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Proceeding Paper

Mechanical Properties of Pineapple Nanocellulose/Epoxy Resin Composites †

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Abstract: A study of materials for wind turbine blades with nanotechnology—from the energy point of view—is an essential topic because resources and fossil fuels are running out. Human beings need to create alternative energies, including wind energy. This research aims to improve the mechanical properties of epoxy resin wind turbine blades by incorporating nanocelluloses obtained from pineapple residues. To determine the quality of the nanobiocomposites, materials with different epoxy resin–nanocellulose ratios were prepared. The mechanical properties of tension, compression, and bending were evaluated, and hardness tests of the material were conducted. The results indicated a general improvement in all the mechanical properties considered over the material without the nanocellulose.

Keywords: blades; nanobiocomposites; nanocellulose; epoxy resin; pineapple waste

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1. Introduction

The primary function of a wind turbine is to transform the kinetic energy into electrical energy produced by the movement of the blades of the wind turbine as a consequence of the passage of the wind through them. The wind circulates on both sides of the blades with different geometric profiles; a depression area is generated on the top face concerning the pressure on the whole face. Following this pressure, a resistance force is generated that opposes the movement, generating force in the rotor through kinetic energy. Turbine blades are elementary for the generation of electrical energy. They are in charge of receiving the power of the wind through speed [1,2].

The useful life and efficiency of the blades depend on their manufacturing. Ancient materials such as wood, steel, and aluminum have been used. Currently, they are manufactured with composite materials such as steel alloys, polyester, or epoxy resin reinforced with fiberglass or carbon fiber. The blades must be light in weight and have adequate mechanical behavior during their useful life. In this research, a material that comes from the agro-industrialization of pineapple cultivation is used. This fruit is widely distributed in Latin America and generates many problems for the environment [3–7].

Because of the extensive area coverage that pineapple cultivation represents, it is crucial to consider the large amount of waste or residues generated from the crop's production and industrial processing. The use and revalorization of these residues would avoid their inadequate disposal. This would be advantageous both from an economic point of view by reducing costs and from the perspective of the mitigation of environmental and health harms. There are methods for obtaining a material called nanocellulose, derived at the nanoscopic level from cellulose, which is part of the structure or plant cell wall of the pineapple and other plants. Cellulose is known to be the main component of the cell walls of plants; it is the most abundant biomaterial on the planet and provides remarkable properties of tensile strength [7–10].

This research aims to improve the mechanical properties of wind turbine blades. It is expected to obtain a composite material between the epoxy resin and the nanocellulose from pineapple peel waste. Incorporating this material aims to improve mechanical properties such as resistance, hardness, and modulus of elasticity, among others.

2. Materials and Methods

2.1. Materials

Pineapple wastes were supplied by Florida Products S.A., (Heredia, Costa Rica). Sodium hydroxide (NaOH), sodium hypochlorite (NaClO), clorhidric acid (HCl), sulfuric acid (H_2SO_4), and ethanol 95% reagents were obtained from Sigma-Aldrich (USA). A commercial epoxy resin (Hawk epoxy R1) with an epoxy resin catalyst (USA, Hawk epoxy C2) was used.

2.2. Nanocellulose Preparation

Pineapple peels were placed in a solution of 20 wt. % NaOH at 70–90 °C for one and a half hours, cleaned, and placed again in 12 wt. % NaOH for one hour. Next, they were bleached with a 2.5 wt. % NaClO solution at 60 °C for two hours. Afterward, white cellulose was treated with 17 wt. % HCl at 60 °C for two hours to obtain microcellulose. Finally, to obtain nanocrystalline cellulose, the acid hydrolysis of microcellulose was carried out using a solution of 65 wt. % H_2SO_4, a temperature of 55 °C, and constant stirring for 60 min. The samples were washed repeatedly with deionized water until they reached a neutral pH. Finally, nanocellulose suspension was dialyzed for 24 h to remove salt residues [6–8].

2.3. Composites Preparation

Epoxy resin with pineapple peel nanocellulose (0, 0.25, 0.5, 1, 2.5, 5, and 10 wt. %) was prepared. Epoxy resin catalyst was used. A glass mold of 10 × 10 cm was used to prepare samples. The mixtures were placed in the glass molds, separately.

Nanocellulose composites were prepared at 220 rpm for 8 min in a stirrer at room temperature. Samples were cured at 30 °C for 1 h, 60 °C for 30 min, and 100 °C for 2 h.

2.4. Sample Characterization

Samples were characterized using the Brinell hardness (HB) test (TH 1100 LEEB brand durometer), as well as tension (tensile strength), compression (compressive strength), bending (bending stress), and torsion (torsional strength) tests (Discovery DHR III Rheometer, TA Instruments). The samples for the analyses were prepared according to the ASTM protocols [11].

3. Results and Discussion

In general terms, it is observed that the addition of nanocellulose from pineapple peel waste generates positive results. The best results are observed by adding 0.25% up to 1% nanocellulose. At higher percentages, the mechanical properties decrease until reaching the brittle point of the material. Figure 1 shows the results of the Brinell hardness (HB) test. The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter loaded on a material test piece. A pineapple nanocellulose content between 0.25 and 2.5% in the samples shows an increase in the BH parameter. Samples with 5% and 10% pineapple nanocellulose show a low BH value.

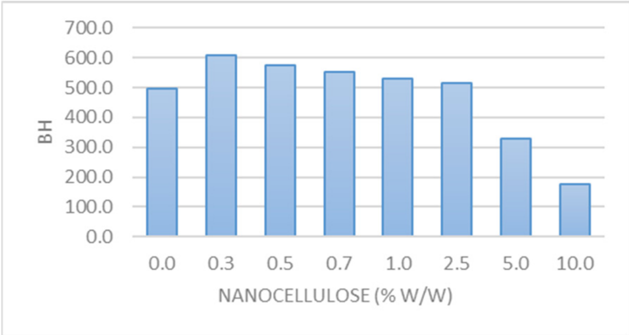

Figure 1. The Brinell hardness (HB) test in epoxy resin samples with nanocellulose obtained from pineapple wastes.

Similarly, Figure 2 shows the results of the tensile strength test in epoxy resin samples with nanocellulose obtained from pineapple wastes. The samples with a nanocellulose content between 0.25% and 1% showed higher tensile strength values than the nanomaterial. This indicates that the nanomaterial acts as a reinforcement for the epoxy matrix. In contrast, at higher values between 2.5% and 10%, it acts as a load that somewhat limits the material's mechanical properties.

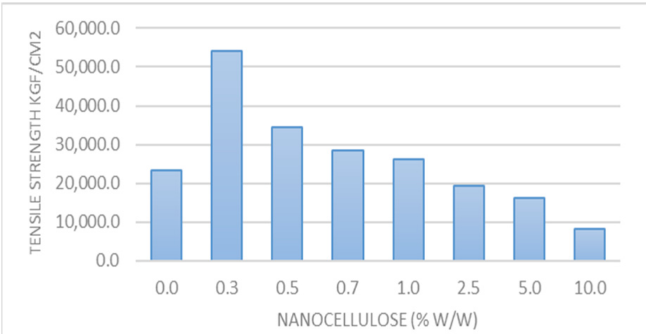

Figure 2. Tensile strength in epoxy resin samples with nanocellulose obtained from pineapple wastes.

Figure 3 shows the variation obtained from the compressive strength tests in the epoxy resin samples. In this case, this parameter significantly decreased for all samples with nanocellulose compared with samples without nanocellulose. The nanocellulose acts as a nanomaterial that decreases the internal pressure of epoxy resin. Samples with nanocellulose are compressed the easiest.

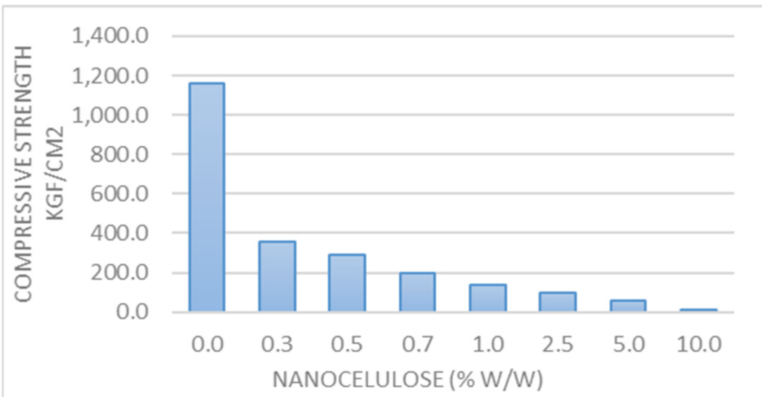

Figure 3. Compressive strength in epoxy resin samples with nanocellulose obtained from pineapple wastes.

Figure 4 shows the bending stress results obtained in all samples. Increased bending stress was observed in samples with 0.25 to 0.7% nanocellulose. Bending stress is a combination of compressive and tensile stresses. Thus, bending stress results are combined, as shown in Figures 2 and 3. Some samples showed an increase in bending stress, and some showed a dramatic decrease.

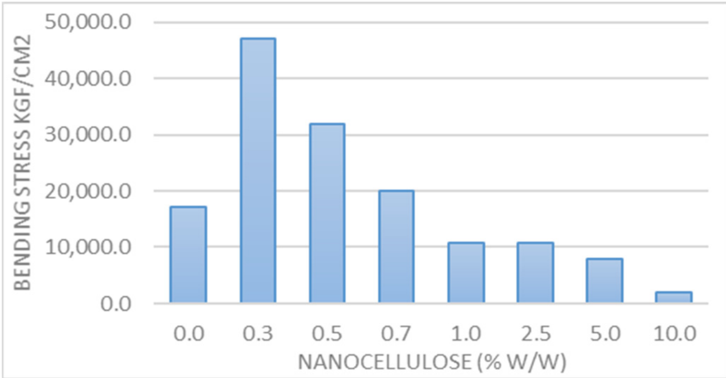

Figure 4. Bending stress test in epoxy resin samples with nanocellulose obtained from pineapple wastes.

Finally, in the torsional stress test (Figure 5), samples with a nanocellulose content between 0.25% and 0.7% show an increase in this property. In the same way, some samples showed a decrease. For example, the 5% and 10% nanocellulose samples showed minor torsional stress, as shown for bending stress.

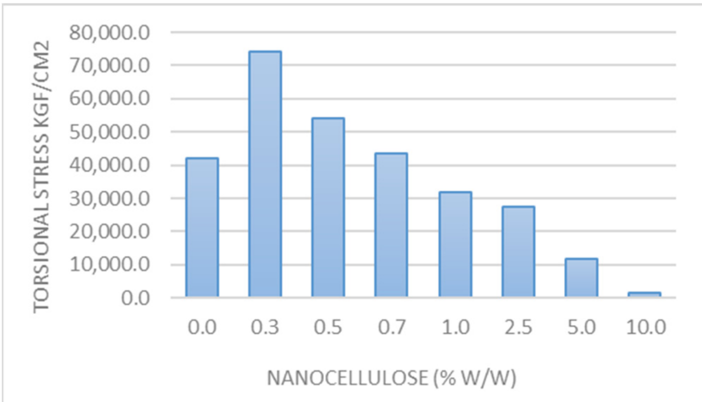

Figure 5. Torsional stress test in epoxy resin samples with nanocellulose obtained from pineapple wastes.

4. Conclusions

Positive results were found concerning the behavior of epoxy resin with inclusions of natural fiber as a nanocellulose base. The agricultural residues of pineapple, usually discarded or destroyed, proved to be a significant source of lignocellulosic biomass suitable for producing nanocellulose. As such, lignocellulosic materials are taken advantage of, and a double effect is achieved: the ecological benefit by eliminating a source of contamination and added economic value provided to the material.

The results indicated a general improvement in all the mechanical properties evaluated compared with the material without the pineapple nanocellulose. The mechanical properties in some epoxy resin samples were increased by incorporating nanocellulose in the polymer. This study could help improve the generation of alternative energies using plastic turbine blades reinforced with natural nanomaterials.

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