Tensile properties of coir and fleece fibers reinforced poly-lactic acid hybrid green composites

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Abstract. Hybrid green composite is a combination of several layers of fiber types or laminate that are arranged with a certain number and sequence. This type is used to replace the deficiencies of both types of fibers and can combine the advantages. In this paper, tensile properties of hybrid green composite biodegradable from natural fibers (coir and fleece) and Poly-Lactic Acid (PLA) matrix were investigated. The synthesis of composite material was carried out with five samples i.e. coir, fleece, 5/15% mass of coir and fleece, 10/10% mass of coir and fleece 15/5% mass of coir and fleece reinforced PLA biodegradable matrix were synthesized using hot press molding at temperature of 170°C pressure of 10MPa and time molding of 10 minutes. Characterization of tensile strength and modulus of elasticity of the material using the Tensile Test Machine ASTM D 638. The result show that the tensile properties (tensile strength and modulus of elasticity) of the sample affected by addition of fiber fraction. The result confirmed with the result of morphology test by SEM (Scanning Electron Microscope).

1. Introduction

Technology is currently experiencing an increasingly advanced development. This has led to an increase in the use and utilization of materials in various fields such as industrial fields, both small and large scale. The use of raw materials in industry such as metals begins to decrease as the technology develops[1]. Since then, many alternative materials have been sought that can be used as metal substitutes. One alternative material chosen is composite material.

In a composite, one of the constituent materials is in continuous phase, and is termed as the matrix, and the other is discontinuous or dispersed phase and is termed as the reinforcement or the reinforcing material[2]. Reinforcing material or reinforcement are embedded in the matrix of the composite and form the discontinuous. It carries the applied load and stress, and imparts improved mechanical properties, including stiffness and strength to the composite. Another important constituent of green composites are biodegradable polymers which act as a matrix. It provides protection to the composite against environmental and chemical attach and binds the reinforcing materials together[3].

In view of this, the concept of “green composites” is more importance these days because increasing environmental awareness, decreasing oil reserves and demands of legislative authorities. This green composite consists of biodegradable polymers as matrix materials and natural fibers as reinforcement materials[4]. Natural fibers that can be obtained from plant, animal and mineral resources. Natural plant based fibers such as coir, sisal, jute and bamboo have many advantages
compared to synthetic fibers, for example low weight, low density, low cost, acceptable specific properties and they are recyclable and biodegradable. They are also renewable and relatively high strength and stiffness and cause no skin irritations [5]. The fibers which are obtained from animals are called animal fibers. Wool, silk and fleece are common examples of animal fibers. They are made up of protein molecules. The basic elements in the protein molecules are carbon, hydrogen, oxygen and nitrogen. Animal fibers have high resiliency but weak when wet because they are bad conductors of heat.

Many researchers in the past have developed composites using natural fibers such as coir [7], [8] and fleece [9] to name the few. Hybrid composites are materials made by combining two or more different types of fibers in a common matrix [5]. Hybrid composites are these systems in which kind of reinforcing material is incorporated in a mixture of different matrices (blends), or two or more reinforcing and filling materials are present in a single matrix or both approaches are combined [6]. The hybridization approach is used to make cost-effective composites. The objective of our work was to analyze the tensile properties (strength and modulus) of coir/fleece hybrid composites. Comparison of the experimental and results was also made by the mass fraction of the fibers. The hybrid mechanisms were revealed with the aid of the Scanning Electron Microscopy (SEM) observations.

2. Experimental methods

2.1. Materials

Coir is a lignocellulosic natural fiber. It is a seed hair fiber obtained from the outer shell, or husk, of the coconut. Classification of coconut plants[7]:

Kingdom : Plantae  
Division : Magnoliophyta  
Class : Liliopsida  
Ordo : Arecales  
Family : Arecaceae  
Genus : Cocos  
Species : Cocos nucifera

![Figure 1](image1.jpg)  
Figure 1. Macroscopic photograph of (a) coir fibers and (b) fleece fibers.

Natural fibers used in this work are coir and fleece as shown in Figure 1. The coir fiber used was obtained from CV. Sumber Sari, Ledok Ombo, Jember, whose physical and mechanical properties of coir and fleece fiber are given in Table 1.

| Properties   | Coir       | Fleece     |
|--------------|------------|------------|
| Density (g/m³) | 1.25-1.5   | 1.3-1.31   |
In this process, the coir fibers are cut into small pieces. The results of the cut off of coir fiber were obtained from chemically with NaOH. Long coir fibers were cut into small pieces and dipped in aqueous solution 6% (w/t) NaOH in 4 hours and followed by mixed well in 1 hour using a home-use mixer. After that, coir fibers are washed using flowing water until it does not feel sticky to ensure the fibers is clean from NaOH. Then the fibers are soaked with 3% (w/t) NaClO in 1 hour for the bleaching process. After that the fibers are again washed using flowing water and lastly dried using a convection oven at temperatur of 100°C until completely dry. Finally, the short coir fibers blended using home-use mixer to get randomness finer fiber.

A biodegradable, thermoplastic biopolymer poly lactic acid (PLA) was chosen as matrix jenis PL 2000 yang diproduksi Miyoshi Oil and Fat Ltd, Jepang. This biopolymer has a density of 1.24g/cm$^3$, a melting temperature of 160-170°C and a glass transition temperature of 60-65°C[10]. It was supplied in granular form. In this study PolyLactic Acid (PLA) must be melted first so that it can be mixed with fibers. The process of matrix melting by heating on an electric stove reaches a temperature of ± 170°C or until the granules of PolyLactic Acid (PLA) appear to melt and stick. Typical physical and mechanical properties of the PLA are shown in Table 2.

| Properties | Value     |
|------------|-----------|
| Density (g/cm$^3$) | 1.26     |
| Tensile strength (MPa) | 11.5     |
| Young’s modulus (GPa) | 1.1      |

2.2. Fabrication of hybrid composites
Synthesis is done by melting the Polylactic Acid (PLA) matrix using Teflon on an electric stove, then the fiber with a predetermined mass fraction is added little by little and stirred together with the matrix. When mixed, the results of the mixture are placed on a mold size (10 x 10 x 1) cm. The mold is then pressed using the Press Machine. The following mixtures were produced (mass percentage): coir 20% + PLA 80%, fleece 20% + PLA 80%, coir/fleece 5/15% + PLA 80%, coir/fleece 10/10% + PLA 80% and coir/fleece 15/5% + PLA 80%.

2.3. Tensile test
After fabrication, the test specimens were subjected to mechanical test as per ASTM standards. Tensile properties of the composites were measured based on ASTM-D 638 and the test speed was 1mm/sec. The nominal dimensions of the specimens were 100 mm x 10 mm x 10 mm. Test was carried out by a universal mechanical testing machine HT 2402. In each variations, three specimens were tested to obtain the average value.

2.4. Morphological characterization
In order to analyze the interfacial bonding between fibers and matrix, the cross-section and the tensile fracture surface of the composite specimens were examined using a HITACHI TM3030Plus Scanning Electron Microscope (SEM).

3. Results and discussion
3.1. Tensile properties of hybrid composites
The experimental tensile strength and modulus of elasticity of the hybrid composite are shown in Figure 2 and Figure 3. Figure 2 shows the tensile strength of the hybrid composite, whose maximum value is 49.184 MPa for 5%:15% ratio. From Figure 2, the addition of fleece fiber into coir fiber composite increases the strength from 5% to 15% of fleece fiber. As the fleece fiber mass fraction increases in hybrid composites from 5% to 15%, the tensile strength of the material increases. Tensile strength decreases when the fiber feather mass fraction is increased to 20%.
Because of the increase in the tensile strength of hybrid composites is higher than that of coir fiber + PLA and fleece fiber + PLA, this is due to the combination of two different fibers so as to increase the tensile strength of composite materials. Whereas in fleece fiber, tensile strength is lower than that of coir fiber composite or hybrid composite. This is because the shape of the fiber in the fleece fiber composite is shorter than that of coir fiber, which affects the tensile strength value.

![Figure 2](image.jpg)

**Figure 2.** Tensile strength of coir/fleece fiber reinforced hybrid composites with different hybrid ratio.

![Figure 3](image.jpg)

**Figure 3.** Modulus of elasticity of coir/fleece fiber reinforced hybrid composites with different hybrid ratio.

Graph of tensile testing results on hybrid coir/fleece composites in Figure 3 shows that the highest modulus of elasticity is in the mass fraction of 5% coir 15% fleece. This shows that the modulus of elasticity in hybrid coir/fleece composites increases with increasing fleece fibers. From Figure 3 the maximum modulus of elasticity of the hybrid composites is 0,1293 GPa for 5%:15% ratio.

3.2. **Morphological structures**

The fractographs of samples were obtained using Scanning Electron Microscope (SEM) after testing for tensile.
Figure 4. Images of the fracture of hybrid composites: (a) coir/fleece 5/15% and (b) coir/fleece 15/5%.

Figure 4 shows SEM micrographs of fracture surfaces and internal microstructure of two specimens of coir/fleece fiber reinforced hybrid composites. The specimen with 5% coir 15% fleece, the fibers make contact with each other (Figure 4a.). It can see the fibers are detached from the resin surface due to poor interfacial bonding with some voids formed on the resin surface due to fiber pull out. The coir/fleece 15%/5% specimen failed in tensile shows the presence of hackles near the fiber. The holes present in the resin are due to fiber pull out due to the tensile load (Figure 4b.) and it appears that coir fiber is more dominating because the composition of the mass is also greater than that of fleece fibers.

4. Conclusions
In this study, the tensile strength and modulus of elasticity of natural fibers reinforced hybrid composites was improved with the increasing of fleece fiber mass content from 5% until 15%. The authors propose that the 5%coir + 15%fleece content reinforced hybrid composites have the best tensile properties and modulus of elasticity. This indicates that the hybrid composites was due to the combination of two different fibers so as to increase the tensile strength of composite materials. Hybrid fiber composites with coir and fleece fibers may open up new applications. However, as inferred from the results presented here, significant improvements in strength and fracture characteristics must berealized for this class of materials.

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