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Mechanical performance of pineapple leaf fiber reinforced poly lactic acid (PLA) biocomposites

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ABSTRACT – Poly lactic acid is a biopolymer that is easily processable and offers goods aesthetics. Biocomposites is prepared by combining poly lactic acid and pineapple leaf fibres (PALF). The aim of this study is to evaluate the mechanical performance of the biocomposites when the fibers are surface treated with alkaline solution (NaOH) prior to fabrication. The fiber length and loading for the composites are 30 mm and 30 wt. %, respectively. The composites were fabricated using a melt mixing process via a ThermoHaake machine before compression molded to produce composite plates with nominal thickness of 3 mm. At preliminary stage, a flexural testing as per ASTMD790 was carried out. As expected, the alkaline-treated composites exhibit much greater flexural strength and modulus in comparison to those of the untreated samples.

1. INTRODUCTION

To-date, with a growing concern and awareness in saving the environment, together with the notion to promote sustainability in manufacturing, *biocomposites* are gaining increasing attention, since they are cost effective and environmental-friendly. Many studies have been done on the use of natural fibers such as kenaf, sisal, jute, ramie and flax to replace the synthetic fibers [1]. However, despite the fact that these materials are low cost and biodegradable, several identified limitations are brittleness, low impact toughness and tensile strength [1–3].

Malaysia is one of the main exporters of pineapple in the world market, after Thailand, Philippine and Brazil [4]. As an example, it has been reported that a total amount of 96, 957 metric tonnes of pineapple have been produced in 2011 [7]. Therefore, to exploit these agricultural wastes, some work has been initiated to extract the pineapple leaf fibers. Pineapple leaf fibre (PALF) exhibit better mechanical properties compared to other naturals fibres are supplied to their high cellulose (70-82 %) and low lignin (5-12 %) content [2, 3].

Polylactic acid (PLA) is a biopolymer, produced by microbial fermentation process of fully renewable resources. Currently, PLA is used in various field of applications such as food packaging, biocompatible medical devices, film and interior automotive parts[2, 3]. PLA is also known for its biodegrability and biocompability features. However, one of the main problems is brittleness. To overcome such problem, one of the common ways is by adding fillers or reinforcement, by means of chemical pre-treatment processes, to improve the brittleness as well as to enhance the overall mechanical and thermal properties of PLA based polymer composites [5].

Previous study in this area has reported that the performance of fibre reinforced composites depend on several factors; these being (i) fibre-matrix adhesion, (ii) fiber volume fraction (iii) fiber orientation and (iv) adhesion at the fiber-matrix interface. The goal is to achieve an efficient stress transfer from the matrix to the fiber when subjected to an applied load [6].

This study reports the result of experimental investigations on the mechanical performance of pineapple leaf fibres reinforced poly lactic acid biocomposites, with fiber pre-treatment using sodium hydroxide (NaOH). At the preliminary stage, the experimental results from flexural testing are presented and discussed for both the treated and untreated PALF reinforced PLA biocomposites.

2. METHODOLOGY

2.1 Material

Polylactic acid, PLA grade 6100D was purchased by NatureWorks, LLC, USA. The main properties of PALF and PLA are given in Tables 1 and 2 respectively. Sodium Hydroxide, (NaOH) was purchase from Merck Chemicals Sdn. Bhd. Pineapple leaf fibres (PALF) from Josapine species.

2.2 Composites preparation

Composites were produced by melt mixing of 30 mm length short PALF fibers and the PLA matrix via melt mixing process in a Thermo Haake machine. Both raw materials were dried overnight to minimise moisture content. Since this machine can feed only 50 g per batch, the same steps were repeated to produce 3 mm thickness of biocomposites. The raw materials, with the ratio of 30/70 for PLA and PALF were feed into the Thermo Haake machine for 15 minutes under temperature 175 °C and rotor speed of 50 min^{-1}. The mixed raw materials were undergoing compression moulding process using a stainless steel mould platen. The raw materials were preheated for 2 minutes and then pressed under pressure of 1.38 MPa and temperature of 175 °C, with a soaking time of 10 minutes, followed by cooling process for 10 minutes prior to demolding of the biocomposites plate. The biocomposites laminates were then cut to size for mechanical characterization.

Table 1 Main properties of PLA (6100D).

Properties	**Value**
Relative Viscosity	3.1
Specific Gravity	1.24
Crystalline Melt	165-180
Glass Melt	55-60

Table 2 Main properties of PALF fibers.

Properties	**PALF**
Density (gcm^{-1})	1.52
Elongation break (%)	3
Young's Modulus (GPa)	6.21
Tensile Strength (MPa)	170

2.3 Mechanical characterizations

Specimens with dimensions of 74 mm x 12 mm x 3 mm were prepared for flexural testing in accordance to ASTM D790. The tests were conducted at crosshead speed of testing of 2 mm/min and maximum load of 1kN. The specimens were placed on two supported stage and load were applied. Universal Testing Machine (UTM) model Instron 5585 was used to conduct the flexural testing.

3. RESULT AND DISCUSSION

3.1 Flexural properties of biocomposites

Table 3 shows the flexural properties of treated and untreated PALF reinforced biocomposites. From the results, treated composites shows higher value for flexural strength and modulus compare to untreated PALF reinforced composites. The flexural modulus is increased from 0.22 GPa for untreated to 0.32 GPa for treated PALF reinforced composites (a 31% increase). This result shows similar trend to the finding from previous work in which the flexural modulus being 4.4 GPa for untreated and 5.6 GPa for treated PALF reinforced composites [5]. In addition, the flexural strength increased by 69% for treated PALF when compared to untreated PALF. These findings are in agreement with the theory that when the PALF fibers are pre-treated i.e. via an alkaline surface treatment, rougher surface of the fibers results in enhanced interfacial adhesion, therefore inducing better fibre-matrix interlocking and consequently enhance the mechanical performance of the composites [5].

Table 3 Flexural performance of treated and untreated short biocomposite.

Properties	**Untreated**	**Treated**
Flexural Strength (MPa)	33.64 ±4.81	107.53 ±10.37
Flexural Modulus (GPa)	0.218 ±0.16	0.32 ±0.02

4. CONCLUSIONS

The preliminary findings obtained from this study have demonstrated the effect of chemical treatment on the mechanical performance of PALF reinforced PLA biocomposites. These observations suggest an improved adhesion achieved by introducing alkaline treatment of the fiber, thereby causing rough surface at the fibre-matrix interface. Consequently, superior mechanical properties of the alkaline-treated PALF fiber reinforced composites in comparison to those of the untreated composites are attained.

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