DEVELOPMENT AND CHARACTERIZATION OF ABS BIOCOMPOSITES REINFORCED WITH PINE SAWDUST AND MICROCRYSTALLINE CELLULOSE

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ABSTRACT

The production of polymer composites reinforced with plant fibers and biomass presents a highly viable alternative for solid waste management. Additionally, these composites generally exhibit superior mechanical properties compared to the original polymer, leading to the development of new materials and potential innovative applications. In this context, this study presents the fabrication and mechanical characterization of polymer composites using an acrylonitrile-butadiene-styrene (ABS) matrix reinforced with wood sawdust and microcrystalline cellulose. The composites were processed using a thermokinetic homogenizer in various constituent proportions and injected at 280°C. Mechanical tests, including tensile and flexural evaluations, were conducted to assess the influence of composition on these properties. The results demonstrated an increase of up to 158% in Young's modulus and 87% in flexural modulus compared to pure ABS. Thus, it was possible to produce composites utilizing lower amounts of petroleum-derived materials, effectively incorporating waste, and achieving enhanced mechanical properties.

Keywords: Polymers. Solid waste. Plant biomass. Tensile strength. Flexural strength.

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1 INTRODUCTION

The growing environmental concerns and the increasing need for sustainable development have intensified research into the use of natural fibers as reinforcements in polymer composites. Composites reinforced with plant fibers offer a multitude of environmental benefits, including biodegradability, renewability, and a lower carbon footprint compared to their synthetic counterparts. These materials not only help in reducing the dependency on non-renewable resources but also promote the utilization of agricultural and forestry byproducts, thereby contributing to waste reduction and resource efficiency[1].

Acrylonitrile-butadiene-styrene (ABS) is a widely used polymer in various industries due to its excellent mechanical properties, impact resistance, and ease of processing. Its versatility and durability make it a preferred material in automotive, electronics, and consumer goods manufacturing. However, the environmental impact of synthetic polymers like ABS has necessitated the exploration of eco-friendly alternatives and enhancements[2].

The development of new polymeric materials that incorporate natural fibers as reinforcements presents a promising solution. These advanced composites not only aim to retain the desirable properties of traditional polymers but also enhance their sustainability profile. By integrating natural fibers such as wood sawdust and microcrystalline cellulose into ABS, researchers can create materials with improved mechanical properties and reduced environmental impact[3]. In this study, composites were produced using ABS reinforced with Pinus sawdust and microcrystalline cellulose, and their mechanical properties in tensile and flexure were evaluated.

2 MATERIAL & METHODS

Polymer Matrix and Reinforcement Materials

The polymer matrix utilized for composite processing was acrylonitrile-butadiene-styrene (ABS), sourced through selective collection. For reinforcement, Pinus taeda wood sawdust with a particle size of 50 mesh, obtained as a byproduct from the carpentry workshop at Centro Universitário de Volta Redonda, was used. Additionally, microcrystalline cellulose (MCC) from Synth, a commonly used additive in pharmaceutical, food, and materials industries to modify chemical, physical, mechanical, and rheological properties, was employed.

Composite Processing

The composites were processed in the Materials Processing Laboratory at UniFOA, following a full factorial design 3^2. The factors were the sawdust content (0%, 10%, and 15%) and the MCC content (0%, 10%, and 15%). After drying the materials in an oven at 100°C for 8 hours, the compositions were processed in a Dryzer MH-50H thermokinetic homogenizer in 150 g batches for approximately 1.5 minutes. Subsequently, the compositions were separately ground in a knife mill and prepared for injection molding at 280°C using a RAY RAM injector, model TSMP. Molds conformed to ASTM D 638-14 and ASTM D 790-17 standards for subsequent characterization.

Tensile and Flexural Testing

Tensile tests were conducted in the Mechanical Testing Laboratory at UniFOA using an EMIC DL-10000 Universal Testing Machine equipped with a 5 kN load cell, at a speed of 5 mm/min. For each composition, five specimens were tested, following ASTM D638-14[4] specifications, with dimensions of 13 mm width, 165 mm length, and 3.2 mm thickness. The results were processed to determine tensile strength (maximum stress), yield stress, and tensile modulus (Young's modulus).

Flexural tests, also performed on the EMIC DL-10000, analyzed five specimens per composition according to ASTM D790-17[5], with dimensions of 13 mm width, 130 mm length, and 6 mm thickness, using a 100 kN load cell, an 80 mm span between supports, at room temperature, and a test speed of 5 mm/min. The data obtained were used to determine flexural strength (maximum stress) and flexural modulus.

3 RESULTS & DISCUSSION

Table 1 presents the tensile mechanical properties calculated from the test data. Analysis of the results indicates that the addition of reinforcements led to superior mechanical properties in all cases. Pure ABS exhibited a Young's modulus of 175 MPa, whereas the composite with 15% sawdust and 15% MCC showed the highest improvement, with a 158% increase (276 MPa). There was also a significant increase in maximum tensile stress, a crucial property for the application of the composite in product development.

Table 1 Tensile properties.

%sawdust	%MCC	Young's Module (MPa)	Tensile Stress (MPa)
Pure ABS		175 ± 16	22,4 ± 1,8
10	0	196 ± 25	25,9 ± 3,1
15	0	214 ± 33	25,3 ± 1,7
0	10	206 ± 21	27,2 ± 2,3
10	10	238 ± 19	29,4 ± 2,0
15	10	253 ± 27	28,6 ± 3,3
0	15	221 ± 12	29,1 ± 1,4
10	15	259 ± 29	30,6 ± 2,1
15	15	276 ± 23	31,2 ± 1,9

The flexural test results are presented in Table 2. Similar to the tensile tests, the composites exhibited superior properties compared to pure ABS, indicating that the addition of reinforcements consistently enhances the mechanical properties of the materials studied.

Table 2 Flexure properties.

%sawdust	%MCC	Flexural Module (MPa)	Flexural Stress (MPa)
Pure ABS		1496 ± 167	46,2 ± 5,1
10	0	1940 ± 203	56,2 ± 6,3
15	0	2018 ± 261	60,6 ± 7,2
0	10	2314 ± 302	58,7 ± 4,2
10	10	2179 ± 257	60,1 ± 6,9
15	10	2403 ± 191	62,9 ± 6,0
0	15	2190 ± 293	56,4 ± 7,8
10	15	2521 ± 316	61,3 ± 8,3
15	15	2798 ± 244	64,5 ± 7,1

In the case of this mechanical property, the composite with 15% sawdust and 15% MCC achieved the most satisfactory results among the tested composites, with a 46.4% increase in maximum flexural stress and an 87% increase in flexural modulus.

4 CONCLUSION

Based on the obtained results, it can be concluded that composites reinforced with pine sawdust and microcrystalline cellulose (MCC) can be successfully produced using recycled ABS. In all cases, the composites demonstrated superior mechanical properties compared to pure ABS. The addition of 15% sawdust and 15% MCC resulted in significantly enhanced mechanical properties, suggesting that the obtained composites can be readily applied in product development.

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