

EFFECTS OF ELECTRON BEAM RADIATION ON MECHANICAL PROPERTIES AND ON THE RESISTANCE TO PUNCTURES CAUSED BY *PLODIA INTERPUNCTELLA* IN CEREAL BAR PACKAGING

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ABSTRACT

Plodia interpunctella is an important pest in stored products in the tropical and subtropical regions, infesting grains and flours. The adult of *P. interpunctella* is a small butterfly with about 15 - 20mm of spread and the female places separately of 100 the 400 eggs in groups on the grains whose hard incubation some days. This insect infesting diverse types of food packaging, depreciating the products and causing economic losses. It is therefore critical for these products a packaging that presents, in addition to good mechanical, barrier and machinability properties, a good resistance to puncture by insects, in order to prevent the contact and spread of pests in the packaged food. This study evaluates the changes on mechanical properties and puncture resistance by *P. interpunctella* in BOPPmet/BOPP structure, used commercially as cereal bar packaging, after electron beam irradiation. The material samples were irradiated up to 120 kGy using a 1.5 MeV electrostatic accelerator, at room temperature, in air, dose rate 11.22 kGy/s. Irradiation doses were measured using cellulose triacetate film dosimeters "CTA-FTR-125" from Fuji Photo Film Co. Ltd. After irradiation the BOPPmet/BOPP samples were subjected to tests of puncture resistance by *P. interpunctella*, tensile tests and penetration resistance. The results showed significant decreases ($p < 0.05$) in the original mechanical properties of the structures according to the radiation doses applied and effective resistance against punctures by *P. interpunctella* for irradiated and non-irradiated BOPPmet/BOPP samples. These results indicate that non-irradiated and irradiated BOPPmet/BOPP structure presents puncture resistance against *P. interpunctella* and that electron-beam irradiation, in conditions studied in this work, may turn the structure inappropriate for cereal bar packaging, due to high reduction its mechanical properties after irradiation.

1. INTRODUCTION

There are many reasons to pack the food, but the main reason is to protect them from the environment. If the goal of treatment is to control the radiation loss by bacterial action, then the main function of packaging is to prevent the recontamination of food, in other cases the function of this may be to prevent the loss or gain of moisture, maintain an atmosphere different from the air, protecting the impacts of food or just keep it clean [1]. Besides protecting the food environment among other things, the packaging should be economical, attractive to consumers, maintain the shelf-life of food, be strong and protect the shape of the product [2].

The dry foods from cereals and grain products are valued by submitting appearance and flavor characteristics. However, in most cases, they have contaminated with high levels of bacteria, fungi, insects that end up resulting in uncontrolled damage of fast food, can cause serious problems in the health of consumers [3]. Pest as beetles, mites, moths and fungi among others, commonly infest stored products and industrialized as: bars, cereals, grains, bran, flour, coffee, tobacco, dried fruit, animal feed, spices, dried plants, causing the visual impairment, promoting the deterioration of products and economic losses.

Among the insects that attack and damage stored products and of plant origin have industrialized the weevil, beetles and moths [4]. These pests cause damage to products such as weight loss and devaluation trade, loss of nutritional value, contamination by the penetration of other bodies such as fungi through openings left by them, presence of mold [5]. The aspect of protection is therefore essential in various stages of production and life of food products which have a target end consumers increasingly aware and demanding. The combination of correct procedures for handling and preparation of these products in accordance with good manufacturing practices (GMP) and appropriate packaging has an important role on the protection and maintenance of the stored products until it reaches its final consumer, reducing the microbiological and oxidative deterioration, and offering enough resistance against invasions from plagues. It's also fundamental for the packaging to have good technical properties to run well in the equipments of the food industry, like good mechanical resistance, good machinability and sealability properties.

The ionizing radiation may cause structural changes at the polymeric materials of the packaging, changing its mechanical, chemical, and thermal and barrier properties. Two simultaneous reactions are the major responsible for the physic-chemical changes due to the incidence of ionizing radiation on the polymeric structures: scission and cross-linking of the molecular chains. These reactions are simultaneous and concurrent and the prevalence of one reaction over the other dictates the changes in the polymers properties. Optimal cross-linking of polymeric chains causes the formation of a macroscopic network and results in a desirable improved mechanical, thermal and barrier properties, of the flexible packaging material [6, 7]. The objective of this work was to evaluate the effects of electron beam radiation in the mechanical properties and puncture resistance against *P. interpunctella* of a flexible plastic packaging used to store cereal bar.

2. MATERIALS AND METHODS

2.1 Materials

The structure studied was bi-oriented polypropylene metallized/ bi-oriented polypropylene (BOPPmet/BOPP) 40 μm thick a very common multilayer structure used in cereal bar packaging.

The nymphs of *P. interpunctella* were obtained from the creations of the Arthropods Laboratory of the Instituto Biológico - São Paulo, where they grow in dried bread and heated room with $27 \pm 2^\circ\text{C}$ and relative humidity of $70 \pm 5\%$.

Cereal bar composed of a mixture of oat flakes, barley flakes, sugar, dried banana, wheat flakes, honey, salt, cashew nuts and cocoa.

2.2 Irradiations

The structure 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. After irradiation the samples were packaged inside plastic bags and stored in a dry and dark place until the realization of the tests.

2.3 Mechanical evaluation

In this study were performed the mechanical tests of tensile strength at break, based on the methodology described at ASTM D 882-91 [8] and the penetration resistance based on the methodology described at ASTM F 1306-90 [9].

In order to consider and evaluate the post irradiation effects, these tests were done eight days after irradiation, and repeated sixty days after irradiation.

2.4 Puncture by *P. interpunctella*

Based on the data obtained from the mechanical tests, the doses of 10, 20 and 60 kGy were selected to run under these tests. For each radiation dose selected, including the non-irradiated, nine samples of the same size were sealed with 25g of cereal bar inside, and equally split in three plastic boxes of 26,5L with 20 adults of *P. interpunctella* in each box during sixty days, starting eight days after irradiation, in a heated room like the one they are created. After this the packaging were evaluated for perforations trough a magnifying glass.

2.5 Statistical Analysis

All the changes observed were confirmed by one-way ANOVA, using the software BioEstat (version 5.0, 2007, Windows 95, Manaus, AM, Brazil), with the significance level of $p < 0,05$.

3. RESULTS AND DISCUSSION

Tensile strength at break: As shown in the Figure 1, were observed significant decreases in the original tensile strength of the BOPPmet / BOPP structure by 2 - 33 % as a function of radiation doses applied, eight days after irradiation, as well as significant decreases between of 28 to 63% sixty days after irradiation ($p < 0.05$).

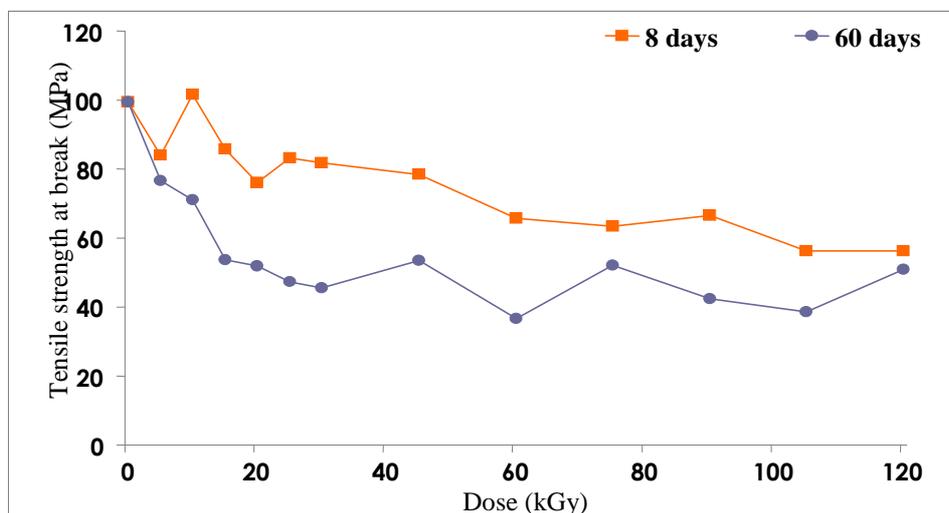


Figure 1. Tensile strength at break as a function of electron-beam radiation dose for the structure BOPPmet / BOPP .

Penetration resistance: The Figure 2 presented the penetration resistance results of the irradiated and non-irradiated film. The results showed significant decreases by 7 - 30% in the original penetration resistance of the film as a function of radiation doses applied, eight days after irradiation and decreases by 22 - 46% sixty days after irradiation ($p < 0.05$).

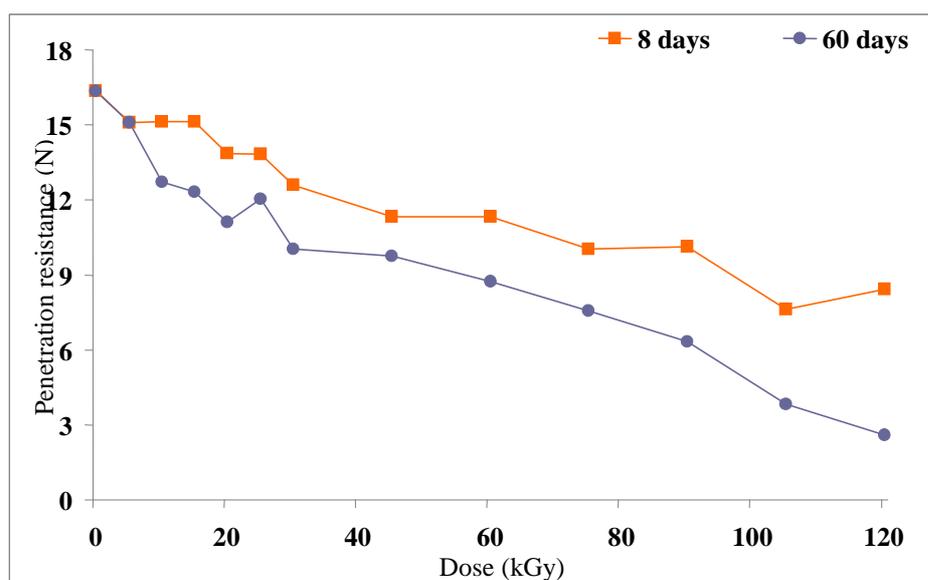


Figure 2. Penetration resistance as a function of electron-beam radiation dose for the structure BOPPmet / BOPP.

Puncture resistance by *P. interpunctella*: The results showed that irradiated and non-irradiated BOPPmet/BOPP structure samples there were no problems with invasion by *P. Interpunctella*.

4. CONCLUSIONS

The results showed that electron-beam irradiation, for the dose range studied, led to great losses in mechanical properties of the film according to the radiation doses applied. **In the case of resistance against punctures by *P. interpunctella*, the results showed that electron-beam irradiation no affected the original resistance of the film.** These results indicate that non-irradiated and irradiated BOPPmet/BOPP structure presents puncture resistance against *P. interpunctella* and that electron-beam irradiation, in conditions studied in this work, may turn the structure inappropriate for cereal bar packaging, due to high reduction its mechanical properties after irradiation.

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REFERENCES

1. V. F. V. Junior; A. C. Pinto; M. A. M. Maciel. "Plantas medicinais: Cura segura?", *Química Nova*, 28, n. 3, 2005.
2. S. B. A. Stanley; C. G. J. Roger. "Food Packaging", *Westport.*: The AVI Publishing Company, Inc, 1970.
3. "Effect of Irradiation on Spices, Herbs and Seasonings: Comparasion with Ethylene Oxide Fumigation," <http://www.food-irradiation.com/Spices.htm> (2003).
4. T. B. Campos. "Pragas dos Grãos Armazenados". *Reunião Itinerante de Fitossanidade do Instituto Biológico*, Ribeirão Preto, 24-25 de set, pp.5-12 (2005).
5. B. P. Magalhães; S. M. Carvalho. "Insetos associados à cultura", *Cultura do feijoeiro: fatores que afetam a produtividade*. Piracicaba, pp.573-589 (1998).
6. GOULAS, A.E.; RIGHANAKOS, K. A.; KONTOMINAS, M.G. Effect of Ionizing Radiation on Physicochemical and Mechanical Properties of Commercial Multilayer Coextruded Flexible Plastics Packaging Materials. *Radiation Physics and Chemistry*, 68, pp.865-872 (2003).

7. E. A. B. Moura; A. V. Ortiz; H. Wiebeck; A. B. A. Paula; A. L. A. Silva; L. G. Andrade e Silva. "Effects of Gamma Radiation on Commercial Food Packaging Films - Study of Changes UV/VIS Spectra". *Rad. Phys. Chem.*, 71, pp.199-202 (2004).
8. American Society For Testing And Materials - ASTM, 1991. Standard Test Methods for Tensile Properties of Thin Plastic Sheeting. ASTM (D 882-91).
9. American Society For Testing And Materials - ASTM, 1994. Standard Test Method for Slow rate Penetration Resistance of Flexible Barrier Films and Laminates. ASTM (F 1306-90).