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COMPARATIVE STUDY ON THE MECHANICAL BEHAVIOR OF ELECTRON–BEAM AND GAMMA IRRADIATED BAGASSE FIBER/HDPE COMPOSITE

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ABSTRACT

The mechanical behavior of Bagasse fiber/HDPE composite irradiated by electron beam and gamma radiation has been studied in this work. The Bagasse fiber/HDPE composite samples obtained by extrusion and injection molding processes were irradiated at 90 kGy using either a 1.5 MeV electron beam accelerator and gamma irradiator "*EMI-9"*, at room temperature in presence of air. It was found that by using either electron-beam and gamma radiation, the mechanical properties of the Bagasse fiber/HDPE composite (***composite***) were improved. However, the results showed significant increases of around 35 % in tensile strength at break for electron-beam irradiated ***composite*** samples in comparison with gamma irradiated samples. Concerning flexural strength and modules there were significant difference between electron-beam and gamma irradiated samples. In addition, these results showed a large reduction in HDPE elongation at break and MFI values due to bagasse fiber addition. The MFI for irradiated ***composite*** could not be determined because irradiated samples did not show any flow.

1. INTRODUCTION

Residues of sugarcane bagasse fiber are widely produced in Latin America as by-products of the sugar and bioethanol industry [1, 2]. In 2010, Brazil produced 737 million tons of the sugarcane, from which about 60 % was used to produce alcohol (bioethanol industry) and ca. 40 % was used to produce sugar. The sugarcane production in Uruguay in 2010 reached the very high value of about 296.000 tons [3, 4]. Due to a large growth of sugarcane industry in these countries, the sugarcane bagasse is a residue generated in high proportions and it is expected to increase in the next years. Although the major portion of the bagasse is currently burnt for energy supply in sugarcane industry, the disposal of this byproduct is so far still inefficient and, consequently, it is critical for agriculture profitability and environmental protection. Sugarcane bagasse is a lignocellulose fiber mainly constituted by around 46 % cellulose and it contains hemicellulose, lignin, fat and waxes, silica and other elements [5, 6].

Many investigations have been performed on the potential of bagasse fiber as a reinforcement in composite materials. Studies have reported that sugarcane bagasse fiber can be used to produce thermoplastic polymeric composites with excellent properties for many applications. [5-9]. Thus, based on theses studies, it may be claimed that the transformation of bagasse into high quality industrial products such as bagasse–polymer composites, can provide a prospective solution for more effective bagasse utilization.

HDPE is a linear polymer HDPE is a linear polymer composed of polymethylene, $(CH2)_n$, and it is defined as a product of ethylene polymerization with a density of 0.94 g/cm^3 or higher. HDPE consumption continues to grow annually, with product substitution and potential new applications, increasing volume sales growth [10, 11].
The melt flow index (MFI) is a measure of the plastic's ability to flow and it is inversely related to melt viscosity. MFI provides an indication of the polymer flow qualities. The MFI has been used at industry to characterize the flow properties of polymers due to simplicity and agility of the technique used in its determination [8].

A promising approach to the controllable modification of the polymer materials properties is based on ionizing radiation treatment, like electron-beam and gamma irradiation. The ionizing radiation processing may affect the polymeric materials, leading to a production of free radicals which may, in turn, lead to a degradation and/or a cross-linking process, with release of gases, discoloration and changes in mechanical, thermal and barrier properties [11-13]. In this work, a comparative study on the mechanical behavior of electron-beam and gamma irradiated Bagasse fiber/HDPE composite was investigated.

2. EXPERIMENTAL

2.1 Materials

The materials used in this study were HDPE resin (HDPE JV060U – commercial grade by Braskem S/A), with MFI = 6.4 g g/10 min at 190 °C/2.16 Kg, specific density = 0. 957 g/cm^3 and sugarcane bagasse fiber from agro-industrial residues.

2.2 Preparation of Bagasse Fiber/HDPE Composite

In order to remove the impurities, the sugarcane bagasse fiber residues were scraped, washed, and kept in distilled water for 24 h. The fiber was then dried at 80 ± 2 ºC for 24 h in an air-circulating oven. The dry fiber was reduced to fine powder, with particle sizes equal or smaller than 250 μm, by using ball mills, and dried again at 80 ± 2 ºC for 24 h to reduce the moisture content. The HDPE resin reinforced with 5.0 % sugarcane bagasse fiber was obtained by mixing 5 parts of dry fiber with 95 parts of HDPE resin (in weight), using an extrusion machine twin screw "extruder ZSK 18 Megalab" made by Coperion Werner & Pfleiderer GmbH & Co. KG. The compounded materials were passed through the different zones of the extruder and finally extruded. The extrudates coming out of the extruder were cooled down by using cold water for a better dimensional stability and wound up manually. Finally, the Bagasse fiber/HDPE composite material was pelletized by a pelletizer. The pelletized composite was then dried at 80 ± 2 ºC for 24 h in an circulating air oven, fed into

injection molding machine and specimen test samples were obtained. The injection molding was carried out using a Sandreto 430/110 injection molding machine.

2.3 Irradiation Treatment

Bagasse fiber/HDPE composite samples were irradiated at radiation dose of 90 kGy using either a 1.5 MeV electron beam accelerator or gamma irradiator EMI-9, at room temperature, in presence of air Electron-beam irradiation was performed at Radiation Technology Center – CTR/IPEN-CNEN/SP, using an electrostatic accelerator (Dynamitron II, Radiation Dynamics Inc.), at dose rate 28.02 kGy/s, energy 1.007 MeV, beam current 5.65 mA and tray speed 6.72 m/min. Radiation doses were measured using cellulose triacetate film dosimeters ‘‘CTA-FTR-125’’ from Fuji Photo Film Co. Ltd. Gamma irradiation was performed at Laboratorio Tecnologico del Uruguay, using a gamma irradiator "*EMI-9"*, dose rate 0,377 KGy/min. Irradiation doses were measured using dosimeters type Red 4032 batch KN from Harwell.

2.4 Mechanical Tests

The tensile tests were performed according to ASTM D 638 [14], the flexural tests were based on ASTM D 790 [15] and the impact strength tests were based on ASTM D 256 [16]. The differences between the results for irradiated and non-irradiated materials were, then, statistically evaluated by ANOVA using BioEstat software (version 5.0, 2007, Windows 95, Manaus, AM, Brazil). Significance was defined at $p < 0.05$.

2.5. MFI Masurements

The MFI measurements were determined with a Microtest extruder plastometer (ASTM 1238-04) in the conditions specified for HDPE [17].

3. RESULTS AND DISCUSSION

3.1 Mechanical Tests Results

These results of the mechanical tests presented show the average values calculated from the data obtained in tests. The standard deviations for results were less than 10 % for all tests.

Figure 1 shows the results of the tensile strength at break for electron-beam and gamma irradiated Bagasse fiber/HDPE composite (***composite***) and for both, non-irradiated HDPE and ***composite***, As seen in this figure, there were no significant differences ($p < 0.05$) in the tensile strength at break of neat HDPE due to bagasse fiber addition. On the other hand, the values for tensile strength at break for irradiated ***composite*** samples by electron-beam were around 150 % and ca 85 % for irradiated ***composite*** samples by gamma-rays when compared with non-irradiated composite samples. These results also show an increase of around 35 % at

tensile strength at break for the electron-beam irradiated ***composite*** in comparison with those irradiated by gamma-rays.

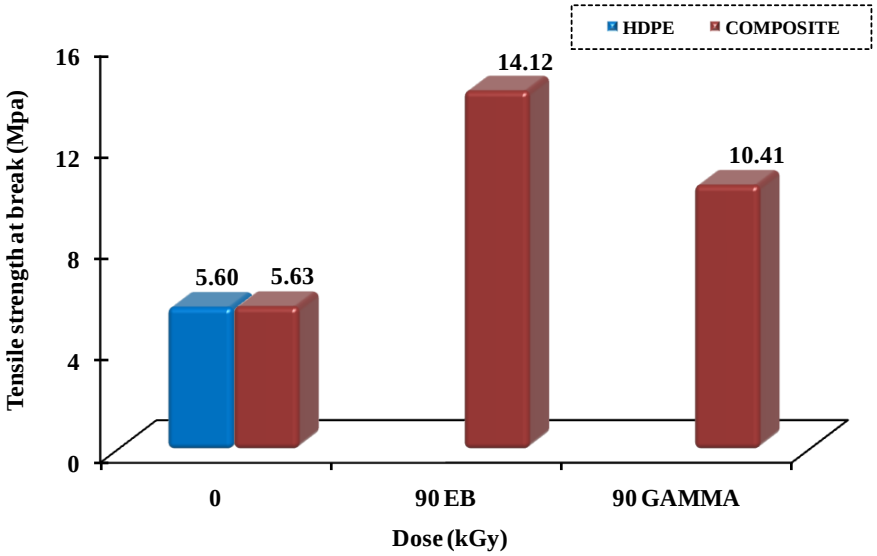

Figure 1. Tensile strength at break for both, non-irradiated HDPE and bagasse fiber/HDPEcomposite, and irradiated bagasse fiber/HDPE composite.

The results of the Elongation at break tests are presented in Fig. 2. Figure 2 shows that the elongation at break of the neat HDPE decreased of about 34 % due to bagasse fiber addition. After ionizing radiation processing there were significant decrease ($p < 0.05$) in this property of around 76 % for irradiated ***composite*** with electron-beam and ca. 60 % for gamma-rays irradiated ***composite,*** when compared with the non-irradiated ***composite***.

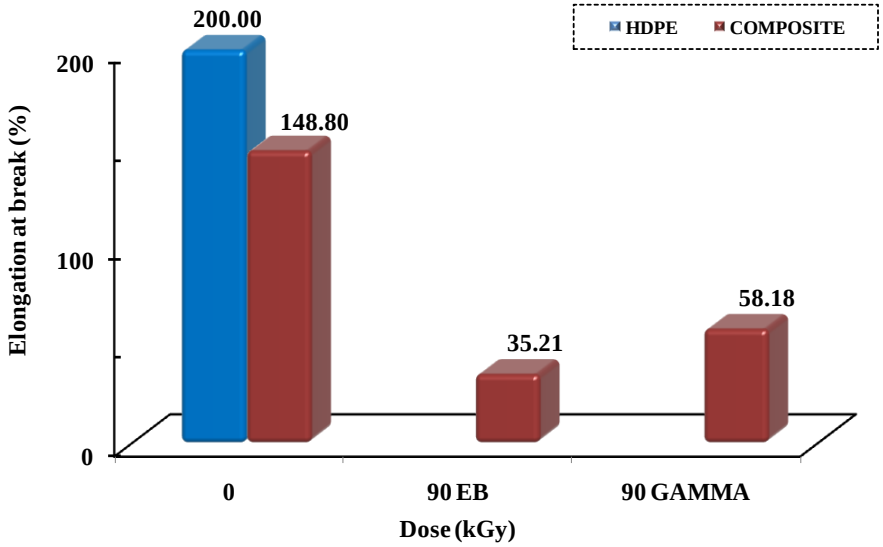

Figure 2. Elongation at break for both, non-irradiated HDPE and bagasse fiber/HDPEcomposite, and irradiated bagasse fiber/HDPE composite.

Figure 3 presents the results for flexural strength tests. As it can be observed, flexural strength for the non-irradiated ***composite*** had a slight decrease (5 %) when compared with HDPE. Both ***composite*** treated by electron-beam and gamma-rays showed an increase of about 25 %, when compared with the non-irradiated ***composite***.

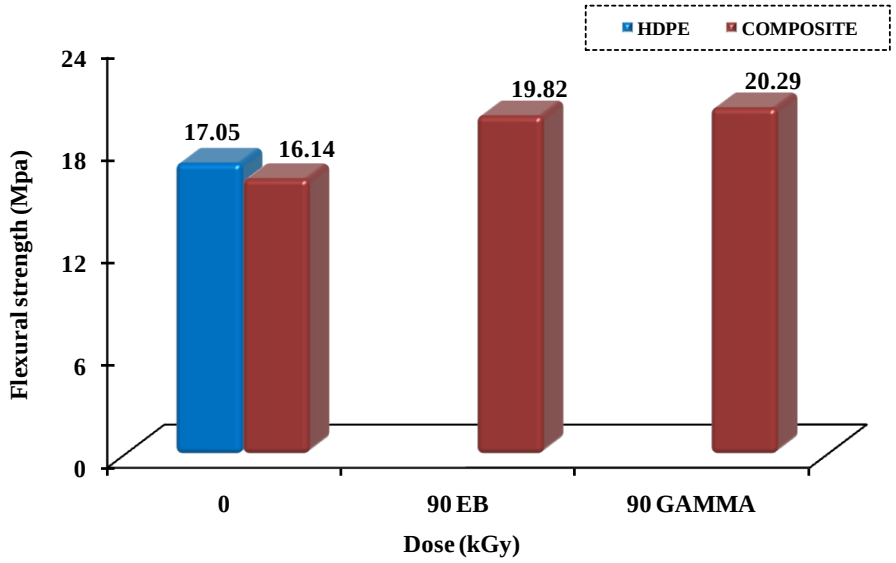

Figure 3. The flexural strength for both, non-irradiated HDPE and bagasse fiber/HDPEcomposite, and irradiated bagasse fiber/HDPE composite.

Figure 4 shows the flexural modulus tests results of the HDPE and bagasse fiber/HDPE ***composite***.

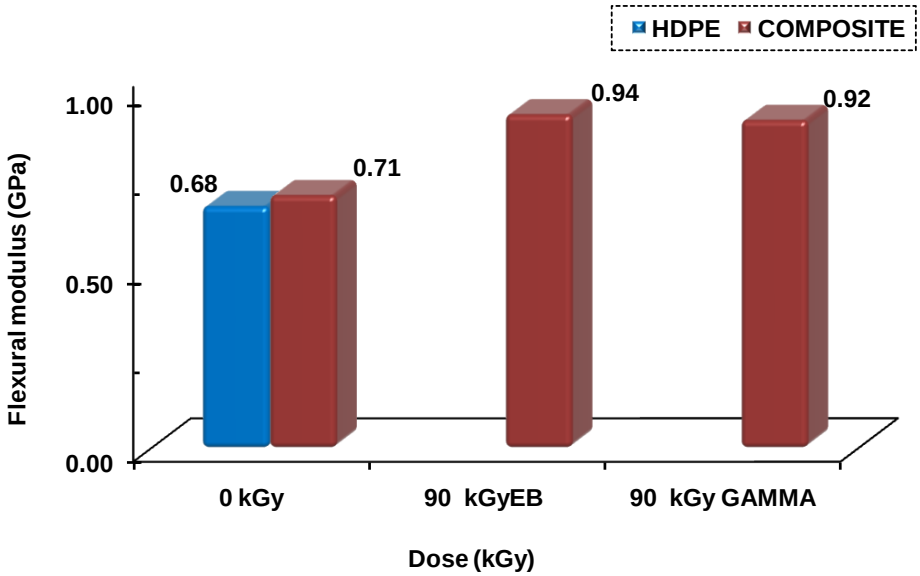

Figure 4. The flexural modulus, for both, non-irradiated HDPE and bagasse fiber/HDPEcomposite, and irradiated bagasse fiber/HDPE composite.

As seen in this figure, the addition of bagasse fiber alone was responsible for a significant increase of ca. 4 % ($p < 0.05$) in flexural modulus of neat HDPE. Concerning irradiation

treatment, the irradiated ***composite*** for both, electron-beam and gamma-rays showed a significant increase of around 30 %, when compared with the non-irradiated ***composite***.

Figure 5 shows the results for impact strength tests. As can be seen, the bagasse fiber addition alone caused a significant reduction of about 28 % ($p < 0.05$) in impact strength of neat HDPE. After electron-beam irradiation, the impact strength of ***composite*** presented a significant decrease of about 24 % in comparison with non-irradiated ***composite***. On the other hand, there was no-significant change in this property for irradiated ***composite*** by gamma-rays, when compared with non-irradiated samples.

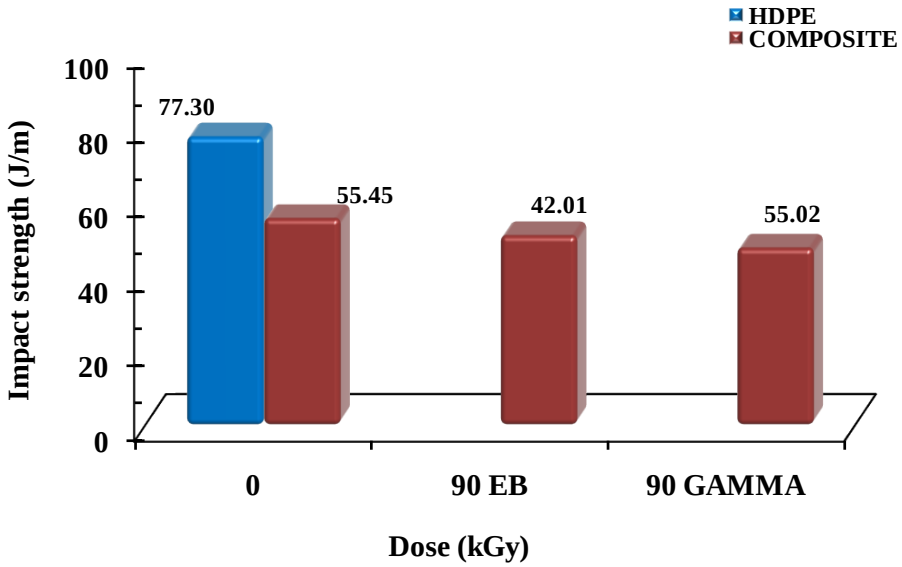

Figure 5. The impact strenth for both, non-irradiated HDPE and bagasse fiber/HDPEcomposite, and irradiated bagasse fiber/HDPE composite.

The results for the MFI measurements are presented in Fig. 6.

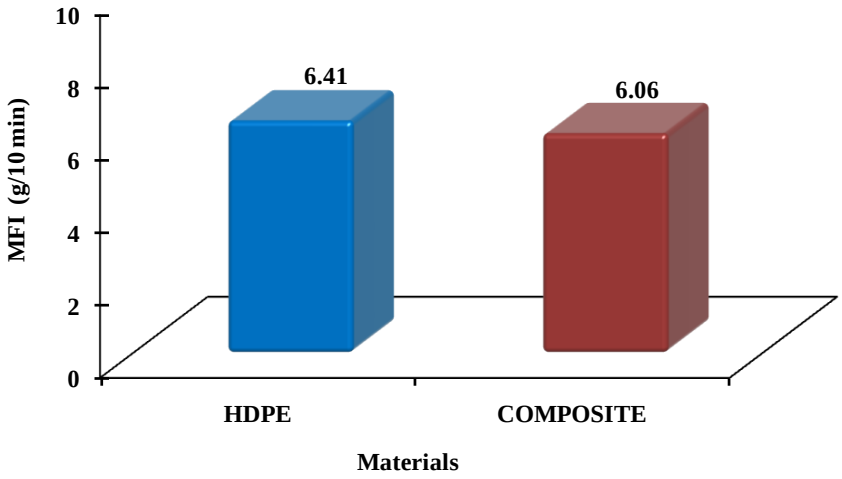

Figure 6. MFI Measurements for non-irradiated HDPE and Bagasse Fiber/HDPE Composite.

These results showed a tendency to a slight decrease in MFI for the HDPE because of bagasse fiber incorporation, suggesting that the addition of this fiber may affect the dynamic viscoelastic melt, since it could reduce molecular mobility and, consequently, the flow. Under the MFI test conditions, the irradiated ***composite*** did not show any flow and therefore, the MFI could not be determined.

4. CONCLUSIONS

The objective of the present work was to investigate the mechanical behavior of Bagasse fiber/HDPE ***composite*** irradiated by electron beam and gamma-rays. Based on the results, it may be claimed that electron-beam irradiation was superior only as far as tensile strength properties are concerned. Regarding flexural properties, both ionizing radiation processes used showed similar results. Therefore, it can be argued that either processes may be used to obtain ***composite*** materials with improved mechanical properties, and that the choice between one of them will depend on which property is relevant for the final application of the product.

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