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SUSTAINABLE COMPOSITES BASED ON POST-CONSUMER POLYPROPYLENE AND MINERAL FILLER

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ABSTRACT

In this work, composites based on post-consumer polypropylene and two types of bentonites (in natura and organophilic) with different contents (2, 5 and 8% by weight) were prepared in a counter-rotating twin-screw extruder. The pelletized samples obtained by extrusion were stamped from plates obtained by compression in a bench press and these materials were characterized through measurement of hardness and impact resistance, as well as optical microscopy (OM) and scanning electron microscopy (SEM). The results indicated decreased hardness and impact resistance. The SEM micrographs showed the absence of agglomerates in the composites prepared with organophilic bentonite.

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INTRODUCTION

Thermoplastics, such as polypropylene (PP), are a class of polymers that soften (and eventually liquefy) when heated, and harden when cooled, processes that are fully reversible and repeatable (Callister, 2018). Due to the wide applicability of thermoplastics in various industrial sectors, these polymers have been replacing many more expensive and heavier materials, so their percentage in dumps/landfillsis steadily rising (Machado *et al*., 2019; Forlin*et al*., 2002; Machado *et al*., 2021). This causes a major environmental problem from disposal of plastic packaging.Because polymeric materials do not decompose easily, their disposal leads to soil and water pollution. In addition, their residues also pose a danger to marine animals when discarded in lakes, rivers or seas. Thus recycling plastics helps to preserve the environment, since this material is reused in new applications (Monteiro *et al*., 2020; Moraes*et al*., 2010; Sarde et al., 2021). Since their advent and technological development, polymers have caused impressive changes in society, thanks to the great diversity of products, ease of processing, low cost and ability for use in products with innovative design, among other advantages. However, the increasing use of these materials has led to the production of a huge amount of post-consumer waste, causing a major environmental impact (Coelho *et al*., 2020; Dinnebier, 2015). One of the most prevalent measures to mitigate the environmental impact generated by polymers is recycling. In this process, manufacturing or processing waste (post-industrial) or discarded articles (post-consumption) are reprocessed into new products. One of the applications of this type of waste is to produce composite polymeric materials (Fernandes *et al*., 2020; Mateus *et al*., 2020; Todor *et al*., 2021). In particular, composites based on the interaction between a polymer and clay minerals such as bentonite, montmorillonite and muscovite have been formulated with improved mechanical and thermal properties (Monsores *et al*., 2017; Banda-Cruz *et al*., 2017; Machado *et al*., 2021). Bentonite is a low-cost mineral that is widely available in Brazil. It belongs to a wide class of minerals of the aluminosilicate or phyllosilicate family and is considered a semi-reinforcing filler for organic polymers (Libano*et al*., 2012; Machado, 2016; Moraes*et al*., 2017; Mahadeva *et al*., 2018). In this context, the present work aimed to develop composites based on post-consumer polypropylene and bentonite (in natura and organophilic).

EXPERIMENTAL PROCEDURES

Materials: The polymer matrix used in this work was polypropylene (PP), obtained from post-consumer packaging. The in natura bentonite (BE) was supplied by the company Bentonorte (Rio de Janeiro). Organophilic bentonite (BO) was obtained in the laboratory by reacting BE with cetyltrimethylammonium bromide.

Preparation of composites: PP composites were prepared with BE and BO (2, 5 and 8% m/m) in a co-rotating twin-screw extruder (Teck Trill), L/D 40 with 10 temperature zones plus the head temperature zone, between 120 and 200 °C, using a screw speed of 40 rpm. All samples were obtained in the form of continuous filaments. The materials were then shredded and packaged. Table 1 reports the designations of the materials.

Table 1. Materials nomenclature

Nomenclature	PP (%m/m)	BE (%m/m)	BO (%m/m)
PP	100	0	0
PP2BE	98	2	0
PP5BE	95	5	0
PP8BE	92	8	0
PP2BO	98	0	2
PP5BO	95	0	5
PP8BO	92	0	8

Obtaining the test bodies: The specimens for the different tests (physical-mechanical and morphological) were stamped from plates obtained by compression in a bench press, Marconi, model MA 098.These plates were obtained using a temperature of 180 °C, pressure of 3 tons for 3 minutes and then they were cooled in a cold press for 3 minutes, thus obtaining the films of the materials.

Characterization

Determination of Hardness: Hardness tests were performed according to ASTM D2240–05 (2010). The Shore D Durometer (Type GS 702) indicated the Shore D hardness values of the analyzed materials. For each sample, the highest and lowest values were excluded, so the arithmetic means of five measurements were calculated.

Impact resistance: The impact tests were carried out in accordance with ASTM D256 with an impact pendulum machine (Ceast model 9050), with a 2.7 J impact hammer.

Optical microscopy (OM): The presence of clay (in natura and organophilic) in the composites at magnifications of 500X was visualized with an optical microscope (Olympus model F440).

Scanning electron microscopy (SEM): Scanning electron microscopy (SEM) analysis was performed using a Hitachi model TM3030Plus microscope to observe specimens coated with gold. Cryogenically fractured cross-sections of the samples were assessed, and the images were obtained at 500 x magnification, at 15 kV.

RESULTS AND DISCUSSION

Overall, the composites showed a slight drop in hardness results (Figure 1). The hardness remained unchanged only for the composite with 2% untreated clay. The addition of the inorganic filler did not promote the expected increase in hardness of the materials. These results can be attributed to the presence of weak interactions between the polymer and the clay particles (Fernandes *et al*., 2020; Seyedzavvar *et al*., 2021). The impact resistance results are shown in Figure 2.All composites had a significant drop in energy absorption in the impact tests compared to the pure polymer. These results reveal that the introduction of clay made the material more fragile, and consequently lowered the impact resistance. Some researchers have report that the presence of organophilic clay increases the impact resistance of polymers, possibly due to the modification of the matrix morphology.In addition, clay can absorb impact energy and reduce the propagation of microcracks (Paiva *et al*., 2006; Oliveira *et al*., 2015). However, this is not always observed (Zare, 2013; Naderi-Samani *et al*., 2017).

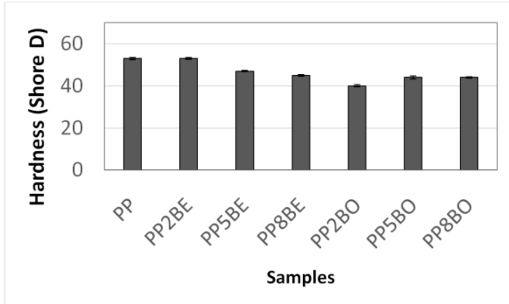

Figure 1. Hardness results for PP and PP/BE and PP/BO composites

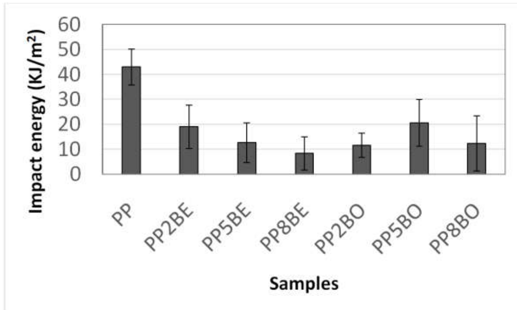

Figure 2. Impact energy for PP and PP/BE and PP/BO composites

Figure 3 shows the optical microscopy (OM) images of in natura bentonite (BE), organophilic bentonite (BO) and post-consumer polypropylene (PP). The optical microscopic images of the two clays revealed that in addition to having the typical shape of the grains, the samples' color and the tendency to form agglomerates at room temperature changed (Machado, 2016). In the PP sample, homogeneity and absence of impurities can be observed.

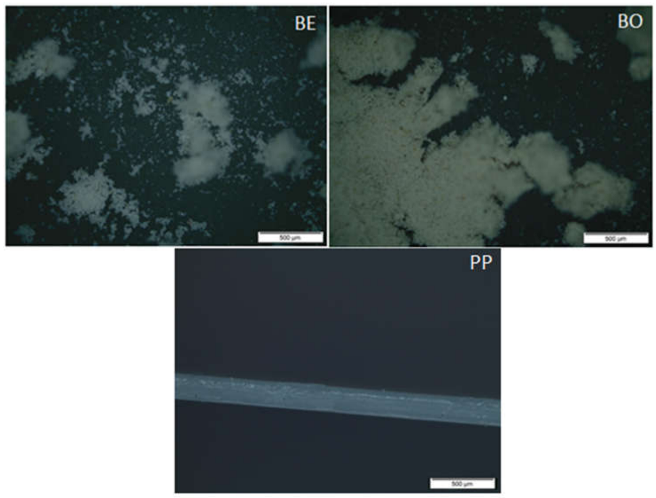

Figure 3. Optical microscopy of BE, BO and PP (5x magnification)

Figure 4 illustrates the micrographs of PP composites with BE and BO. Optical microscopy was used as a preliminary method to observe the degree of charge dispersion in the polypropylene matrix. Through the micrographs, it was possible to observe the presence of clay agglomerates with different dimensions in all compositions. The influence of organic salt on BO did not have decisive importance in the dispersion of clay in the polymer, since all composites presented very similar morphologies, with the presence of agglomerates, indicating heterogeneity of the material (Alves *et al*., 2013; Hanken*et al*., 2019; Olivera *et al*., 2019).

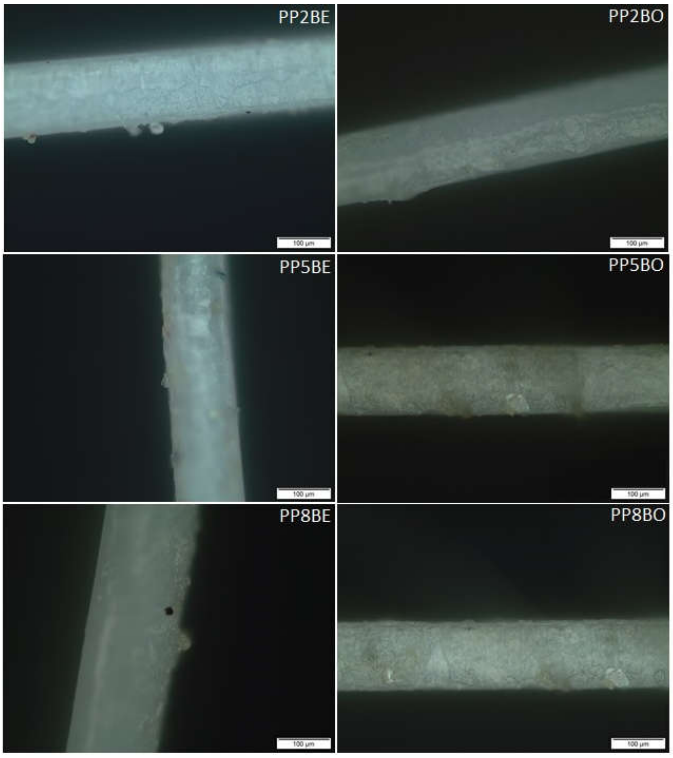

Figure 4. Optical microscopy of PP composites with BE and BO (20x magnification).

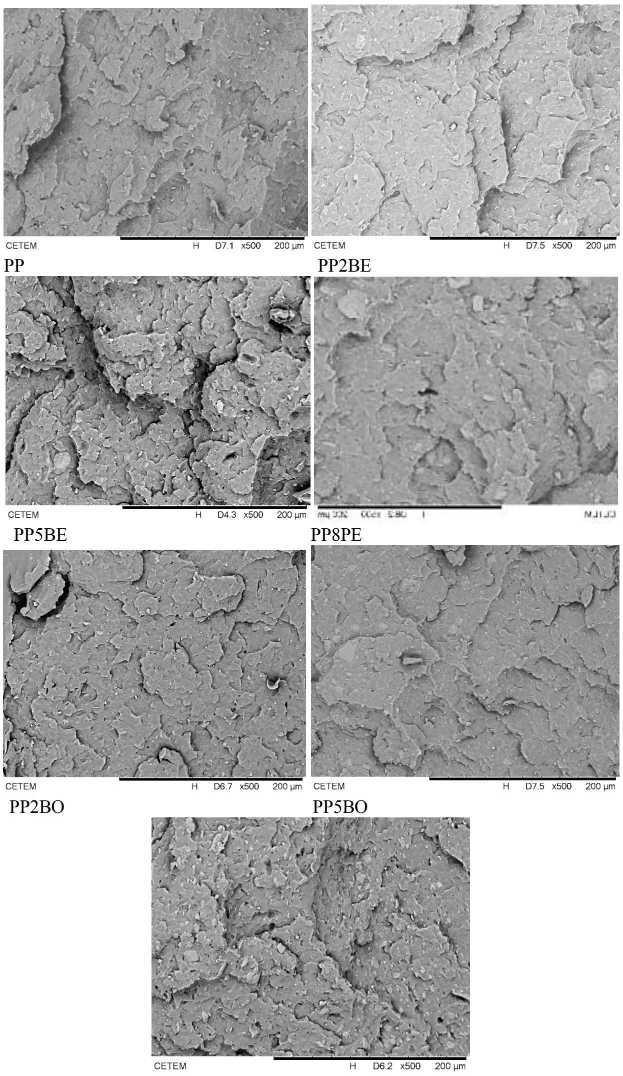

Figure 5. SEM micrographs of PP composites with BE and BO (500 x magnification)

Figure 5 shows the micrographs of PP and composites. The unmodified bentonite (BE) is not evenly dispersed, with the presence of agglomerates and poor adhesion to the polymer. On the other hand, agglomerates are absent in the modified clay (BO) under the same magnification. In BO, some clay particles can be seen within the matrix structure, as also observed by Ramos *et al.* (2005).

CONCLUSION

In this work, composites were prepared by the incorporation of different types and concentrations of bentonite in post-consumer PP matrix. The addition of the inorganic filler promoted a reduction in hardness of the composites and made the material more fragile, and consequently reduced the impact resistance. We did not observed agglomerates in the composites prepared with organophilic bentonite. The results obtained showed that post-consumer polypropylene and bentonite can be considered to produce sustainable composites.

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