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Characterization of Xylanase-Treated Karagumoy Fiber Reinforced Composite (KFRC)

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Abstract

This work determined the effects of enzyme treatment on the mechanical properties of natural fiber-reinforced composite using *Pandanus simplex* (karagumoy) fibers. Physical modification using enzyme improved chemical and mechanical properties of fibers and the karagumoy fiber-reinforced composites (KFRCs) produced. Enzyme concentration and soaking time were used as treatment parameters. The treatment scheme improved the mechanical properties of fibers and composites, as well as, the composites' water absorption property. The composites' mechanical properties- tensile and flexural strength- were measured using universal testing machine (UTM). The morphology of fibers and composites was determined through a scanning electron microscope (SEM) and results indicated a reduced fiber diameter for the treated fibers and an increase in fiber surface roughness, thereby resulting to improved adhesion or compatibility between the hydrophilic fiber and the hydrophobic matrix. FTIR analysis results of the fibers further supported this finding as evidenced by the reduction in OH groups of the enzyme-treated karagumoy fibers.

Keywords: natural fiber, enzymatic treatment, mechanical properties, water absorption

1. Introduction

Natural fibers are light, renewable and also an inexpensive high-specific-strength resource. The combination of interesting mechanical and physical properties together with their sustainability led to the development of natural fiber-reinforced composites (Pickering, et al, 2016). One such natural organic filler that can be used are the *karagumoy* fibers. *Karagumoy*, with the scientific name *Pandanus simplex*, are indigenous to the Philippine provinces of Albay, Sorsogon, Cebu, Leyte, and Tayabas where they are currently used for local handicraft industries (Tropical Plants Database). *Karagumoy* belongs to the pandan family. Pandans or screw pines, are true tropical shrubs or trees. The fruit also resembles that of pineapple. Even the finest leaves of pandan can be distinguished from pineapple leaves, as in the former a row of more or less prominent spines is always present along the midvein.

Enzymatic treatment of fibers has been found to be very effective because the reactions catalyzed are specific for a particular purpose (Ammayappan, 2013) with the added benefits of energy and water savings, cost reduction, improved product quality and process integration (Konczewicz & Kozlowski, 2010). Enzymes are specifically directed to the degradation of pectic substances, controlling the risk of degrading other structural polysaccharides (hemicelluloses & cellulose) of the fiber cell wall. The major advantage of enzyme treatment is absence of toxic chemical substances commonly used in many of the fiber treatment processes (Choi, et al, 2015).

The technical benefit of enzymatic treatment includes the removal of lignin, wax, and non-crystalline parts from the fiber surface, significantly increasing wetting and adhesion properties, which leads to improved interfacial bonding between fiber and matrix (Jana De Prez, et al, 2018).

Karagumoy fiber as reinforcement material for polymer-bonded composites has not been established, hence this study aims to develop and evaluate the mechanical properties of *karagumoy* as reinforcement material for polyester composites and to investigate the effect of surface treatment and moisture absorption on the mechanical properties of the composite.

2. Materials and Methods

2.1. Fiber preparation and treatment, preparation of composite and mechanical test

The karagumoy fibers used in this study were collected from Sogod, Bacacay, Albay. The leaves were decorticated and retted for 1 week. The retted fibers were washed, slightly pressed, air-dried at room temperature and finally, oven-dried at 50°C for 1-2 hours. Initially, the fibers were initially cut into 12-cm and 17-cm length for flexural and tensile strength testing, respectively. Enzyme treatment was observed for 1, 2 and 4 hours. After treatment the karagumoy fibers were neutralized using tap water (i.e., pH = 7) and dried. Flatbars and GI sheets were used as mold in producing composites. Mechanical tests were carried out using the Shimadzu AGS-X Ultimate Testing Machine.

3. Results and Discussion

Compared to untreated fibers there is an observed general increase in the tensile strength, tensile strain and modulus of elasticity for xylanase enzyme-treated fibers as shown in Figure 1. Xylanase pretreatment of pulps break down the lignin-carbohydrate bonds and increase the interweaving chance of fibers and enhance the bonding between fibers, which contribute to improved fiber strength properties (Liu, et al, 2012).

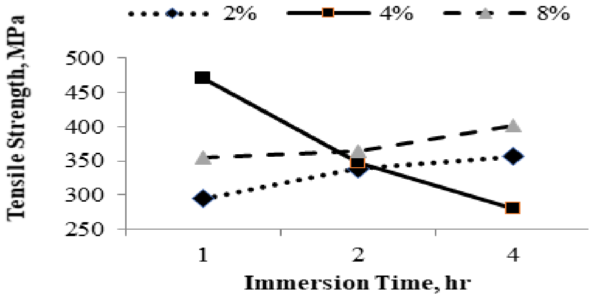

Figure 1. Tensile Strength (TS) of enzyme-treated karagumoy fibers vs. immersion time at different xylanase concentrations

KFRCs with enzyme-treated fibers have higher tensile strength values obtained as shown in Figure 2 with the highest value observed for 8% and 4 hour-immersion time, which is at 61.6935 MPa, and this value is 114% much higher than that of untreated KFRC. At this condition of longer treatment time more fibers are already exposed and bond with each other and the greater amount of xylanase used provides a greater amount of coupling agent between the fibers and matrix.

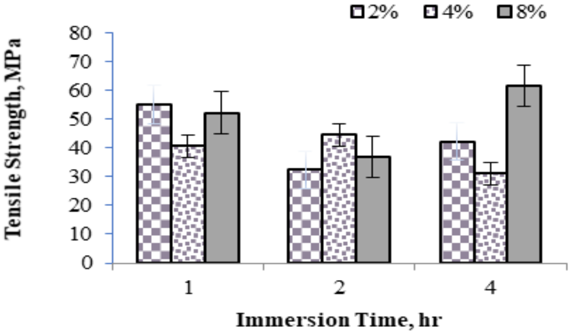

Figure 2. Graphical representation of the tensile strength of untreated and enzyme-treated KFRC

Xylanase only catalyzes the cleavage of hemicellulose molecules so they are not consumed in the reaction. The unconsumed xylanase will then react with the exposed cellulosic fibers. The hydrophilic part of the enzyme reacts with the hydrophilic fiber while the hydrophobic part of the enzyme will be linked to the hydrophobic matrix thereby acting as a coupling agent between the polymer matrix and karagumoy fiber reinforcement (Takahashi, et al, 2013)

3.1 Water Sorption Behavior of Untreated and Enzyme-treated KFRC

Figure 3 shows the graph of % water absorbed versus the square root of time which shows that enzyme treatment is effective in decreasing the water sorption property of the KFRCs. The treatment increases the bonding between the cellulose molecules in the fibers while making a decrease in the affinity of the karagumoy fibers towards water.

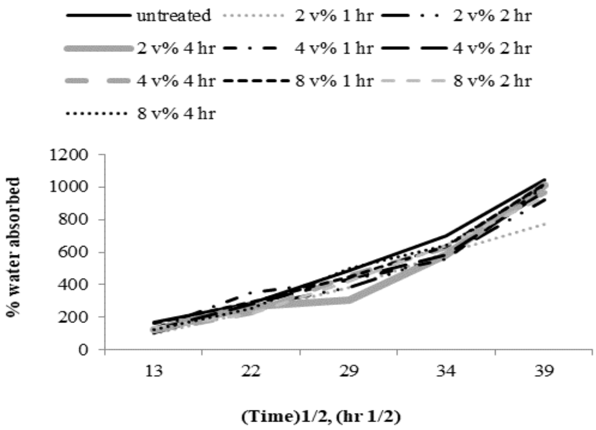

Figure 3. Graph of %water absorption vs $\sqrt{time}$ for untreated and enzyme-treated KFRCs

4. Conclusion

A natural fiber-reinforced composite using *Pandanus simplex* (karagumoy) fibers was developed and the mechanical properties were determined. Enzyme treatment sufficiently improved the mechanical properties of *karagumoy* fibers with the highest tensile strength value of 470,6590 MPa that was obtained at 4% xylanase concentration and 1 hour treatment time. The mechanical properties of the resulting karagumoy fiber-reinforced composites improved, with the highest tensile strength value of 61.6935 MPa obtained at 8% xylanase concentration and 4 hour treatment time.

Lastly, enzyme treatment of karagumoy increases the bonding between the cellulose molecules in the fibers thereby decreasing the affinity of karagumoy fibers towards water, as evidenced by the low moisture uptake of enzyme-treated KFRCs compared to the untreated KFRCs.

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