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PRELIMINARY EVALUATION OF THE RHEOLOGICAL PROPERTIES OF HIGH DENSITY POLYETHYLENE (HDPE) WITH USE OF RECYCLING REOLOGY AGENT

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ABSTRACT

The High Density Polyethylene (HDPE) is a thermoplastic material with good performance and general use properties in the manufacturing industry being processed and blow molded, extruded and injected. Its low cost and easy processing makes HDPE one of the materials most used in the manufacture of several products in the world. Being a thermoplastic, its recycling is allowed, through a simple process and without major demands, however, due to the large consumption a large amount of material is generated in addition to costly recycling processes. In the recycling process there are losses of properties and the quality of the material thus compromising the use of the same, as well as, its applications in the market. The objective of this work is to study an additive developed as a rheology modifying agent for use in recycled materials. The materials were prepared according to 8 types divided into two groups with and without addition of additive and in the process condition being reprocessed or milled. Preliminary results such as Fourier Transform Infrared (FTIR) spectroscopy indicate the presence of peroxide in the additive, but in small amounts without the ability to completely crosslink. Mechanical tests with the test Proof Bodies (CP) for tensile, impact and flexural strength show great improvement in their properties, however in the fluidity index there is a decrease. The thermogravimetric or Thermogravimetric Analysis (TGA) tests present little variation of the mass loss for the CP, and the Differential Scanning Calorimetry (DSC) the presence of endothermic reactions. This work can contribute by facilitating the use of recycled HDPE in a more practical and efficient manner, taking into account the industrial and environmental demands from the addition of additive with maintenance of the mechanical properties of the recycled material.

1. INTRODUCTION

PE is a partially crystalline polymer, flexible whose properties are markedly influenced by the relative amount of amorphous and crystalline phases. Its commercial production began in the 1950s and among the types of polymers is the one with the highest installed capacity with global consumption in 2006 at around 67 million tons and an estimated 80 million in 2010 [1].

PE is inert to most common chemicals due to their paraffinic nature, their high molecular weight and their partially crystalline structure [2]. The density is related to the crystallinity of the polymer and reflects its chemical structure and molecular organization. Thus the density of the polymers increases as they crystallize, due to the increased packaging of the molecules. The higher the crystallinity, the higher the properties of density, stiffness, dimensional stability, chemical resistance, abrasion resistance, melt temperature, temperature of use [3]. It is widely used for the production of bags, packaging and household goods such as pots and jars. In addition, they are light, non-toxic and chemically resistant, and can come into contact with food and pharmaceuticals without transmitting odor or flavor [4].

The High Density Polyethylene (HDPE) is a thermoplastic material with high molecular weight and good mechanical, physical and chemical properties thus presenting general use in the processing industry. It is processed through the methods: extrusion, injection and blow. Its low cost and easy processing makes HDPE one of the materials most used in the manufacture of various products. Being a thermoplastic, its recycling occurs naturally, through a simple process and without great demands, however, the quality of this recycled material can compromise its use, as well as its applications in the market. It is already known that the use of Dicumyl Peroxide (DCP) in recycled high density polyethylenes, presents improvement of significant mechanical properties. However, depending on the amount of peroxide used the polymer undergoes crosslinking to a high degree and can't be recycled subsequently [5]. This work has as objective to evaluate the efficiency of the rheology modifying agent in the crosslinking of recycled high density polyethylene by analyzing the recovery of its rheological and mechanical properties, compared to the properties of the virgin material.

2. MATERIALS AND METHODS

The HDPE was prepared according to two groups, both with rheology modifying additive under conditions 0%, 0.4%, 0.7% and 1%, the former being the ground material, resulting from the injection burrs, and the material reprocessed from Empresa Polibalbino, according to table 1.

Table 1: Sample

Material	Additive
Ground material	0
Ground material	0.4% additive
Ground material	0.7% additive
Ground material	1% additive
Reprocessed material	0
Reprocessed material	0.4% additive
Reprocessed material	0.7% additive
Reprocessed material	1% additive

The additive will be mechanically incorporated into the reprocessed and recycled material. For comparison, the following tests were performed: Determination of Fluidity Index (MFI), performed by Plastometer according to ASTM D 1238. Determination of tensile strength, modulus of elasticity, yield strength, maximum breaking strength and their respective deformations on EMIC equipment according to ASTM 638. Determination of IZOD impact strength ASTM D 256 and Flexural strength ASTM 790. DSC tests on Q20 V24.11 build 124 equipment. Oscillatory rheometry was performed on virgin and ground material (rheometer Antor Paar MCR 102), Peltier plate heating, plate-plate geometry, plate size 25mm, temperature 200 ° C, angular frequency 0.1 to 100 1 / s, amplitude 2%. The samples for this assay were injected discs. After this comparison of the reprocessed and additive ground materials, we will be irradiating samples of reprocessed and ground with gamma irradiation at doses 20kGy and 50kGy, according to the test flow chart below:

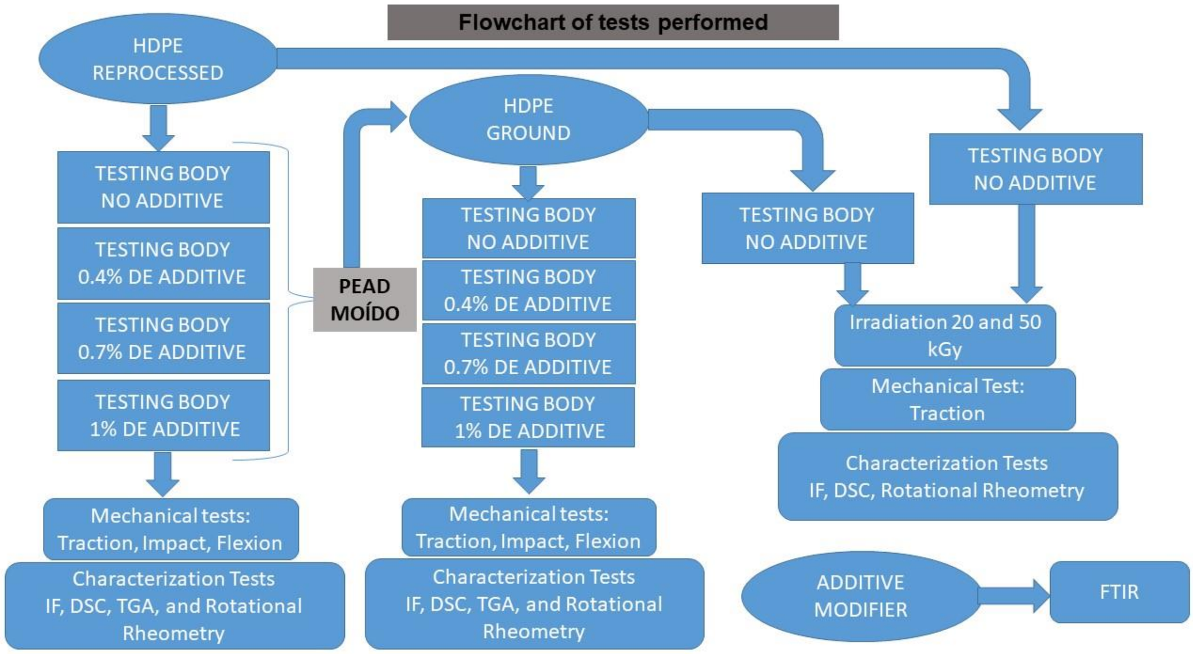


Figure 1: Flowchart of tests performed

2.1 Raw material used

For this study will be used the following materials:
a) Reprocessed HDPE material used for the injection process. Polybalbino Supplier
b) ground material from injection branches from the same source (reprocessed polybalbine HDPE) used for the injection process.
c) Modifying additive: Material available in pellets to improve mechanical properties.

2.2 Additive

The additive was developed through HDPE itself as a vehicle. Being applied 10% Peroxide Bis (pure solid) and 90% HDPE. Peroxide was melted at 38 ° C and mixed with HDPE in a planetary mixer. The granules were coated with peroxide.

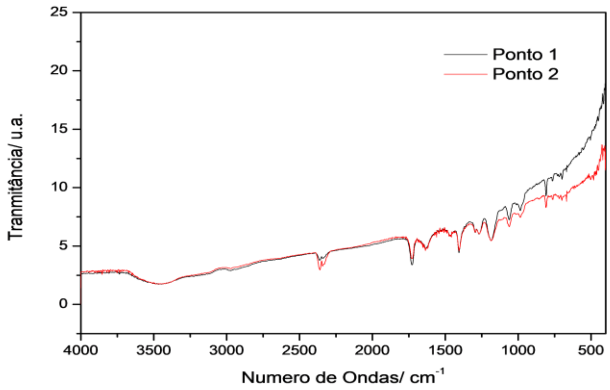


Figure 2: Fourier Transform Infrared (FTIR) of the crosslinking agent sample.

The transmittance spectrum shows peaks that indicate the presence of peroxide in polyethylene. Being used in adequate proportions, it is possible, in principle, to recover properties by partial crosslinking of the polymeric chains.

3. RESULTS AND DISCUSSIONS

3.1. Mechanical Properties

The mechanical properties were: traction standard ASTM 638, impact standard Izod ASTM D 256 and flexion ASTM 790, according to table 2.

Table 2: Mechanical properties - flexion and traction

A Description	Type	Result	B Description	Type	Result
Ground material	0	4539	Ground material	0	4112
Ground material	0.4% additive	4971	Ground material	0.4% additive	4114
Ground material	0.7% additive	5446	Ground material	0.7% additive	4354
Ground material	1% additive	6329	Ground material	1% additive	4723
Reprocessed material	0	5171	Reprocessed material	0	4769
Reprocessed material	0.4% additive	5484	Reprocessed material	0.4% additive	4996
Reprocessed material	0.7% additive	5667	Reprocessed material	0.7% additive	5241
Reprocessed material	1% additive	6196	Reprocessed material	1% additive	5318

A. Results of flexion test. B. Results of traction tests.

In relation to the flexion tests, according to table 2 (A), the additive improves the properties at all levels, especially for the ground material (1%), which surpasses all the results when compared to the processed CP (6329 kgf/cm^2).

The traction tests, table 2 (B), showed an improvement in the properties of both CPs especially with the addition of 1% peroxide to the ground material (4723 kgf/cm^2), thus reaches the same level as a reprocessed material with additive (4769 kgf/cm^2).

Table 3: Mechanical properties – fluidity

Material		Fluidity	
Description	Type	Average (g/10min)	Standard deviation
Ground material	0	173.595	7.199
Ground material	0.4% additive	187.288	9.094
Ground material	0.7% additive	188.039	16.345
Ground material	1% additive	212.81	16.008
Reprocessed material	0	224.412	33.71
Reprocessed material	0.4% additive	224.477	16.223
Reprocessed material	0.7% additive	228.758	38.653
Reprocessed material	1% additive	239.2731	46.282

The results of the fluidity tests indicate a decrease in all CP, but are more evident in the material ground with 1% of additive.

3.2 Characterization Tests

For the TGA, minimum variations were observed in the initial temperatures around 300°C, with minimum variations in initial temperatures around 490°C. A single-stage thermal decomposition is observed for all CPs according to Derived Thermogravimetry (DTG). The ground material showed a reduction in residual mass loss of 0.44% (896.8 oC), with the addition of 1% additive and 0.7% (896.8°C), with the addition of 0.7 % of additive when compared to HDPE soil without additives (0.84%, 896.8°C). The indices are better for the virgin material at all levels, respectively, and in decreasing order, in the percentages 0.7% (0.2%, 896.8°C), 1% (0.25%, 896.8°C) and 0.4% (0.38%, 896.8°C) when compared to virgin HDPE without additives (0.39%, 896.8°C). The DSC test shows a characteristic endothermic peak in both heaters in the 130-135 ° C range, characterized by the melting point for both CPs with a small displacement for the virgin PC with 1% additive (128.53 ° C, ΔH J / g) of 106.4).

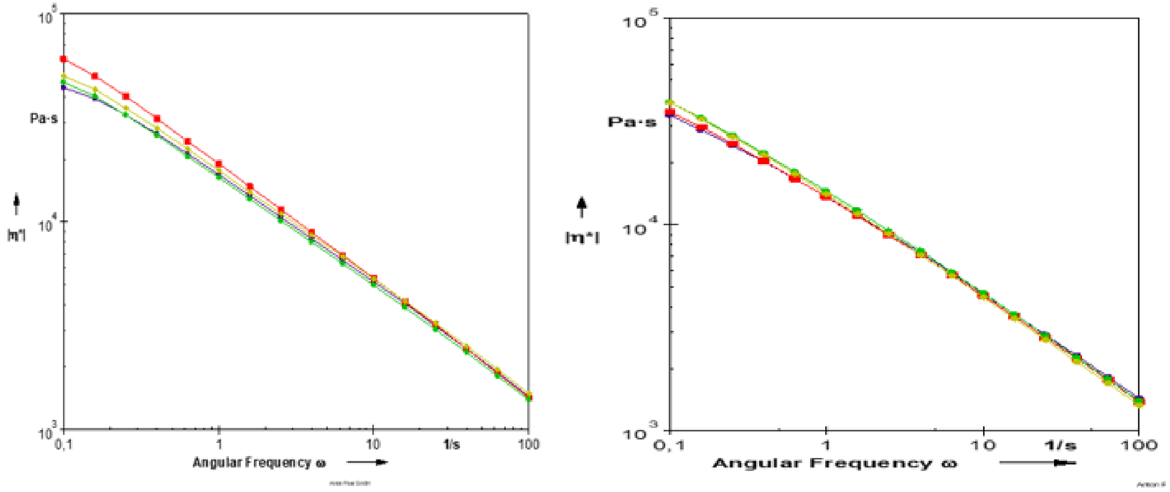
Table 4: Results MFI (Flow index)

Material		Fluidity	
Description	Type	Average	IF (g/10min)
Ground material	0	0,1307	7,84
Ground material	0,4% additive	0,1165	6,99
Ground material	0,7% additive	0,1145	6,87
Ground material	1% additive	0,104	6,24
Reprocessed material	0	0,142	8,52
Reprocessed material	0,4% additive	0,139	8,38
Reprocessed material	0,7% additive	0,1395	7,83
Reprocessed material	1% additive	0,1275	7,69

Through the test of determination of the index of fluidity, a decrease in the index is verified as the percentage of additive characteristic of peroxide increases.

3.3 Rheology Results

Oscillatory rheometry was performed on reprocessed and ground material (Antor Paar MCR 102 rheometer), Peltier plate heating, plate-plate geometry, plate size 25mm, temperature 200 ° C, angular frequency 0.1 to 100 1 / s, amplitude 2%. The samples for this assay were injected discs.



Reprocessed material *Ground material*

Figure 2 - Comparison of reprocessed material and ground in pure formulations, 0.4%, 0.7% and 1% additive.

Finally, we separated the samples of ground HDPE and reprocessed HDPE, both samples without additive and submitted to irradiation of 20kGy and 50kGy, aiming to improve the properties without a complete crosslinking, comparing the improved samples with additive.

4. CONCLUSIONS

With the initial results of the use of the additive, there was an improvement in the mechanical properties of the recycled material. The flow rate is reduced due to the low use of peroxide. Results from rheology tests show that the additive increases the viscosity of the material. According to references cited, there is no application of this additive manually, the applications cited in other articles and dissertations were performed by extrusion, this shows the importance of this study. Regarding the irradiated samples with 20 kGy to 50 kGy, there is a significant improvement of properties, close to the use of additives.

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