

THE INFLUENCE OF ELECTRON-BEAM IRRADIATION ON SOME MECHANICAL PROPERTIES OF COMMERCIAL MULTILAYER FLEXIBLE PACKAGING MATERIALS (PET MET/LDPE)

Beatriz R. Nogueira¹, Vítor M. Oliveira¹, Angel V. Ortiz² and Esperidiana A. B. Moura¹

¹ Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
brnogueira@ipen.br

² UNIPAC Embalagens Ltda.
Rua Arnaldo Magniccaro, 521
04691-060 São Paulo, SP
angel.ortiz@unipacnet.com.br

ABSTRACT

The treatment with electron-beam radiation is a promising approach to the controllable modification of the properties of the polymeric flexible packaging materials, in order to adjust their properties. In recent years electron-beam irradiation have been efficiently applied in the flexible packaging industry to promote cross-linking and scission of the polymeric chains in order to improve material mechanical properties. On the other hand, ionizing irradiation can also affect the polymeric materials itself leading to a production of free radicals. These free radicals can in turn lead to degradation and or cross-linking phenomena. The influence of electron-beam irradiation on mechanical properties of commercial multilayer flexible packaging materials based on laminated low-density polyethylene (LDPE) and metallized poly(ethylene terephthalate) (PET) was studied. The PETmet/LDPE structure was irradiated with doses up to 120 kGy, using a 1.5 MeV electron beam accelerator, dose rate 11.22kGy/s, at room temperature in presence of air. The results showed that penetration resistance of the irradiated PETmet/LDPE film increase up to 10 %, except for radiation dose of 30 kGy that resulted in a slight decrease of ca. 3%, while the sealing resistance decreased ca. 8–26% in all doses ($p < 0.05$). In addition, the samples of PETmet/LDPE film at 45, 60, 75 and 105 kGy presented a gain up to 18 % in their original tensile strength at break, a gain of ca. 38% in their original elongation at break for radiation dose of 45 kGy and ca. 17% for radiation doses of 60, 75 and 120 kGy.

1. INTRODUCTION

The treatment with ionizing radiation to improve polymeric materials properties has become more attractive industrially. The packaging industry have incorporated in their production process the ionizing radiation to improve properties as, barrier, thermal, chemical and mechanical, in order to extend their application field [1,2]. In the flexible packaging industry, the manufactures have applied the electron-beam radiation doses to promote cross-linking and scission of the polymeric chains to improve mechanical properties of the material. These cross-linking and scission processes are simultaneous and concurrent and the predominance of one or other depends of the chemical structure of the polymer and irradiation conditions [2-4]. Today, the multilayer coextruded flexible packaging is gaining much attention in packaging industries for food applications because such materials combine a number of desirable properties (barrier to gases and water vapor, organic compounds, mechanical resistance, machinability and relatively low cost) that no single material possesses [5,6]. The

purpose of the present work was to evaluate the influence of electron-beam irradiation on some mechanical properties of commercial flexible multilayer structures used for food packaging.

2. EXPERIMENTAL

The samples of the structure PETmet/LDPE, 112 μm thick (PET 12 μm /LDPE 100 μm), were irradiated up to 120 kGy using a electrostatic accelerator (Dynamitron II, Radiation Dynamics Inc., 1.5 MeV energy, 25 mA current and 37.5 kW power), at room temperature, presence of air, dose rate of 11.22 kGy/s. Irradiation doses were measured using cellulose triacetate film dosimeters “CTA-FTR-125” from Fuji Photo Film Co. Ltd. The mechanical properties tests were carried out on structures eight days after irradiation to consider post irradiation effects. Mechanical properties were determined using an INSTRON Testing Machine model 5564 and a seal packaging machine Mical model SE450. The tensile tests were carried out according to ASTM D 882-91 [7], the penetration resistance based on ASTM F 1306-90 [8] and sealing resistance according to ASTM F88-00 [9]. The difference between results for irradiated and non-irradiated structures was then evaluated statistically by one-way ANOVA using BioEstat software (version 5.0, 2007, Windows 95, Manaus, AM, Brazil). Significance was defined at $p < 0.05$.

3. RESULTS AND DISCUSSION

The tensile strength at break data of non-irradiated (control) and irradiated multilayer structure are given in Fig. 1. As it can be seen, there were significant increased ($p < 0.05$) up to 18 % in tensile strength at break of PETmet/LDPE irradiated with 45, 60, 75 and 105 kGy, but for the other irradiation doses there were no significant difference ($p < 0.05$).

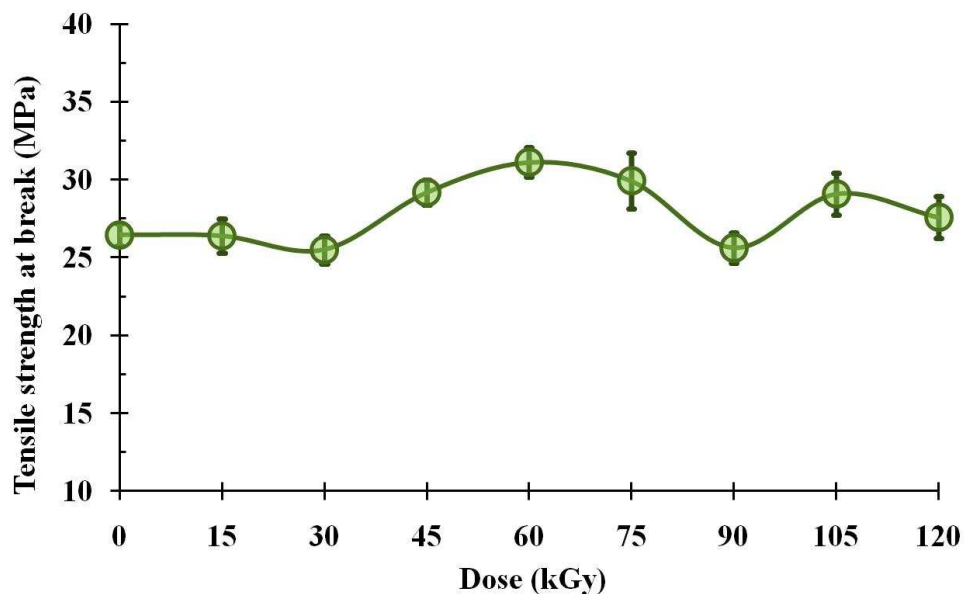


Figure 1. Tensile strength at break as a function of electron-beam irradiation for the structure PETmet/LDPE.

The results of the percent elongation at break tests are summarized in Fig. 2. In terms of elongation at break, the PETmet/LDPE showed an increase ($p < 0.05$) up to 15% at 45 kGy and ca. 6% at 60, 75 and 120 kGy.

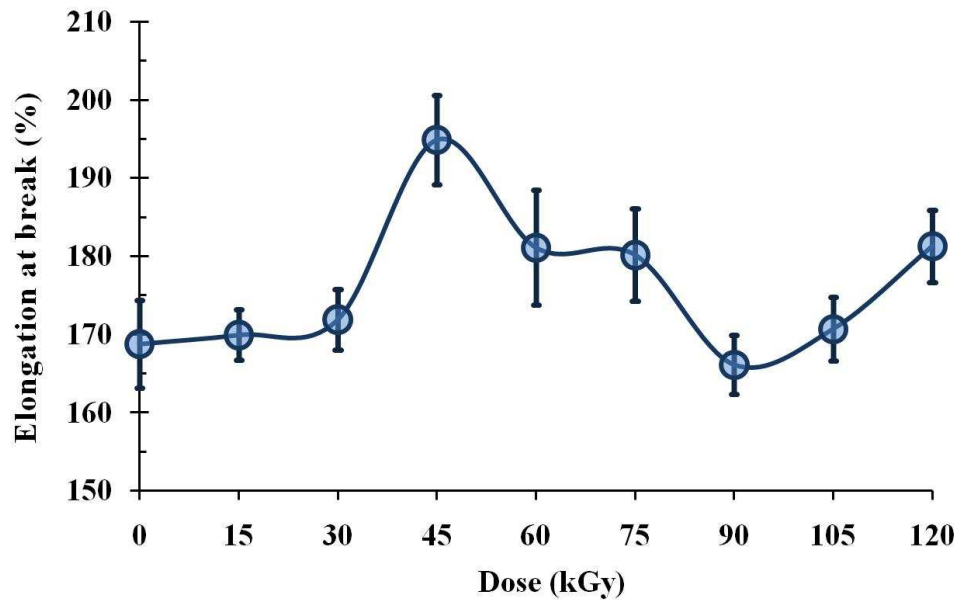


Figure 2. Percent elongation at break as a function of electron-beam irradiation for the structure PETmet/LDPE.

The Fig. 3 presented the penetration resistance results of the irradiated and non-irradiated film. The results showed significant differences ($p < 0.05$) in penetration resistance of the films for all range dose studied. As it can be seen, the original penetration resistance of the film increased up to 14 % as a result of the radiation doses applied except for 30 kGy that presented a slight decrease of ca. 3 %.

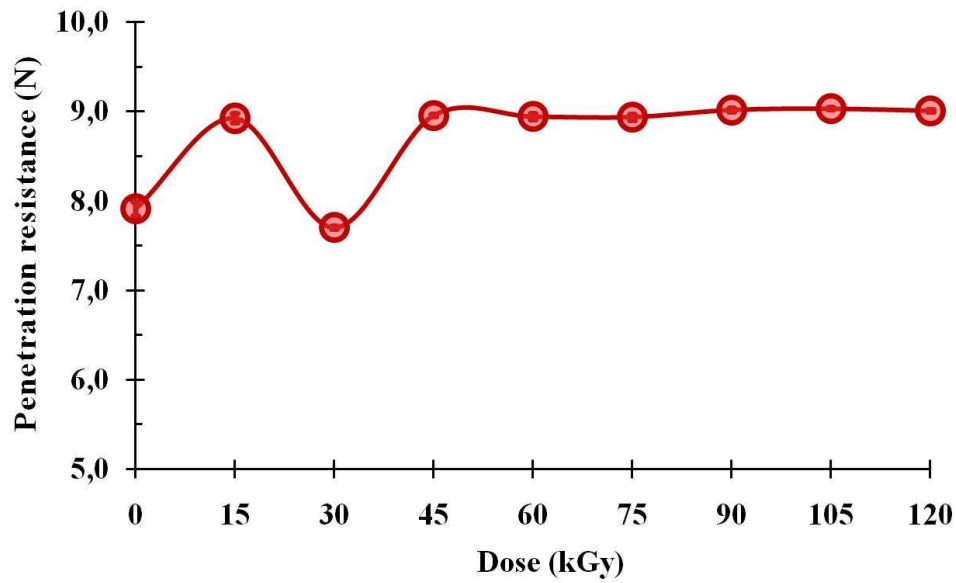


Figure 3. Penetration resistance as a function of electron-beam irradiation for the structure PETmet/LDPE.

In the case of sealing properties (Fig. 4), electron-beam irradiation caused significant decrease ($p < 0.05$). The decrease of sealability of PETmet/LDPE in the dose range studied was ca. 8–26% except for 60 kGy that did not showed significant differences.

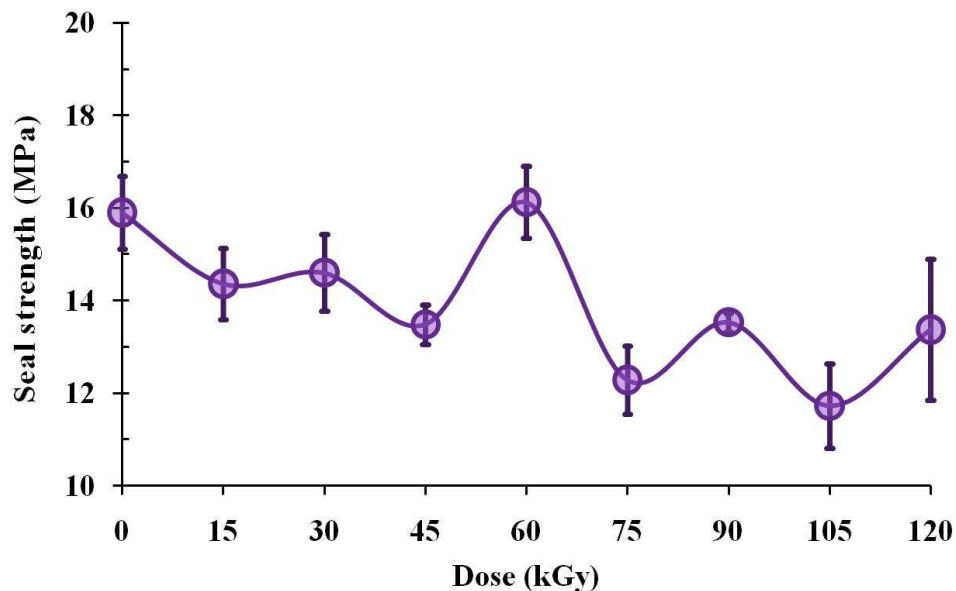


Figure 4. Seal strength as a function of electron-beam irradiation for the structure PETmet/LDPE.

The loss of sealability showed at this figure may be related with a crystallinity change of LDPE layer due to the increase of the amorphous phase, because the predominance of cross-linking process on LDPE chains irradiated, once LDPE is responsible for the sealing of the structure PETmet/LDPE. The gains of tensile strength showed in Fig. 1 also suggest a predominance of cross-linking by irradiation, since an increase in tensile strength is directly linked to cross-linking of polymeric chains. Considering that PET is more resistant to radiation effects than LDPE and that polyethylene usually has its tensile strength improved as a function of radiation applied these results indicate that LDPE layer suffered cross-linking process after irradiation [10].

4. CONCLUSIONS

The objective of the present study was to evaluate the influence of electron-beam irradiation on mechanical properties on a commercial multilayer structure PETmet/LDPE. In general, the results showed that electron-beam irradiation, for the dose range studied, led to gains in mechanical properties of the film, specially for 45, 60 and 75 kGy, except in terms of sealing properties that resulted in a loss for all dose range studied. These results suggest a predominance of cross-linking of polymeric chains of the LDPE layer. To confirm these results future analysis as DSC and TGA can be made. By now, mechanical tests showed that ionizing radiation, in conditions studied in this work can be used to improve mechanical properties of the PETmet/LDPE structure, especially for tensile and penetration resistance, which are very important properties in flexible food packaging.

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