INFLUENCE OF PHYSICAL TREATMENT IN CURAUA FIBER ON POST-CONSUMPTION HDPE COMPOSITES

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Abstract - In the last years there has been an increase at the interest in composites reinforced with vegetable fibers. However, due to its hydrophilic character, in most cases, vegetable fibers need to undergo chemical treatments to obtain better adhesion to the polymer matrix. To avoid the need for chemical treatments, this study aims to analyze the influence of physical treatment on curaua fibers (FC) used as reinforcements in the polymer matrix of post-consumer high density polyethylene (HDPEpc). The samples were characterized by means of water absorption tests, contact angle measurements and impact testing. The results obtained showed that the composites HDPEpc/FCwb, where the fibers were subjected to physical treatment, showed greater hydrophobicity and impact resistance than the other composite materials analyzed. It is concluded that the removal of the impurities present in the fibers contributes to a better fiber-matrix interaction and greater performance of the composite material.
Keywords: *physical treatment, curaua fiber, high density polyethylene, injection molding, thermoplastic composite.*

Introduction

With less than a century of large-scale use, polymeric materials are increasingly present in our lives. Every day new applications for polymers appear. This wide versatility is due to the enormous flexibility of the properties presented by these materials, contributing to the continuous emergence of innovations. However, polymer materials do not always have the necessary properties for a given application. When we use a certain type of polymer in products that require greater mechanical strength such as civil construction parts, automotive industry, or any other application that is replacing a metal part, there is a need to incorporate reinforcements in the polymer matrix [1]. Many of our modern technologies require materials with unusual combinations of properties that cannot be met by conventional materials. Thus, combinations and properties of the materials were, and are still being, expanded through the development of composite materials [2].

Although we often do not realize, most of the plastic artifacts sold, mainly packaging and non-durable goods, become waste in less than a year or after a single use. Since many natural resources are not consciously used by man, it becomes relevant to search for innovations that consider the concept of sustainability in its principles. Analyzing this scenario, the reuse of post-consumer high density polyethylene (HDPEpc) presents itself as an alternative to offer a more noble destination to various discarded packages, avoiding an improper destination by the consumer. In addition to the environmental vision, can be highlighted the economic face of this process, since plastics have high added value, and your disposing of them in the environment portrays a less efficient use of the resources used in its production chain.

According to Ferreira *et al.* [3], the most attractive features of thermoplastic composites are the potential for low-cost manufacturing, high fracture resistance, good impact resistance and good

resistance to micro-crack propagation. Furthermore, we have the possibility of replacing synthetic fibers with natural fibers, becoming an economical alternative, promising and ecologically friendly.
However, the properties of polymer composites reinforced with discontinuous and random vegetable fibers depend on several factors that determine the surface area capable of transferring tension from the matrix to the fibers [4]. Among these factors, can be highlighted the improvement of vegetable fibers.
In the literature [5] there are reports that chemical treatments (mercerization, silanization and acetylation) used to modify the fiber structure are efficient to improve the interfacial interaction between the fiber and the polymer matrix, however the chemical compounds used are toxic, causing a great environmental impact. Therefore, looking for the most natural and sustainable way to improve plant fibers, the present study, aims at evaluating the influence of superficial cleaning treatments in vegetable fibers used as reinforcements in polymeric matrix.

Experimental

Materials

For the formulation of composites, was selected the post-consumer high density polyethylene (HDPEpc) as a polymeric matrix, coming from jars/packaging of manipulated products; curaua fiber (FC) as reinforcement and grafted polyethylene with maleic anhydride (PE-g-MA) as coupling agent. According to the treatment received, before obtaining the composite material, the curaua fibers were separated into three groups: fibers in natura (FCn), fibers washed in distilled water at room temperature (FCw) and fibers washed and brushed (FCwb). The compositions, in percentage of mass, of the evaluated samples are specified in Table 1.

Table 1 – Formulation of samples.

Samples	HDPEpc (%)	FC (%)	PE-g-MA (%)
HDPEpc	100	-	-
HDPEpc/FCn	77	20	3
HDPEpc/FCw	77	20	3
HDPEpc/FCwb	77	20	3

Then, the materials were mixed and homogenized in the HAAKE Rheomix OS Polylab chamber to obtain the composite material. This mixture underwent a process of reduction of granulometry and, later, the specimens were made by the injection molding process in a Mini-Jet II piston injector.

Characterization Methods

The water absorption content of the composites was determined according to the ASTM D570 [6] standard through the 24-hour immersion test in distilled water. To determine the degree of hydrophobicity of composite materials, based on ASTM D7334 [7], the wettability tests were performed using a contact angle measurement system with a digital optical microscope to capture the images and the Surftens software to perform the analysis and, subsequent, the contact angle calculations. To carry out the test, 10 drops of distilled water were placed on the surface of each sample. The evolution of drop behavior was analyzed after 3 (initial angle) and 180 seconds (final angle). Lastly, to analyze the mechanical strength, impact tests were performed in accordance with ASTM D-4812 [8], using the CEAST IMPACTOR II equipment with a 2.75 J hammer. For each formulation, were tested 7 specimen (dimensions 6.3 x 1.25 x 0.3 cm) without notch.

Results and Discussion

Water Absorption Contents

Vegetable fibers, due to its basic constitution of cellulose, hemicellulose, and lignin, have strong hydrogen bonds, being highly hydrophilic [9][10]. Considering its hydrophilic nature, water absorption is an important aspect when producing a material using vegetable fibers as reinforcement. Based on this, in Fig. 1 a comparative graph for the analyzed samples is shown.

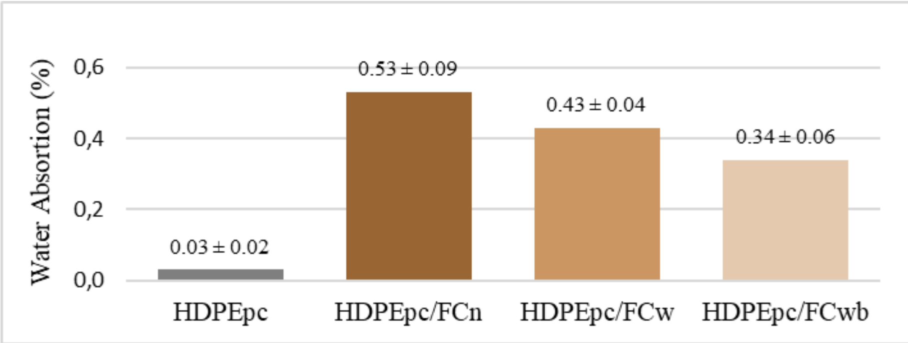

Figure 1 – Result of the averages of the water absorption of the samples analyzed in 24h.

As it is possible to observe, composite material samples have a higher water absorption content which may be due to swelling of the fibers in the cut section of the specimens, where it has alive corners, and the fibers would have direct contact with the water. Despite this, the sample HDPEpc/FCwb showed the lowest absorption when compared than the other composites. This effect suggests that there was a greater interaction between the vegetable fiber and the polymer matrix, it can be correlated with the physical pre-treatment of the fiber by brushing and the use of the compatibilizing agent in the formulation. According to Gassan e Bledzki [11], fibers treated with coupling agent are more resistant to moisture absorption, as these promote an increase in adhesion to the matrix-fiber.

Contact Angle

The contact angle test was used to study the effect of fiber incorporation into the polymer matrix, specifically in change of the surface hydrophobicity. For such, after deposition of the water drop on the surface, images of the drops were captured at 3 and 180 seconds, to analyze the wettability of the composite material surface. In Fig. 2 the images of water drops deposited in the analyzed samples are shown.

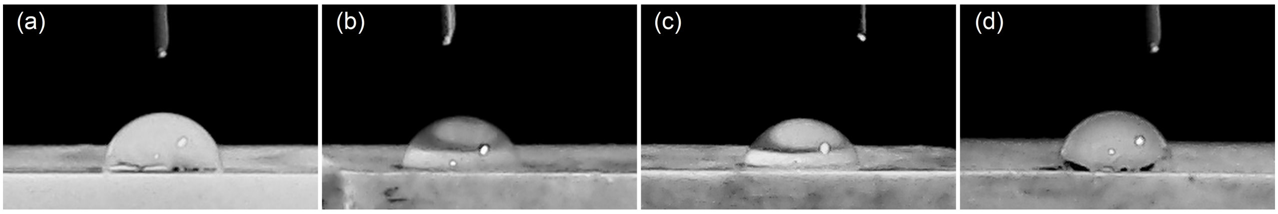

Figure 2 – Images of water drops on the surface of the samples: (a) HDPEpc; (b) HDPEpc/FCn; (c) HDPEpc/FCw e (d) HDPEpc/FCwb.

Comparing the behavior of water drops under the surface of the samples, it is possible to observe that the surface treatment influenced the contact angle of the composite material, as it is visualized a smaller scattering. This effect can be seen in Fig. 3, where the results of the contact angles of the samples are presented.

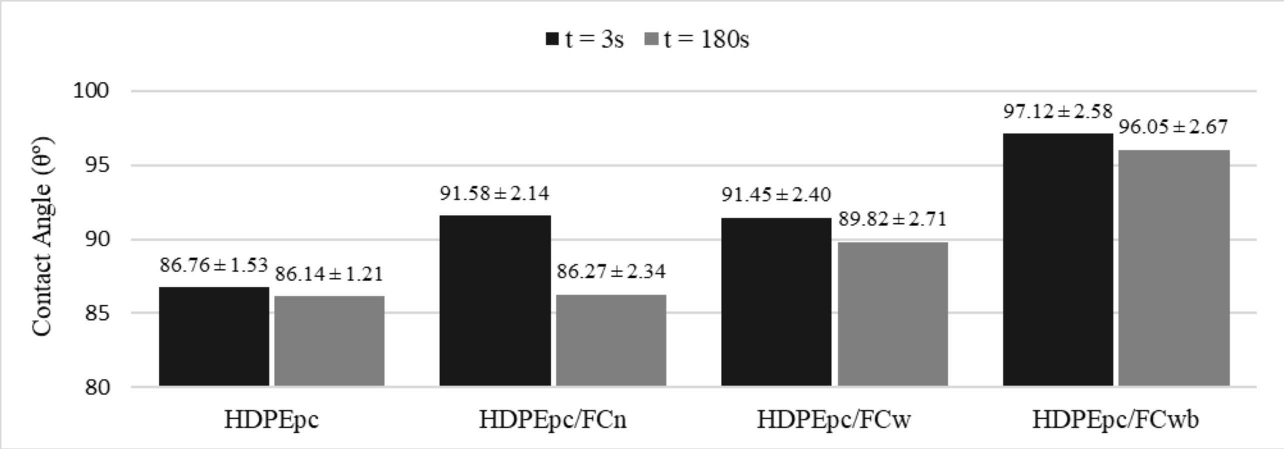

Figure 3 – Comparative result of the contact angle of the analyzed samples.

It is observed that, the largest contact angles are shown by the HDPEpc/FCwb samples, inferring that superficial treatment of vegetable fibers positively influences at the contact angle of the material. This increase is due also to the use of the coupling agent in the formulation, thus increasing their hydrophobicity.

Furthermore, the samples proved to be stable, as there was no significant variation in the angle during the test. Particularly, for the effect on sample HDPEpc/FCn, which presented a greater variation between the initial and final angle, one can cite the "Cassie-Baxter" phenomenon; where, at first the drop may be suspended under the matrix crystals, but with the passage of time, moves through the created porosity, leading to decreased contact angle [12].

Izod Impact Test

According to the literature [4][5], the ability to transfer stresses from the matrix to the fibers depends, above all, on the good fiber-matrix adhesion. To assess the mechanical properties of composite materials, the Izod impact test was carried out where, after the hammer fall, there was a total fracture of the specimens. The result of the average impact strength values of the analyzed samples is shown in Fig. 4.

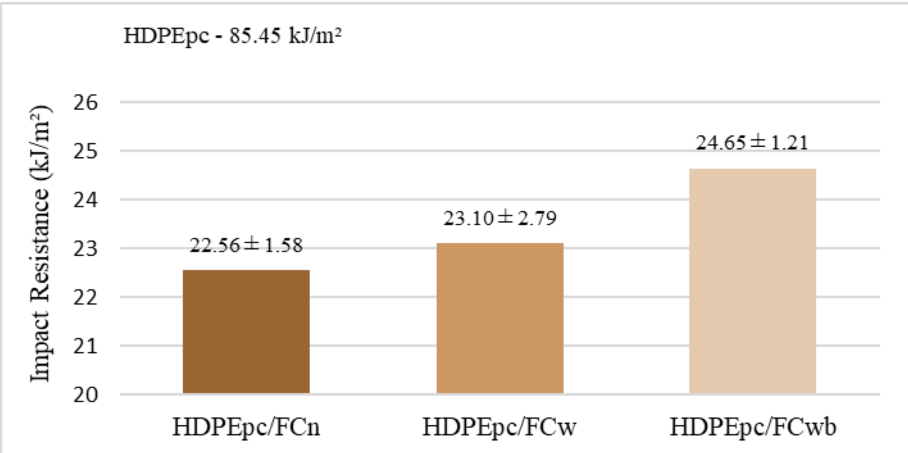

Figure 4 – Impact resistance of the analyzed samples.

In this case, the samples of composite materials HDPEpc/FCwb absorbed greater energy on impact with average values of 24.65 kJ/m², followed by HDPEpc/FCw with 23.10 kJ/m² and HDPEpc/FCn with 22.56 kJ/m². Indicating, again, that the fiber brushing process contributed to the increase in mechanical performance. On the other hand, the HDPEpc samples showed an average value of 85.45 kJ/m², proving the excellent tenacity of the polyethylene matrix even after reprocessing.

According to studies [13], the decrease in impact resistance is associated with increased stiffness (biggest module) and, therefore, lower flexural elongation of composite materials.

Conclusions

From the results obtained, it can be concluded that the composite materials HDPEpc/FCwb, where the fibers underwent a surface pre-treatment (washing, drying, and brushing), showed greater hydrophobicity and impact resistance than the other composite materials analyzed. Demonstrating that the removal of impurities presents in the fibers, through simple cleaning processes, has a positive influence on the production of thermoplastic polymers reinforced with vegetable fibers.

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