

Wood-plastic composite based on post-consumer HDPE and vermiculite

Comósito madeira-plástico à base de HDPE pós-consumo e vermiculita

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Alcir B Fernandes

Graduando em Tecnologia de Polímeros

Instituição: Fundação Centro Universitário Estadual da Zona Oeste, UEZO

Endereço: Avenida Manuel Caldeiras de Alvarenga, 1203, Campo Grande, CEP: 23070-200, Rio de Janeiro – RJ, Brasil

e-mail: bomfim03@yahoo.com.br

Patricia S da Costa Pereira

Doutora em Ciência e Tecnologia de Polímeros pelo Instituto de Macromoléculas Professora Eloisa Mano, IMA - Universidade Federal do Rio de Janeiro (UFRJ)

Instituição: Fundação Centro Universitário Estadual da Zona Oeste, UEZO

Endereço: Avenida Manuel Caldeiras de Alvarenga, 1203, Campo Grande, CEP: 23070-200, Rio de Janeiro – RJ, Brasil

e-mail: patriciapereira@uezo.rj.gov.br / patyscp@gmail.com

<https://orcid.org/0000-0002-6919-032X>

Daniele Cruz Bastos

Doutora em Ciências em Engenharia Metalúrgica e de Materiais pelo Programa de Engenharia Metalúrgica e de Materiais da Coppe - Universidade Federal do Rio de Janeiro, Brasil

Instituição: Fundação Centro Universitário Estadual da Zona Oeste, UEZO

Endereço: Avenida Manuel Caldeiras de Alvarenga, 1203, Campo Grande, CEP: 23070-200, Rio de Janeiro – RJ, Brasil

e-mail: danielebastosuezo@gmail.com / danielebastos@uezo.rj.gov.br

<https://orcid.org/0000-0001-7368-9329>

Elaine V Dias Gomes Líbano

Doutora em Ciência e Tecnologia de Polímeros pelo Instituto de Macromoléculas Professora Eloisa Mano, IMA - Universidade Federal do Rio de Janeiro (UFRJ)

Instituição: Fundação Centro Universitário Estadual da Zona Oeste, UEZO

Endereço: Avenida Manuel Caldeiras de Alvarenga, 1203, Campo Grande, CEP: 23070-200, Rio de Janeiro – RJ, Brasil

e-mail: elainelibano@uezo.rj.gov.br / elainevdg@yahoo.com.br

<https://orcid.org/0000-0001-8165-875X>

ABSTRACT

In this work, wood plastic-composites (WPCs) were prepared by the incorporation of vermiculite in the post-consumer HDPE. The processing of WPCs with different clay contents (2, 5 and 10% by weight) was carried out in a mono-extruder. The specimens were obtained by compression and characterized by density (ASTM D792), hardness (ASTM D2240) and melt flow index (MFI, ASTM

D1238). The composites obtained showed a tendency of increased density and reduced MFI from 5% clay. However, no significant difference in WPC hardness was observed in relation to the matrix.

Keywords: HDPE, post-consumer, vermiculite.

RESUMO

Neste trabalho, compósitos madeira-plástico (WPCs) foram preparados através da incorporação de vermiculita em PEAD pós-consumo. O processamento dos WPCs com diferentes teores de argila (2, 5 e 10% em massa) foi realizado em extrusora mono-rosca. Os corpos-de-prova foram obtidos por compressão e caracterizados por densidade (ASTM D792), dureza (ASTM D2240) e índice de fluidez (MFI, ASTM D1238). Os compósitos obtidos apresentaram uma tendência ao aumento da densidade e redução do MFI a partir de 5 % de argila. Entretanto, não foram observadas diferenças significativas na Dureza dos WPCs em relação à matriz.

Palavras chave: PEAD, pós-consumo, vermiculite.

1 INTRODUCTION

Recycling is one of the most common measures to reduce the environmental impact generated by polymers. The production of new materials with the reuse of waste is a new trend in the market that aims at the same time to obtain ecologically correct products and reduce the production cost. Plastic lumber is an example of a product obtained from the reprocessing of varied plastic wastes, mainly high-density polyethylene (HDPE) (Mateus *et al.*, 2020; Martins *et al.*, 2019; Matos, 2015; Zoch, 2013).

Plastic lumber is widely used in garden furniture, decks, fences, facades, gates, decorative items and playground equipment, among others (Müzel, 2017).

The production of wood-plastic composites (WPC) with reinforcing fillers (glass and polymeric fibers, calcium carbonate, vegetable fibers and clay minerals) has proved to be a good alternative both to improve the properties of plastic wood and to reduce the percentage of waste and the corresponding environmental impact (Gerardo *et al.*, 2020; Kieling *et al.*, 2019; Ge *et al.*, 2018; Talgatti *et al.*, 2017).

Gerardo *et al.* (2020) studied the influence of mica (muscovite type) particle size on the wetting behavior, morphological, physical, and chemical properties of recycled HDPE. The mica particle size did not significantly affect the properties of rHDPE, so the authors suggested the use of larger particle sizes, which can reduce the final cost of the product and improve the properties of post-consumer polymers.

Vermiculite (VMT) is a clay mineral of the mica family that is used as a filler in polymeric composites to reduce costs and/or modify properties such as modulus, hardness, thermal stability, opacity and gloss (Líbano *et al.*, 2018; Fernández, 2017; Araújo *et al.*, 2015; Gencel *et al.*, 2014; Gomes *et al.*, 2009).

This study aimed to find alternatives for the use of plastic lumber by applying it as raw material for the production of WPCs with vermiculite, with potential use in civil construction. The processing of WPCs with different clay contents (2, 5 and 10% by weight) was carried out in a mono-extruder. The WPCs were characterized by density (ASTM D792), hardness (ASTM D2240) and melt flow index, MFI (ASTM D1238).

2 EXPERIMENTAL PROCEDURES

2.1. MATERIALS

The plastic lumber waste (recycled high-density polyethylene. or r-HDPE) used in this work was provided by Companhia Municipal de Limpeza Urbana (Comlurb, the municipal sanitation company in the city of Rio de Janeiro).

The plastic lumber waste was first sawed on a band saw, ground, washed with water and dried in an oven at a temperature of 80 °C. The subsequent stages of material processing consisted of manual separation to eliminate coarse residues. Finally, a magnet was passed over portions of the cut material to attract any small metallic elements, which were not observed.

The clay used in this study was vermiculite in its natural form, with a particle size of 177 µm, supplied by the company Brasilminérios.

2.2. WPCS PREPARATION

WPC processing with different levels of VMT (2, 5 and 10% by weight) was carried out in a mono-screw extruder (AX Plásticos) with three temperature zones (165, 170 and 170 °C) from the head to the die, respectively.

Table 1 shows the mass proportions of each component that was obtained. For characterization, the pellets with each particle size were pressed at 170 °C and 3 tons for 300 seconds and cooled in a cold press for 60 seconds.

Table 1. WPCs (rHDPE/VMT) processed.

Material	Weight percentage (% m/m)
Plastic lumber (recycled HDPE)	100
rHDPE/VMT 2	98/2
rHDPE/VMT 5	95/5
rHDPE/VMT 10	90/10

2.3. CHARACTERIZATION:

2.3.1. Density

The density was determined according to the ASTM D792-2013 standard with a densimeter (Gehaka model DSL 910) using five specimens of each prepared composite.

2.3.2. Hardness

The Shore D hardness test was performed on composite materials according to ASTM D2240-2010, using a Shore D durometer (Type GS 702), at five different points of each specimen.

2.4.3. Melt flow index

To determine the melt flow index (MFI), a CEAS Quick Index instrument was used according to the ASTM D1238-2013 standard, at a temperature of 190 °C and load of 2.16, using five specimens from each sample, weighed on an analytical scale (Mars AY220).

3 RESULTS AND DISCUSSION

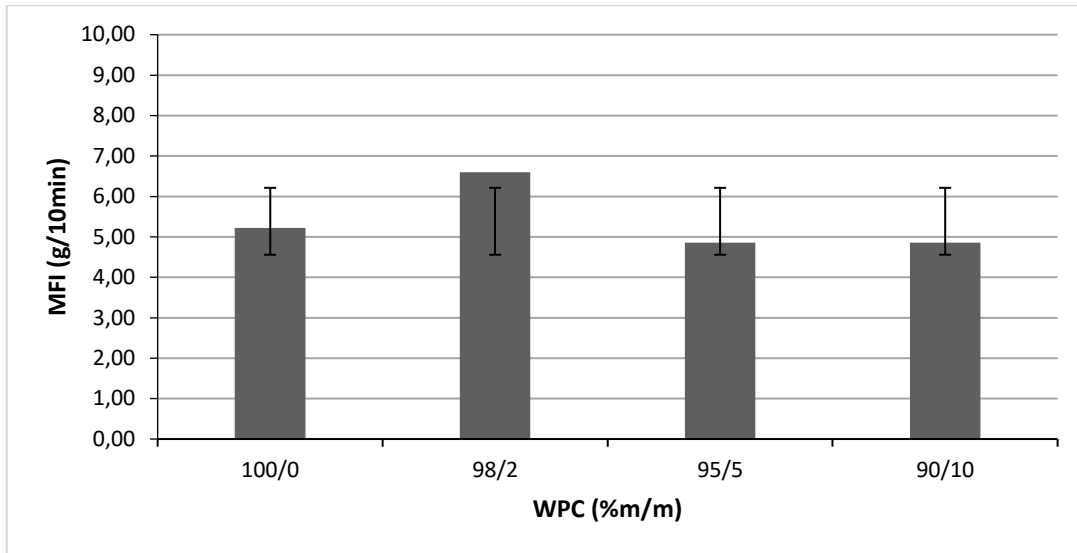
Table 2 and Figures 1 to 3 show the results of density, hardness and MFI for WPCs (rHDPE/vermiculite).

The decrease in the viscosity (MFI increase) with 2% clay can be ascribed to the alignment of the clay particles in the direction of the flow. A slight increase in the viscosity (MFI decrease) was observed with the addition of 5 and 8% clay, which may require higher energy consumption in the extrusion process (Gerardo *et al.*, 2020; Hanken *et al.*, 2019). However, the results obtained did not affect the composite processability by extrusion, since the permissible MFI values for extrusion processing are around 0.1 – 0.3 g/10min (Kajaksa *et al.*, 2018; Soccalingame *et al.*, 2015; Pereira *et al.*, 2015).

Table 2. Density, Hardness and MFI of WPCs (rHDPE/vermiculite)

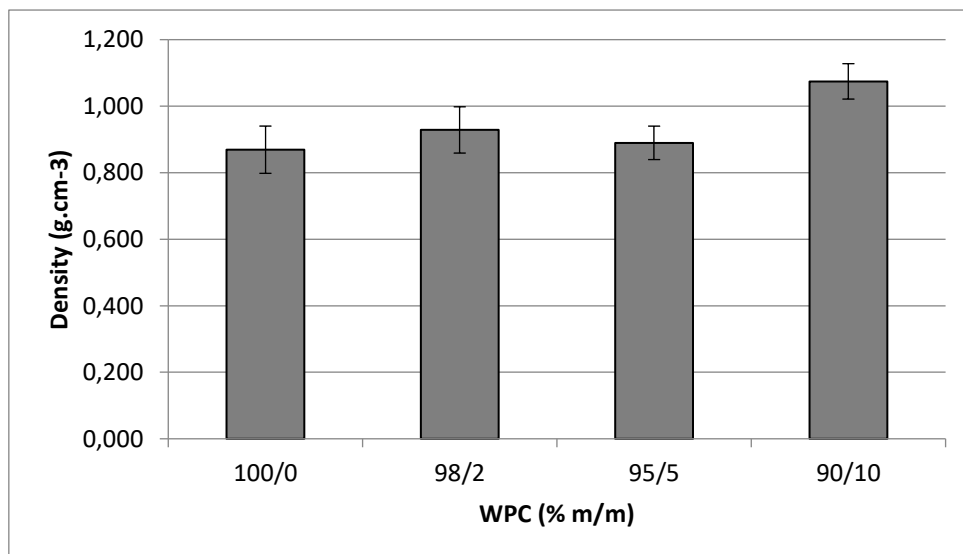
Material	% (m/m)	Density (g/cm ³)	Hardness (Shore D)	MFI (g/10min)
rHDPE	100	0.869 ± 0.071	0.480 ± 0.044	5.22 ± 0.02
rHDPE/VMT 2	98/2	0.929 ± 0.069	0.440 ± 0.055	6.60 ± 0.00
rHDPE/VMT 5	95/5	0.890 ± 0.050	0.470 ± 0.027	4.86 ± 0.06
rHDPE/VMT 10	92/8	1.075 ± 0.053	0.440 ± 0.042	4.86 ± 0.00

Figure 1: WPCs (rHDPE/VMT) MFI



The results obtained for plastic lumber waste density were in accordance with those reported by Gerardo *et al.* (2020), $0.815 \pm 0.087 \text{ g.cm}^{-3}$. The WPCs' density increased slightly with vermiculite addition, which can be attributed to good matrix/filler adhesion. The good interaction is probably related to the additives present in the recycled HDPE, which act as plasticizers. Considering the standard deviation, it can be said that the addition of up to 8% vermiculite did not change the density of the composites (Bastos *et al.*, 2018; Martins *et al.*, 2019; Gerardo *et al.*, 2020; Gonçalves *et al.*, 2020).

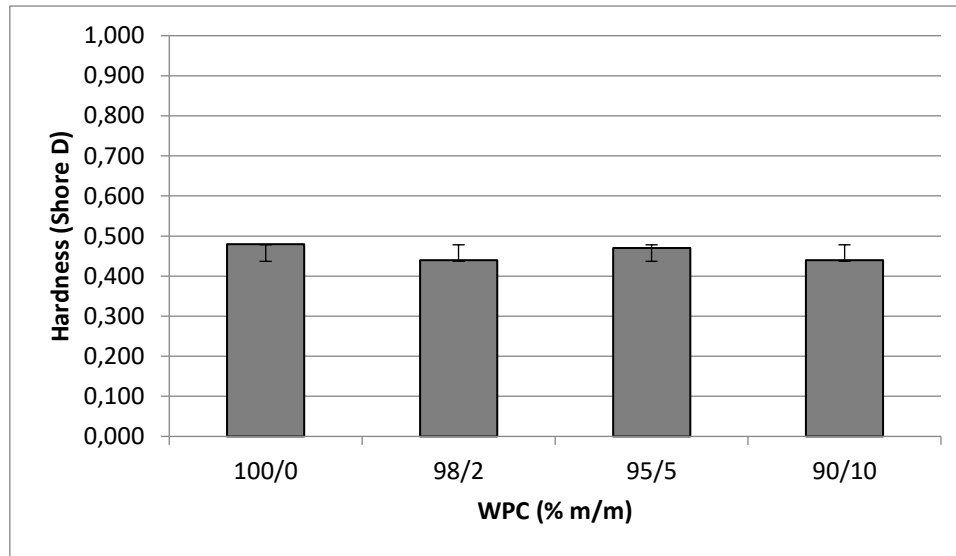
Figure 2: WPCs (rHDPE/VMT) density.



No significant differences in WPC hardness were observed in relation to the matrix material.

The hardness results showed that the addition of the inorganic fillers up to 8% was not enough to change the hardness of the composites. Similar results were found by Gonçalves *et al.* (2020). The increase in inorganic filler proportions should increase the rHDPE hardness (Martins *et al.*, 2020).

Figure 3: WPCs (rHDPE/VMT) hardness



4 CONCLUSION

In this work, WPCs were prepared by the incorporation of vermiculite in the post-consumer HDPE matrix. The evaluated properties were density, hardness and melt flow index. The addition of vermiculite up to 10% did not significantly affect the studied properties. The good adhesion between matrix and filler and the good processability found for the WPCs studied suggest that a greater proportion of vermiculite should be incorporated in the HDPE matrix.

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