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EFFECT OF IONIZING RADIATION ON POLYPROPYLENE COMPOSITES REINFORCED WITH COCONUT FIBERS

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ABSTRACT

The use of the polymeric composite materials has been increasing but these materials have environmental problems related to the discard. To reduce the discard deleterious effect, coconuts, sisal, as well as sugar cane pulp natural based fiber have been studied to replace the synthetic ones. These fibers embedded in a polymeric matrix plays a similar role as the synthetic ones, in terms of mechanical and thermal properties. The natural fibers are environmentally friendly, easy to recycle and biodegradable. The aim of this work is the study of ionizing radiation effects on the properties of recycled polypropylene composites, reinforced with 10%, 15% and 20% of the coconut fibers, using as coupling agent a substance based on maleic anhydride (MAPP) graphitized polypropylene. The samples were molded by injection, irradiated and submitted to thermal and mechanical tests. The mechanical properties (hardness, impact strength and tensile strength), temperature of thermal distortion (HDT) and Vicat softening temperature of the non irradiated and irradiated composites were determined. The irradiation doses were of 30, 50 and 100kGy in a gamma cell. Regarding the thermal and mechanical properties of non-irradiated samples, the incorporation of coconut fibers to polypropylene resulted in a decrease of impact strength, tensile strength and Vicat softening temperature as well as in an increase in hardness and HDT. This result indicates that the coconut fibers do not act like a reinforcement agent but as biodegradable filler. In the irradiated samples, it was observed a decrease in the impact strength, tensile strength, HDT, and thermal distortion temperature and an increase in the hardness and tensile strength. The Vicat softening temperature shows no change.

1. INTRODUCTION

Industrial components produced from plastics have been increasing since the middle of the 1950. The project evolution due to the new environmental law promotes plastic based materials with extraordinary chemical and physical properties. They have been introduced in many applications, as for example in the aeronautical industry, were they can be considered as new materials. The combination of two or more materials leads to a new material class named as composite materials, with higher properties, that can not be achieved by the individual parts [1].

One of the more studied and used polymeric matrixes for obtain loaded or reinforced polymers is the polypropylene (PP), therefore, due its properties and low cost presents good conditions of commercialization [2-3].

Currently, the more used reinforcements in the industry are the synthetic fibers, mainly the glass fiber, due its good physical and chemical properties. On the other hand, these materials, have problems related to the discarding, therefore they are not biodegradable being, therefore, harmful to the environment. Ahead this, due to the increasing appeal for ambient and social questions, natural materials capable to substitute those aggressive ones to the nature has been studied. In this direction, many researches deals with the substitution of synthetic fibers by the natural fibers, as coconut, sisal, bamboo, among others, beyond the use of recyclables polymeric matrixes and already the recycled ones [4-6].

The natural fibers are increasing in application as reinforcement in thermoplastic and thermosetting polymers, due to properties as good mechanical resistance and low density. The synthetic fiber substitution, as the glass fibers, by the natural ones, have being studied, and they offer some advantages: are renewed resources and available in great amount, are biodegradable, presents lower abrasive nature, can be recycled, although it still presents high cost. The availability of great amounts of such fibers with mechanical properties well defined is generally prerequisite for the successful use of these materials [5-7].

The PP matrix already is used in many industrial applications, mainly in the automobile industry, in the manufacture of components as the covering of panels, lateral of doors of trucks, as well as other internal covering parts of automobiles. Moreover, toy industries have invested in research in this area, being utilized the PP with wood flour filler [8].

In the mix process of polymeric matrix with the dispersed phase, due the different nature of materials can occur problems of linking in the interface. For a perfect combination between the matrix and the dispersed phase are used additive that have the function of to act as coupling agents. They act as molecular bridges in the interface of the two phases [7-8].

The grafting maleic anhydride polypropylene compound (MAPP) is one of the types of coupling agents more used in polymeric materials [9]. In the present work were used the MAPP and barium titanate of will be used as coupling agent.

The ionizing radiation is a process capable to modify the properties of a material and can be used as an alternative in the development of new polymeric materials [10].
The main effects caused in polymers by the ionizing radiation are the main chain scission and appearance of crosslinking [11].

When the crosslinking predominance forming three-dimensional nets. The process occurs by the recombination of radicals formed by irradiation of polymer. In the crossed linking, the polymeric chains connect themselves through covalent joining generated by chemical joining or by radiation.

During the crosslinking, there is an increase of the molecular weight, mechanical resistance, and three-dimensional nets of the system, viscosity and the reduction of the solubility of the irradiated polymer and a change in the temperature of the transition glass in amorphous phase of the irradiated polymer. This mechanism also depends on the dose, dose rate, concentration, irradiation atmosphere among others. However, the polymer sensibility to parameter changes depends on the type and size of the chains, as well as the polymer morphology [12-13].

The aim of this work is to study the effects of ionizing radiation on the properties of recycled polypropylene composites, reinforced with coconut fibers.

2. EXPERIMENTAL

2.1. Materials

In this work were used the following materials:
- Virgin polypropylene: PP Prolen TM 6100, supplied by Quattor Indústria Petroquímica S.A., with density of 0.95 g/cm^3;
- Recycled polypropylene: polypropylene collected in the campus of Presbyterian Mackenzie University;
- Coconut Fiber: supplied by POEMATEC;
- Barium titanate: supplied by Certonic Ind. e Com. Ltda.;
- MAPP: OREVAC CA, grafting maleic anhydride polypropylene, supplied by Atofina.

2.2. Methods

Were studied 5 types of samples composites: virgin PP, pure recycle PP and recycle PP with addiction of 10, 15 and 20% of coconut fiber.

- ***Treatment of coconut fiber*:** The fibers were treat during 30minutes with 1% of the one solution containing 5% of ethanol in water, with pH 4.5-5.5, correct with ethanoic acid, where 2% the barium titanate (TiBa) coupling agent were dissolved. After this time, the fibers were washed with ethanol and to follow were dried in oven, for 2hours, approximately 40°C.

- ***Components Mix*:** the mix of the coconut fiber with recycled polypropylene contends 0.5% of MAPP was carried through in the calender in a temperature of approximately 180°C. The calendered composition was perforated through a mill of knives. After the samples were developed in a Torque Rheometer Haake, model Rheocord 90. It was connected to a simple extrusion screw with the following temperatures in the heating zones: 160ºC, 165ºC, 170ºC, 170ºC, using an internal mixer Rheomix 600 as accessory. It was connected to a simple extrusion screw with the following temperatures in the heating zones: 170ºC, 175ºC, 190ºC, 200ºC. The samples based on pure virgin PP and pure recycled PP also were processed by calendaring and extrusion.

- *Samples molding:* after extrusion the pure PP, the pure recycled PP and recycled PP contain 10, 15 and 20% of coconut fiber were molded by injection, in accordance with the respective technical norms.

- ***Samples irradiation***: The samples were exposed to gamma rays from Cobalto-60 at doses: 30, 50 and 100kGy.

The samples were characterized by: tensile strength (ASTM D-638-94); impact Izod strength (ASTM D-256); thermal distortion temperature-HDT (ASTM D-648) and soften Vicat point (ASTM D-1525-81).

The comportment of the composites was determined by thermal analysis by differential scanning-calorimetry (DSC). It was carried through in the band of temperature between 40 and 250^{o}C, in a reason of heating of 10^{o}Cmin^{-1} and nitrogen atmosphere. To calculate the cristalinity degree of the samples was used the reference value to fusion enthalpy of the polypropylene (210 Jg^{-1}) [14].

3. RESULTS AND DISCUSSION

3.1. Tensile Strength

The tensile strength was determined for composites of pure virgin PP, pure recycled PP and PP reinforced with 10, 15 and 20% of coconut fibers to irradiated and non irradiated samples. Fig. 1 and 2 present the results of tensile strength for studied composites.

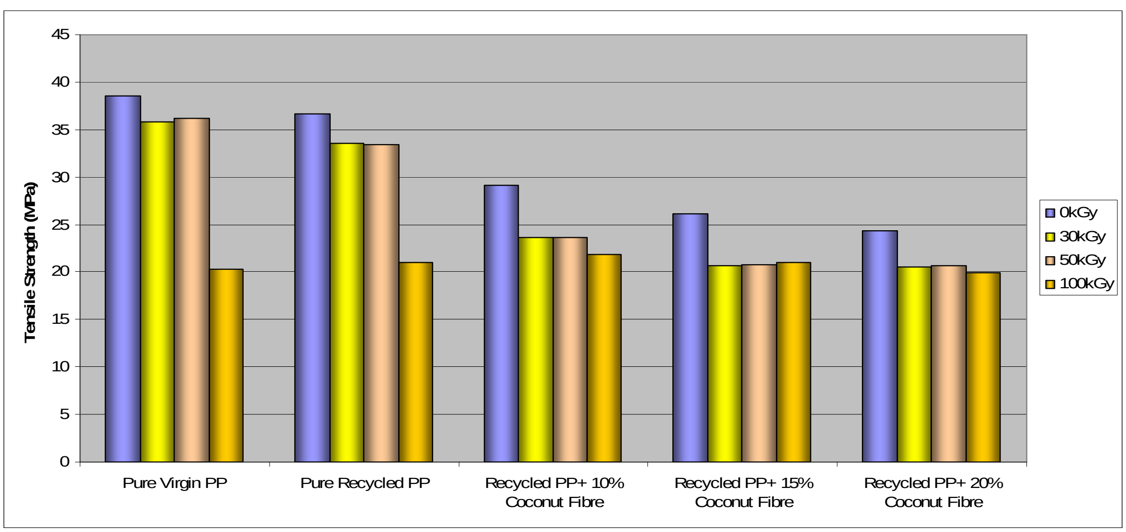

Figure 1. Tensile Strength of pure virgin PP, pure recycled PP and PP/coconut fiber samples, irradiated and no irradiated.

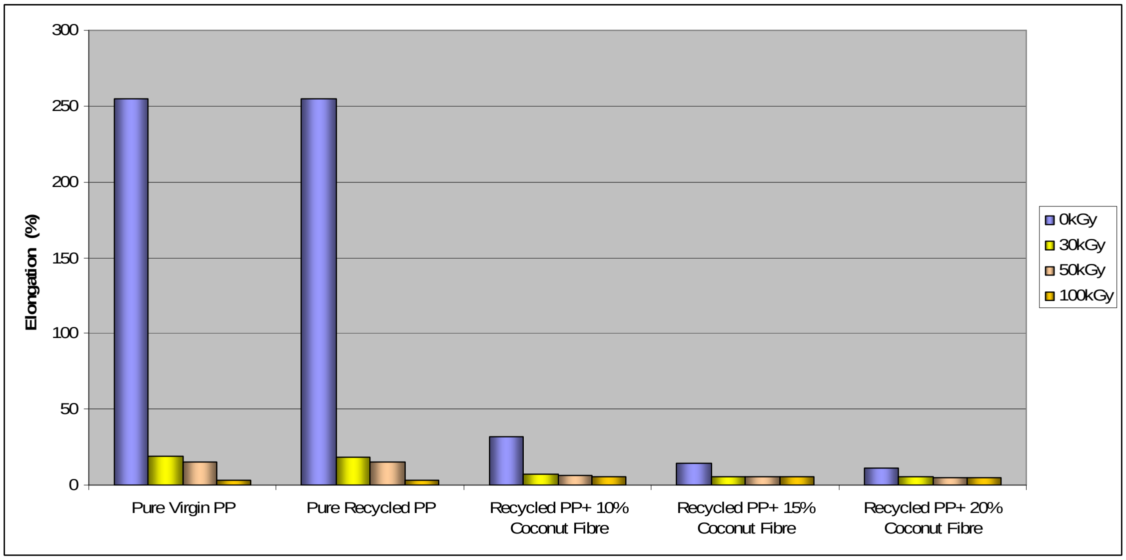

Figure 2. Elongation of pure virgin PP, pure recycled PP and PP/coconut fiber samples, irradiated and no irradiated.

The results show that:

- Due to degradation during the recycling the pure recycled presents tensile strength values smaller than the pure virgin PP;

- The tensile strength of the pure recycled PP is significantly higher that the tensile strength of the recycled PP reinforced with coconut fiber;

- The fiber addition decreases the elongation of composites. The decrease is proportional to the fiber concentration;

- The coconut fiber addition hardens the material, diminishing its elasticity;

- The tensile strength and elongation decrease with the irradiation due to its effect on the polymeric matrix degradation;

- To samples contend the same coconut fiber concentration irradiated at 30 and 50kGy the tensile strength is practically the same;

- To samples contend coconut fiber present the same elongation.

3.2. Impact Strength Izod

Fig. 3 presents the results impact strength for PP/coconut fiber samples.

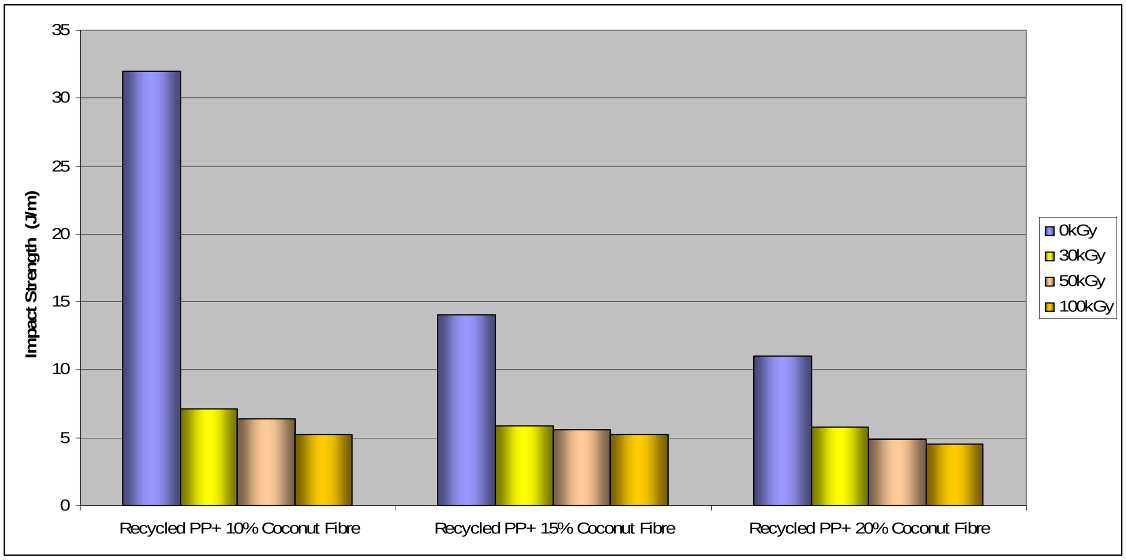

Figure 3. Impact Strength of irradiated and no irradiated PP/coconut fiber samples.

The results show that:

- The impact strength values decrease with the fiber concentration in the composite;

- The impact strength decrease with the irradiation due to its effect on the polymeric matrix degradation.

- To samples contend 15 and 20% of the coconut fiber the impact strength is practically the same.

3.3. Thermal Distortion Temperature-HDT

Fig. 4 presents the results of HDT tests for samples obtained.

Analyzing the values of Figure 4, it can be observed that:

- The presence of the coconut fiber increases the HDT;

- The ionizing radiation decreases the HDT of the samples, probably due to the degradation effect on the polymeric matrix;

- The HDT increase with the dose irradiation for the same coconut fiber concentration;

- The reinforced samples present HDT values higher than pure virgin PP;

- The addition of fiber reinforcement increases the HDT values in accordance with the fiber concentration, in the range studied in this work;

- The fiber introduced in the composite increase the thermal stability of composites.

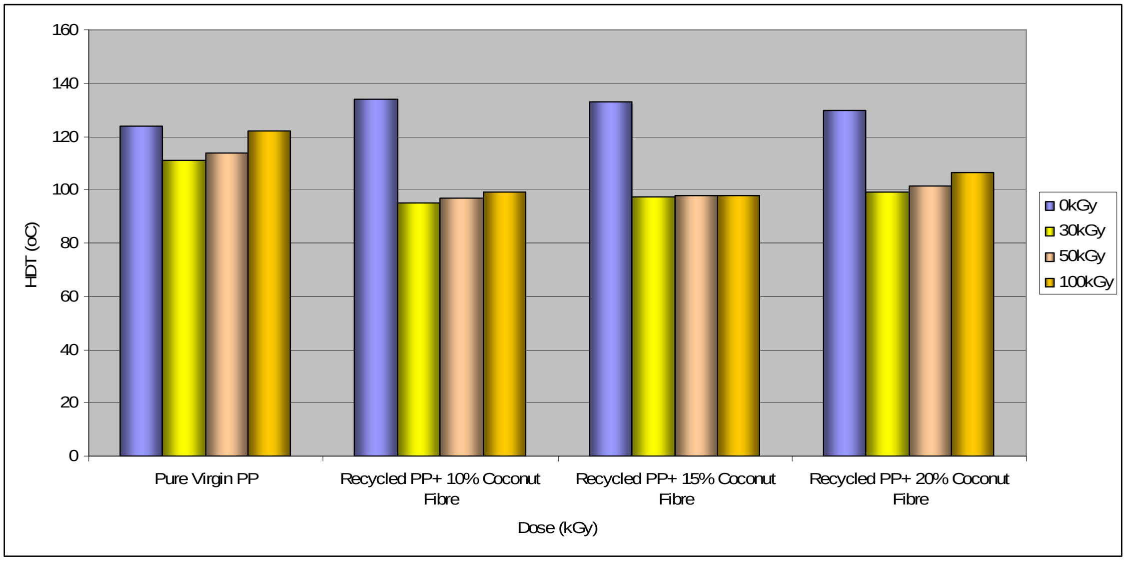

Figure 4. HDT for irradiated and no irradiated, pure virgin PP and PP/coconut fiber samples.

3.4. Soften Vicat Point

Fig. 5 shows the results obtained by soften Vicat point test for the studied composites.

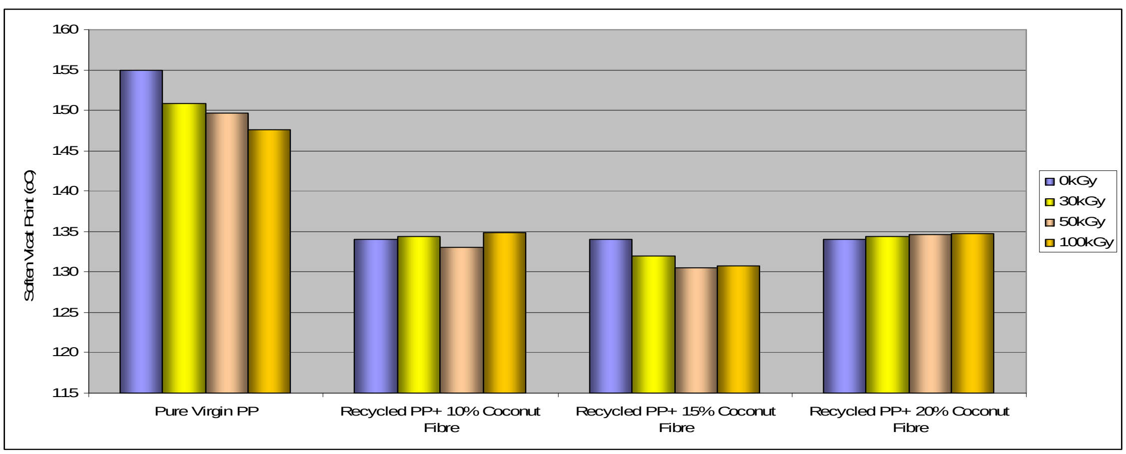

Figure 5. Soften Vicat point for irradiated and no irradiated, pure virgin PP and PP/coconut fiber samples.

The results show that:

- The addiction of fiber reinforcement decreases the soften Vicat point of the samples. The reduction for all concentrations studied was the same. Probably, the degradation are not related to the fiber contend;

- To pure virgin PP samples, the soften Vicat point decrease with the radiation dose, due to degradation caused by ionizing radiation;

- The soften Vicat point are practically unchanged in the samples charged with coconut fibers.

3.5. Differential Scanning-Calorimetry (DSC)

The Table shows the DSC results obtained to no irradiated samples. It was observed that there aren't significant changes in the propylene melting temperature in coconut fiber presence. It was observed changes in the crystallization temperature of composites (+5^{o}C). This increase is due to alteration of crystalinity caused by coconut fibers (decrease in the polypropylene crystalinity degree).

Table 1. Values obtained in DSC curves.

	Pure Virgin PP	Recicled PP+10% Coconut Fiber	Recicled PP+15% Coconut Fiber	Recicled PP+20% Coconut Fiber
T_m (^{o}C)	160.4	161.7	161.8	162.0
T_c (^{o}C)	111.5	118.0	118.5	118.6
ΔH_m (J/g)	85.6	55.6	53.1	54.4
ΔH_c (J/g)	96.5	61.2	58.0	59.5
Crystalinity degree (%)	40.8	37.2	30.4	29.3

4. CONCLUSIONS

- Due to degradation during the recycling process the pure recycled PP presents tensile strength values smaller than the pure virgin PP;

- The coconut fiber addition decreases the tensile strength, the elasticity and the impact strength of composites;

- The ionizing radiation causes degradation in polymeric matrix in studied radiation doses;

- The tensile strength, impact strength and elongation decrease with the irradiation due to degradation of the polymeric matrix caused by irradiation;

- The coconut fiber addition increase the HDT values, and the soften Vicat point are practically unchanged in the samples charged with its.

- The coconut fiber presence in the composite increase the thermal stability of material, in the range studied in this work;

- The coconut fibers presence cause an alteration (reducing the crystallinity of polypropylene matrix.

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