenon is similar to that reported by previous researchers [21-22].

The addition of natural fiber into the PVA matrix also affects the biodegradation process because the natural fiber undergoes an alkalization treatment process so that it can be related to the rate of biodegradation that the fiber that has undergone chemical processing makes the rate of biodegradation faster. Another factor that affects the rate of biodegradation in biocomposite samples is the hydrophilic nature of the PVA matrix that absorbs water in the soil resulting in increased weight loss after the burial process [22].

The results of this biodegradation rate can be confirmed by the results of tensile tests and fracture morphology where bagasse cellulose fibers do not have a significant effect. This is due to several factors including poor bonding between the matrix and the fiber, the amount of porosity, and the accumulation of fibers in some parts of the matrix.

#### **4. Conclusions**

Biocomposite films from Polyvinyl Alcohol (PVA) as a matrix and sugarcane bagasse cellulose fiber as filler were successfully prepared using the solution casting method. The addition of cellulose fiber from sugarcane bagasse in PVA matrix does not have a strengthening effect on the tensile strength of the biocomposite. This is evidenced by the phenomenon of a gap, porosity, and poor bonding between the matrix and the fiber. This is indicated because the biocomposite fabrication process is not good during the matrix and fiber mixing process. This biocomposite is environmentally friendly as evidenced by a weight loss of over 40% after 15 days of burial in the soil.

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