INFLUENCE OF SUGARCANE FIBER CONTENT ON THE PROPERTIES OF ACRYLONITRILE BUTADIENE STYRENE COMPOSITE

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ABSTRACT

In this work, an Acrylonitrile Butadiene Styrene (ABS) matrix composite was evaluated, an engineering terpolymer with high performance mechanical properties, reinforced with sugar cane fibers at levels of 5%, 10%, 15% and 20% in mass, to verify the influence of these vegetable fibers on the ABS matrix. The samples were prepared in a thermokinetic mixer and analyzed using mechanical tensile tests, fluidity tests and scanning electron microscopy (SEM). With the results obtained, it can be observed that the increase in fiber content generates a decrease in the flow index values of the composites due to the decrease in the mobility of the polymer chains. In the mechanical tensile test, there was a significant improvement in the maximum force tension with the addition of 20% (w/w) of sugarcane fiber in relation to pure ABS. The micrographs showed that the presence of sugar cane fiber made the surface rougher, and in addition, there was some interaction between the matrix and the fiber.

Keywords: acrylonitrile butadiene styrene, vegetable fiber, composite.

RESUMO

Neste trabalho foi avaliado um compósito de matriz de Acrilonitrila Butadieno Estireno (ABS), um terpolímero de engenharia com propriedades mecânicas de alto desempenho, reforçado com fibras de cana-de-açúcar nos teores de 5%, 10%, 15% e 20% em massa, para verificar a influência destas fibras vegetais na matriz ABS. As amostras foram preparadas em misturador termocinético e analisadas por meio de ensaios mecânicos de tração, testes de fluidez e microscopia eletrônica de varredura (MEV). Com os resultados obtidos pode-se observar que o aumento do teor de fibras gera uma diminuição nos valores do índice de fluidez dos compósitos devido à diminuição da mobilidade das cadeias poliméricas. No ensaio de tração mecânica, houve melhora significativa na força máxima de tensão com a adição de 20% (m/m) de fibra de cana em relação ao ABS puro. As micrografias mostraram que a presença da fibra da cana-de-açúcar tornou a superfície mais áspera e, além disso, houve alguma interação entre a matriz e a fibra.

Palavras-chave: Acrilonitrila butadieno estireno, fibras vegetais, compósito.

1. INTRODUCTION

The progression of technological innovation within the automotive, aerospace, and naval domains over the preceding four decades has spurred significant interest and investment in the exploration of novel materials. Previously exclusive to metallic alloys, the attainment of high stiffness values has been observed in composites [1–3].

A composite material is characterized as any multiphase substance comprising a substantial proportion of its constituent phases, strategically amalgamated to achieve an optimal combination of properties [4].

Historically, composites have been integral for over three millennia, evidenced by their utilization in blending straw and clay for construction purposes. These composites can be categorized into three distinct classes: laminated, particulate, and fibrous. In contrast to this ancient practice, the evolution of polymers can be attributed to the burgeon of the petroleum industry over the past century [5].

Commencing from 1955 onward, the proliferation of polymers in terms of both quantity and diversity led to the emergence of polymer matrix composites, heralded for their commendable mechanical attributes, non-conductivity, non-magnetism, chemical resistance, and substantial weight reduction vis-à-vis metallic alloys [6].

Polymer matrix composites may be delineated as either thermosetting or thermoplastic. Despite their commendable attributes, thermosets are encumbered by the incapacity for remolding[7–9]. Thus, the present study employs acrylonitrile-butadiene-styrene (ABS) copolymer, an engineering thermoplastic renowned for its superior performance attributes including high hardness, gloss, tenacity, flexibility, and electrical insulation properties [10–12].

Glass fiber, as a composite filler, ascended to commercial prominence during the Second World War [13], primarily targeting high-temperature electrical applications [14,15]. Subsequent years witnessed the advent of advanced fibers such as boron, carbon, and aramid [16,17].

Vegetable fibers have garnered considerable attention globally in recent decades among reinforcing materials [18,19]. The substitution of synthetic fibers, such as aramid and glass, with natural alternatives stems from the burgeoning demand for renewable source materials, thereby mitigating environmental impacts and fostering new investment prospects within Brazil's agricultural sector. Beyond cost efficiencies, the inclusion of natural fibers within thermoplastics engenders enhanced mechanical properties compared to pristine polymers [20,21]. Consequently, this study endeavors to assess the mechanical disparities across composites featuring varying fiber concentrations.

2. MATERIALS AND METHODS

To prepare the composites, pellets of Acrylonitrile Butadiene Styrene AF 3500 were used, with a fluidity index of 5.0 g/10 min and density of 1.04 g/cm³, supplied by Engeflex Brazil, manufactured by Formosa Chemicals & Fiber Corp., Taiwan and Sugarcane fiber, donated by UFSCar, which were used without any type of treatment.

For the processing and obtaining of the nanocomposites, both the terpolymer and fiber were added together in the Draiss MH – 100 type mixer and processed until homogenization based on the difference between fiber concentrations, five types of samples were prepared.

Table 1 illustrates the values of the different proportions between matrix and filler.

Table 1. Composite Formulation

Sample	Fiber (%)	ABS (%)
I	0	100
II	5	95
III	10	90
IV	15	85
V	20	80

Obtaining the test specimens

After obtaining the composites at Draiss, they were formed in a hydraulic press preheated to 190°C for 20 seconds. Soon after, it was cooled in another hydraulic press which had a water-cooling system (25°C), resulting in sheets approximately 2.5 mm thick. The test specimens were obtained using a standardized cutting tool in accordance with ASTM 3039/D 3039M.

Mechanical Tensile Test

The mechanical test was carried out on a DL 3000 testing machine, EMIC Test Equipment and Systems Ltda, with a 19kN load cell. The equipment, as well as the Mtest software version 3.01 and VirMaq LBP 2.0 are in the Materials Characterization Laboratory at the Faculty of Technology of Sorocaba.

The Elastic Modulus and Maximum Breaking Stress were determined using the specimens tested at speeds of 2 mm/min. with a load of 2kN.

Melt Flow Index (MFI)

The MFI of the samples was carried out with the help of a DSM plastometer, model MI3P, kindly made available by the company Melida Commerce and Industry Ltda. The parameters used were in accordance with the ASTM D-1238 standard, with a temperature of 200°C and a load of 5kg.

Scanning Electron Microscopy (SEM)

The samples were fractured and metallized with gold in a DentonVacuum Desck V metalizer with a current of 30 mA for 60 seconds. The photomicrographs obtained from the fractured and metallized surfaces were captured by a JEOL JSM-5900LV scanning electron microscope (JEOL Ltda., Akishima, Japan), operated at 3kV at the Technological Plasma Laboratory (LaPTec) of the Paulista State University (UNESP), Campus Sorocaba.

3. RESULTS AND DISCUSSION

According to Table 2, where the fluidity index results are presented, it can be observed that samples with a higher sugarcane fiber content present lower fluidity index value. This means that samples with 5% and 10% have greater flow when compared to samples with 15% and 20%. Confirming that the presence of fibers significantly affects the viscoelastic dynamics of the material. It is notable to observe the reduction in the mobility of the ABS molecular chains, due to the increase in the percentage of sugarcane fiber, because the fibers cause obstruction in the mobility of the ABS molecular chains, when included as reinforcement. Another point to be taken into consideration, when sugar cane fiber is added to the ABS matrix, it can lead to variability in the sizes of the ABS molecular structure, indicated by the breakage of molecular chains [22–25].

Table 2. Sample Melt Flow Index.

Melt Flow Index (g/10 minutes).			
II	III	IV	V
5.75	3.91	3.00	2.01

The photomicrographs of the fractured surfaces of the composites obtained through SEM are illustrated in figure 1.

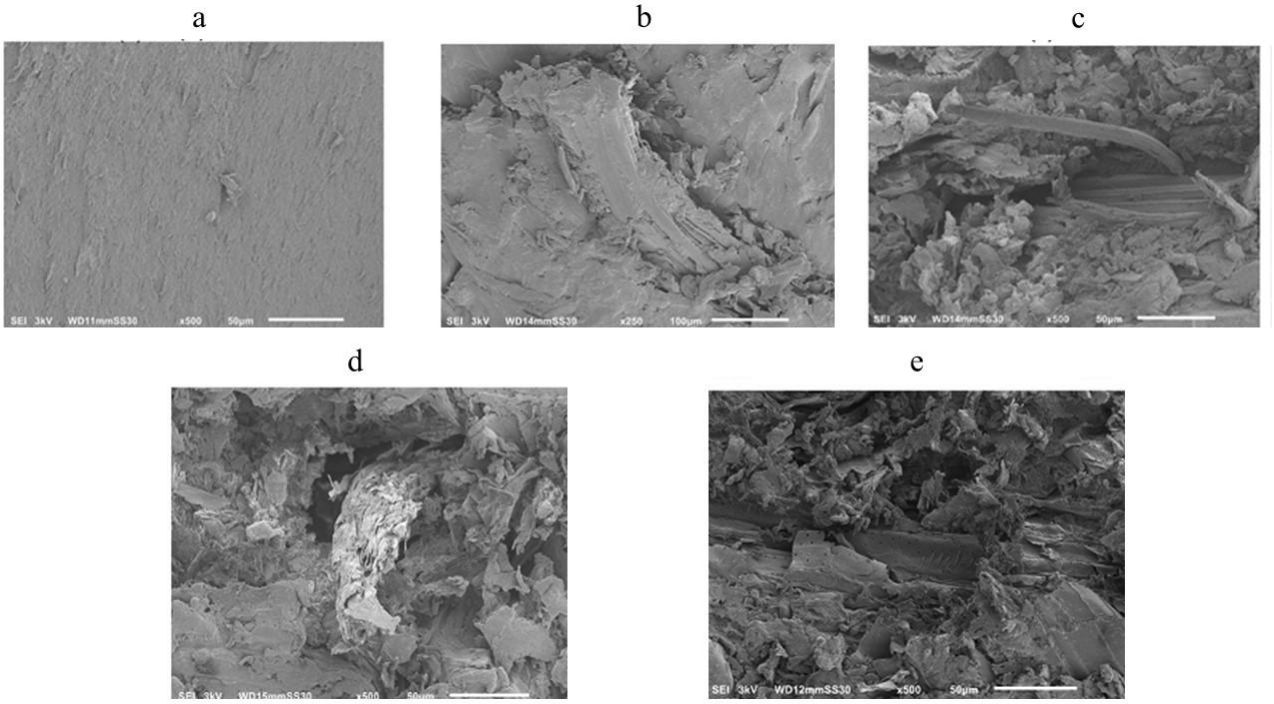

Figure 1. (a) pure ABS; (b) ABS with 5% (w/w) sugarcane fiber; (c) ABS with 10% (w/w) sugar cane fiber; (d) ABS with 15% (w/w) sugar cane fiber; (e) ABS with 20% (w/w) sugar cane fiber.

In figure 1a, pure ABS, the surface is smooth and regular, unlike samples with sugar cane fiber, which have a rough surface typical of cellulose, this is due to the increased fragility of the composites in relation to ABS. pure. In all images of the composites (from 1b to 1e) it is possible to observe the polymeric matrix covering the sugarcane fiber, which is an indication of good interaction between the phases. In general, there was some difficulty in observing the fibers. It is suggested that this behavior can be justified by the fact that the fracture was not carried out at low temperature, causing the matrix to encapsulate the fibers of the fractured surface [26,27].

Table 3 shows the values obtained for the elastic modulus of pure ABS and its composites with sugar cane fiber. The addition of sugar cane fibers increases the stiffness of the system, that is, there was an increase in the elastic modulus value of the composites. Furthermore, it is also noted that, unlike pure ABS, the composites did not show elongation when subjected to traction, which means an increase in the fragility of the material [28].

Table 3. Elastic modulus of pure ABS and its composites with sugar cane fiber.

Elastic modulus (MPa)				
I	II	III	IV	V
856.4	1156.3	1136.3	1229.7	1602.3

The increase in the elastic modulus of the composites in relation to pure ABS is evident when observing Table 3. The sample with 20% (w/w) of sugar cane fiber had an elastic modulus value 87% higher than the sample made of pure ABS. This characteristic is due to the good interaction between the fibers and the matrix [29].

Table 4 shows the obtained Stress at Maximum Strength values.

Table 4. Stress at Maximum Strength of pure ABS and its composites with sugar cane fiber.

Stress at Maximum Strength (MPa)				
I	II	III	IV	V
25.0	31.3	28.9	24.9	35.4

The fiber content in a composite directly contributes to the variation in its tension and flexural modulus [30].

In all samples studied, except sample IV, there was an increase in maximum force tension compared to pure ABS, with sample V, with a concentration of 20% (w/w) of sugar cane, being the one that stands out the most. This can be justified by the good distribution and interaction between the fibers and the polymeric matrix. In the case of the sample with 15% (w/w) of sugar cane, where the tensile strength of the composite is lower than that of the matrix, it is suggested that this behavior is due to an irregular distribution of fibers in the matrix during processing or insufficient loading, so that the fibers act as a defect and weaken the material [31].

According to studies, the mechanical resistance of a composite containing natural fibers decreases with high filler levels, making the composite support a lower load when compared to the pure polymer. It is noted that in this study a similar case does not occur, as the sample with 20% (w/w) fiber showed an increase in the elastic modulus value and in the tension at maximum force compared to pure ABS. Therefore, this would indicate that it is still possible to add percentages

greater than 20% (w/w) of sugarcane fiber to the ABS matrix without compromising the mechanical results of this type of composite [32].

4. CONCLUSIONS

In conclusion, the incorporation of sugarcane fibers in ABS composites has demonstrated significant effects on the material properties. The study revealed that an increase in fiber content led to a decrease in the flow index values of the composites, indicating a reduction in the mobility of the polymer chains. Additionally, the mechanical tensile tests showed a notable improvement in maximum force tension with the addition of 20% (w/w) sugarcane fiber, highlighting the potential for enhanced mechanical properties in ABS composites. The micrographs further illustrated a rougher surface texture and suggested some level of interaction between the matrix and the sugarcane fibers. These results underscore the promising role of sugarcane fibers as a reinforcing agent in ABS composites, offering opportunities for the development of sustainable and high-performance materials in various engineering applications.

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