CHARACTERISTICS OF FIBER TREATMENTS ON TENSILE AND IMPACT STRENGTHS OF PINE RESIN/ARECA HUSK FIBER BIOCOMPOSITES

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ABSTRACT

In this study, alkali treatment was carried out on natural fibers to increase their mechanical strength, change the chemical composition, and clean the fibers of impurities. Areca husk fibers (AHFs) were soaked in an alkaline solution, and dried. Alkali-treated fibers were blended with preheated pine resin, and the tensile and impact strengths of the pine resin/AHFs biocomposites were evaluated. The fibers treatment, the tensile strength increased by about 11% and increased by about 33% compared with untreated fiber biocomposites. Alkali treatment also increased the value of the Young's modulus of the fibers by about 9.2%. The impact strength of the pine resin increased by nearly 42% from the presence of 10% by weight AHF content. For the pine resin/AHFs biocomposites, the impact strength increased 24% compared with untreated AHFs. The mercerization increased the adhesion of the fiber-matrix interface, enabling efficient transfer of tension from the matrix to the AHFs. By the SEM, increased adhesion bonding between the matrix and the fibers was also detected. This is significant, considering that tensile and impact strengths are some of the most important mechanical properties of a composite material that are affected by the bonding force between the matrix and the fibers.

Keywords: alkaline, areca husk fibers, pine resin.

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1. INTRODUCTION

Utilization of natural fibers in the science of materials has been widely developed [1,2], especially natural fibers derived from agricultural waste that has been not utilized to the fullest. Along with the increasing public awareness of environmental pollution and the use of renewable natural materials various agricultural waste began to be developed [3].

Given all this time in the material use of synthetic fiber has been done because of several advantages of synthetic fibers. But on the one hand synthetic fibers have serious flaws in terms of biodegradability, high initial processing cost, recycling, energy consumption, machine abrasion and health hazards [4,5].

One type of agricultural waste that has potential as a biocomposite reinforcement is areca husk fibers (AHFs) [6,7], which are quite abundant, have a low density, are renewable, can naturally decompose, and have good mechanical properties. Areca trees will bear fruit depending on the soil conditions, and the average areca tree in Indonesia after the age of 5–8 years produces fruits in the shape of a round egg with lengths between 3.5 and 7 cm. A hard, fibrous fruiting wall covers the endosperm and the husk weighs about 60%–80% of the total weight of the fruit. The fiber length is 5–6 cm on average and the diameter is 0.3–0.5 mm [8]. In general, the chemical composition of the areca nut consists of lignocellulose, which comprises cellulose, hemicellulose, lignin, and other components [9]. Lignocellulose is an organic material contained in plants and is hydrophilic because it contains many hydroxyl groups. Since the composite matrix is generally hydrophobic, this often leads to low composite material interface bonds. Therefore, it is necessary to apply certain treatments to natural fibers that are to be used as reinforcement in composites to improve the binding ability with the matrix, which can also affect the chemical composition of the fiber and fiber structure and reduce natural fiber moisture. A common chemical treatment is alkali (NaOH) treatment, which is one method to increase cellulose content through hemicellulose and lignin removal [10]. As the strength and stiffness of plant fibers depend on the cellulose content, increased cellulosic content is a key factor for improving fiber properties. Alkali treatment can purify and repair the fiber surface to lower surface tension and increase the interface bonding of the fibers and matrix [11]. The alkalization process brings up cellulose and removes impurities on the surface of natural fibers, such as lignin and pectin, to improve the mechanical properties of fibers [12,13].

The matrix used in this study as a composite material does not damage the environment. Therefore, the proposed biocomposite is environmentally friendly too. Using areca husk fibers and pine resin will help to save resources. Pine resin has hydrophobic characteristics and is soluble in neutral solvents or nonpolar organic solvents (ethyl ether, hexane, and oil solvents) [14–16]. Colophony is used as a mixing agent in sizing agents, printing ink factories, varnishes, and adhesives. In [17,18], colophony esters of pine resin processing were reported to be widely used in the printing ink, coating, and adhesive industries. In [19], the use of colophony as a glue showed that it is fractal is 1.3319, which means that colophony has a level of regularity of grains/aggregates that is less regular, making it easier for other substances to be absorbed into the grain structure; in other words, it has good adhesiveness. Based on the characteristics of the properties of colophony, it is possible to use it as a matrix in a composite, given that the potential for the development of natural composites is very high [20]. Considering the importance of surface treatment as an initial step in the process of making natural-fiber-reinforced biocomposites, we investigated the effect of alkali treatment of fibers (NaOH) on the tensile strength, impact strength, and morphology of natural fibers in a pine resin/areca husk biocomposites.

2. MATERIALS AND METHODS

Pine resin (1.1 g/cm³) was obtained from KPH East Bali, and areca husks were from Payangan, Gianyar, Bali. The fiber was selected from the ripe areca, as shown in Figure 1. These areca husk fibers had a high cellulose content (54%) and a low lignin content (21%) [21].

Figure 1. Natural fibers (a) Areca fruit and (b) areca husk fibers.

2.1. Retting

The process of retting the fibers was done mechanically by separating the fruit core from the husk, and the husk of the areca was cleaned in a water medium until the areca husk fibers detached from the connective tissue. Furthermore, the fiber was immersed in water for about one week. It was then removed, cleaned, and allowed to air-dry. [22].

2.2. Pine Resin Preparation

Pine resin was heated at a temperature of 170 °C 90 min, with a magnetic stirrer speed of 400 rpm until golden-colored.

2.3. Tensile Properties

The specimens of tensile tests were based on ASTM D638. The tests were undertaken by use of an universal testing machine to determine the tensile strength, tensile modulus, and elongation at break at room temperature. The testing conditions used were load cells of 0.5 kN with a crosshead speed of 2 mm/min. The reported values are the average of at least five measurements.

2.4. Impact Strength Measurement

Impact tests were performed with an impact machine according to ASTM D256, with notched Izod impact strength. Five specimens were measured for each sample.

2.5. Morphological Characterization by SEM

Pine resin/areca husk fiber biocomposites were mounted into specimen stubs using double-sided adhesive.

3. RESULTS

3.1. Tensile Test Results

Tensile strength is defined here as the force per unit area (N/mm^2 or MPa) required to break the biocomposite material. This test was performed until complete failure or breaking. The effect of chemical treatment and volume fraction on the tensile strength of areca husk fiber reinforced pine resin biocomposites with 5%, 10%, 15%, and 20% fiber loads is reported in Table 1.

Table 1. Mechanical properties determined by tensile test (TS, tensile strength; ϵ , elongation; E, modulus)

Biocomposite	TS (MPa)	ϵ (%)	E (GPa)
Pine Resin (PR) (S-1)	0.08	0.71	0.01
AHF-NT (S-2)	148.32	20.05	2.33
AHF-T (S-3)	164.86	17.47	2.89
PR/AHF-NT (10:90) (S-4)	4.25	2.32	0.08
PR/AHF-T (5:95) (S-5)	3.87	1.08	0.07
PR/AHF-T (10:90) (S-6)	5.65	1.72	0.09
PR/AHF-T (15:85) (S-7)	4.90	1.88	0.11
PR/AHF-T (20:80) (S-8)	4.27	1.97	0.16

Table 1 shows the mechanical properties (TS, ϵ , and E) of biocomposites containing different charcoal treatment fibers. The biocomposite tensile strength was strongly influenced by the adhesiveness of the fiber and matrix, where chemical treatment with NaOH affected the tensile strength and tensile modulus (E). The NaOH treatment increased the tensile strength of the biocomposites significantly by about 33% compare with biocomposites made with untreated fibers.

Figure 2. Tensile strength of areca husk fiber after treatments **Figure 3.** Elongation of areca husk fiber treatments.

3.2. Impact Test Results

Table 2. Experimental impact strength of the biocomposite samples

Composite	T1	T2	T3	T4	T5	AVERAGE
Pine Resin (PR)	0.0332	0.0324	0.0384	0.0401	0.0495	0.0387
PR/AHF-NT	0.0411	0.0421	0.0498	0.0403	0.0488	0.0444
PR/AHF-T (5:95)	0.0466	0.0445	0.0474	0.0504	0.0483	0.0474
PR/AHF-T (10:90)	0.0600	0.0534	0.0515	0.0519	0.0577	0.0549
PR/AHF-T (15:85)	0.0486	0.0436	0.0493	0.0546	0.0492	0.0490
PR/AHF-T (20:80)	0.0421	0.0436	0.0525	0.0467	0.0449	0.0460

During the impact testing process the specimen must be loaded in the testing machine and be subjected to pendulum swings until it fractures or breaks. Using the impact test, the energy needed to break the material can be easily measured to determine the toughness of the material and the yield strength. The effect of strain rate on the fracture and ductility of the material can be analyzed using the impact test.

Figure 4. Impact strength comparison of pine resin, fibers and pine resin/areca husk fiber biocomposite.

3.3. Morphology of Areca Husk Fibers

After the process of retting, the areca husk fibers turned a brownish color, as shown in Figure 5, and had a density value without alkali treatment of 0.633 g/cm³.

Figure 5. Morphology of samples (a) pine resin and (b) AHF before treatment. (c) AHF after treatment observed with SEM

Figure 6. Biocomposite morphology of pine resin/areca husk fibers without alkali treatment observed with SEM: (a) 400× and (b) 500× magnification.

Figure 7. Morphology of pine resin/areca husk fiber biocomposite with alkali treatment observed with SEM: (a) 400× and (b) 500× magnification.

4. DISCUSSION

4.1. Tensile Strength

The tensile strength comparison of the different combinations of areca husk fiber/pine resin biocomposites is presented in Fig.2. The figure shows that the 10% areca husk fiber and 90% pine resin biocomposites performed better than the other composite combinations tested. This indicates that the immersion conditions improved the adhesion of the fiber-matrix interface and the wettability, allowing the efficient transfer of stress between matrix and fiber. Also as reported by Mohanty et al. [2001], alkali treatment reduces the fiber diameter and thereby improves the aspect ratio and the mechanical characteristic of the composite.

Figure 3 shows that the elongation of break (ϵ) of the biocomposites was affected by different treatment and fiber volume fractions compared with the biocomposites made with untreated fibers. However, the addition of treatment fibers resulted in an increase in the value of ϵ compared the fiberless pine resin. As shown in Fig.4, the elongation of break (ϵ) of the treated fibers decreased by 35% compared with the untreated fibers.

4.2. Impact Strength

Figure 4 shows the impact strength of the biocomposite. The surface treatment increased the impact strength of the biocomposite. The impact strength of the treated biocomposite surface

was higher than the pine resin matrix itself. The impact strength of the pine resin increased by nearly 42% with the presence of 10% by weight AHF content. For the pine resin/areca husk fiber biocomposites, adhesion of the fiber matrix interface from the alkali treatment, which removed natural and artificial impurities and resulted in a rough surface topography [12].

4.3. Morphology of Areca Husk Fibers

The morphology of the tensile surface of the untreated fibers and alkali treated pine resin/areca husk fibers biocomposites is shown in Figure 6, which illustrates some of the remaining holes after the fibers were pulled out of the matrix, some of which appear to have been broken and damaged. A visible gap can be found between the fiber and pine resin matrix in Figure 6, indicating poor interfacial adhesion. However, the gap virtually disappeared in the case of fibers treated with NaOH (Figure 7), proving there was good compatibility in the pine resin/areca husk biocomposites which led to the enhancement of the interface and mechanical properties of the biocomposite. Untreated fibers could be easily pulled out of the interface area with poor compatibility, resulting in the rapid partial collapse of the pine resin. However, alkali-treated fibers had good adhesion with the pine resin matrix, which could effectively spread and transfer stress, leading to improvements in the mechanical properties of the biodegradable pine resin/areca husk fiber biocomposites. Consequently, the results indicate that alkali treatment of fibers is required to improve the adhesion of fiber-matrix interface before biocomposite processing.

5. CONCLUSIONS

In this study, pine resin/areca husk fiber biocomposites with different fiber contents were developed. The effect of alkali treatment on the interface and mechanical properties of the pine resin/areca husk fiber biocomposites was studied, and the following conclusions can be drawn:

- The mechanical properties of the studied AHFs were measured and evaluated. Alkali treatment of AHFs increased the tensile strength by 11% compared with AHFs without treatment.
- The alkali treatment of AHFs increased the surface roughness of the fibers, causing a mutual mechanical increase between the fibers and the pine resin matrix in the composite.
- The tensile strength of the biocomposite increased with treatment by up to 25%, but it was more than 33% and the impact strength increased 24% for the 10% AHF volume fraction.
- The study also showed that the alkalization process can modify the fiber surface, which significantly contributes to improving the interface properties of the biocomposite.

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