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Effects of gamma radiation on commercial food packaging films—study of changes in UV/VIS spectra

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Abstract

The effects of gamma irradiation doses up to 100 kGy on the optical properties of different commercial packaging films were studied in this paper. The packaging films analyzed were: polyethylene "LDPE", amide 6-amide 6.6 copolymer "PA6-PA6.6" and poly(ethylene terephthalate) "PET". An investigation on film samples before and after irradiation was performed by UV/VIS spectroscopy. The results showed that, in the absorption spectra of irradiated LDPE and PA6-PA6.6 films, a red-shift in the wavelength of the UV cutoff and a marked reduction in % transmittance (at low wavelengths) occur with increasing radiation dose. With respect to PET samples, no significant changes were observed in either light absorption or transmittance.

Keywords: Gamma radiation; Polymer film transmittance; Polymer film absorbance

1. Introduction

The use of ionizing radiation in foodstuff pasteurization has shown to be effective and reliable in controlling foodborne pathogens and in extending the shelf life of the final products. In 1997, the US Food and Drug Administration approved the irradiation of fresh and frozen red meat. Since then, the interest in radiation processing of foodstuffs has been renewed (Ross and Engeljohn, 2000).

Foodstuffs are prepackaged prior to irradiation, to prevent subsequent recontamination by microorganisms. Ionizing radiation can affect the polymeric food packaging material itself. Irradiation of polymers generally leads to formation of free radicals and ions, with effects such as simultaneous scission and cross-linking of the polymeric chains. If irradiation is carried out in the presence of oxygen, formation of gases and low molecular weight radiolysis products may occur. Also, polymers used in food packaging often contain additives that could potentially undergo degradation upon irradiation, and the degradation products formed might migrate into the foodstuff and affect its organoleptic properties and toxicological safety. The mechanical and optical properties of a polymeric packaging material can be affected by both cross-linking and degradation processes (Killoran, 1983). Optimal cross-linking of polymeric chains causes the formation of a macroscopic network and results in a desirable lower permeability and improved mechanical properties of the flexible packaging material. On the other hand, irradiated packaging materials may acquire undesirable optical properties as a consequence of unacceptable color formation or increased light transmittance in the near UV range, which, in turn, might reduce the foodstuff's

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Table 1
Main characteristics of the packaging materials used in the irradiation tests

Film name[a]	Extruded film material	Thickness (μm)	Manufacturer
Unipac-PE-60	Low density polyethylene—LDPE	60	Unipac Embalagens Ltda.
Unipac-PA-30	amide 6-amide 6.6 copolymer—PA6-PA6.6	30	Unipac Embalagens Ltda.
Unipac-PET-12	Bi-oriented poly(ethylene terephthalate)—PET	12	Du Pont

[a] Reference to flexible packaging manufacturer Unipac Embalagens Ltda.

shelf life (Clough et al., 1996). In this study, we have examined the effects of gamma irradiation on the optical properties of some commercial plastic packaging films that are widely used by the meat industry in Brazil.

2. Experimental

The experiments were carried out using monolayer plastic packaging films obtained from commercial film manufacturers (Table 1). The nylon and polyethylene films are air-cooled blown extruded films, and neither was subjected to IBC (internal bubble cooling). The PET film is a standard bi-oriented film used by the food packaging industry for printing and lamination. Pieces of each packaging material ($14 \times 14\,cm^2$) were cut from commercially available sheets and irradiated individually. Industrially, these films do not undergo any complementary treatment (sterilization or similar decontamination procedure) because they are produced under strict GMP (Good Manufacturing Practices). Hence, irradiation was carried out without any further intervention on the samples. Prior to irradiation, fifteen samples were placed in a cylindrical device made of 304 stainless steel and then irradiated at different doses within the 0–100 kGy range. Irradiation was carried out at room temperature, in air, and at dose rates of 5.35–5.78 kGy/h, using a ^{60}Co source of the "GammaCell 220" type (Atomic Energy of Canada Limited). Irradiation doses were measured with cellulose tri-acetate "CTA-FTR-125" dosimeters from Fuji Film. The films were tested 1 week after irradiation. In order to avoid any effect of either natural or artificial light on the samples prior to testing, they were placed in a black plastic bag and stored in a drawer in the laboratory. UV/VIS spectra were obtained using a Shimadzu UV1601PC spectrophotometer.

3. Results and discussion

Each final spectrum represents the average of 4 samples of equal size and thickness obtained randomly from non-irradiated and irradiated PE, PA or PET film.

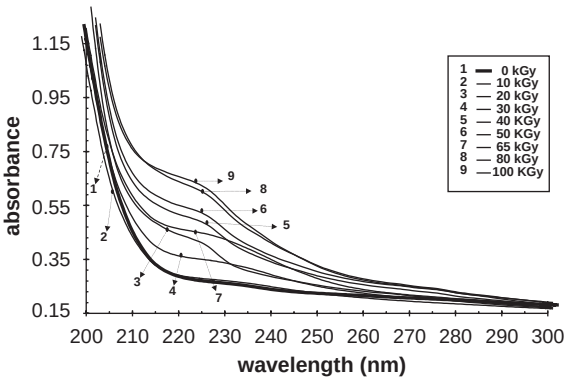

Fig. 1. Absorption spectra of Unipac-PE-60 samples before and after gamma irradiation doses up to 100 kGy.

3.1. Unipac-PE-60 film

Upon visual examination, Unipac-PE-60 samples presented a slight yellowish coloration and also emitted unpleasant off-odor after irradiation above 15 kGy. The intensity of such alterations increased with radiation dose. Fig. 1 shows the changes in absorption spectra of Unipac-PE-60 upon exposure to a dose range of 0–100 kGy. As can be seen, irradiated samples tend to exhibit a red-shift in the wavelength of the UV cutoff and the formation of an absorption tail. It is worth noting that, for these polyethylene samples, absorbance does not increase at 10 kGy; increases with very slight differences between spectra for doses of 40 and 50 kGy, and also of 80 and 100 kGy, but increases displaying an inconsistent behavior at doses of 20, 30 and 65 kGy. Also, absorbance is apparently more affected by irradiation at wavelengths 210–250 nm. The changes observed could be due to unsaturations and the presence of carbonyl and hydroxyl compounds. Irradiation of LDPE gives a combination of degradation and cross-linking, accompanied by the formation of unsaturated products. If the irradiation is carried out in the presence of air, in most cases carbonyl and hydroxyl compounds are formed (Spinks and Woods, 1990). At present, we have no explanation for the observed behavior at 20, 30 and 65 kGy. Fig. 2 shows the variation in % transmittance of

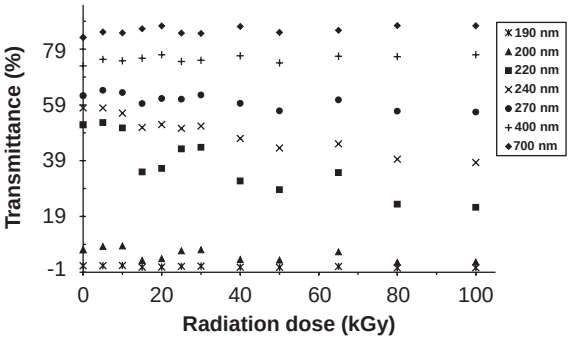

Fig. 2. Variation in % transmittance with radiation dose of Unipac-PE-60 samples after gamma irradiation doses up to 100 kGy.

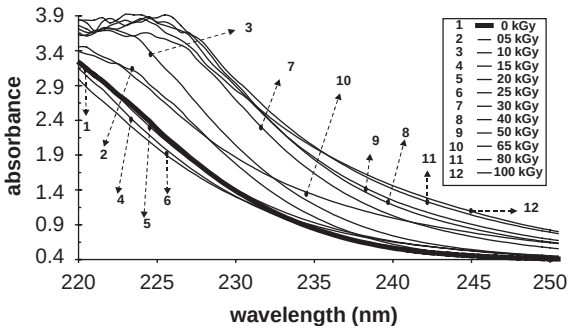

Fig. 3. Absorption spectra of Unipac-PA-30 samples before and after gamma irradiation doses up to 100 kGy.

Unipac-PE-60 samples with increasing radiation dose at some wavelengths. It is possible to see that gamma irradiation leads to a decrease in % transmittance at low wavelengths and to a slight increase at higher wavelengths. It is clear that, at wavelengths within the UV range, there is a reduction in light transmission with increasing gamma radiation dose that is very marked in the spectral region between 195 and 240 nm; interestingly this suggests that the UV barrier has improved in the irradiated material.

3.2. Unipac-PA-30 film

After irradiation, Unipac-PA-30 samples become brittle and give off strong and unpleasant odors, whose intensity increase with radiation dose. Fig. 3 shows the variation in absorption spectra for samples of Unipac-PA-30 after exposure to a dose range of 0–100 kGy. As can be seen, the irradiated samples exhibit a red-shift in the wavelength of the UV cutoff and the formation of an absorption tail, except in the 15–25 kGy dose range, where light absorption is similar to the non-irradiated material. Note that the absorbance of Unipac-PA-30

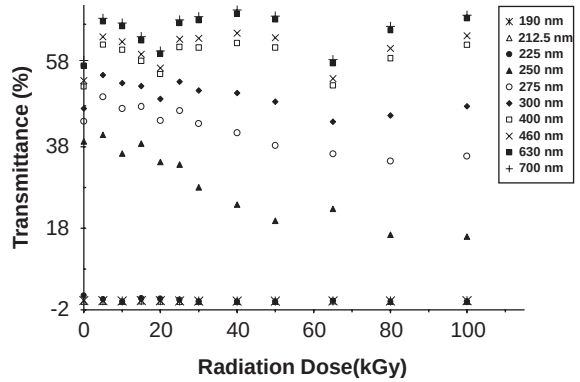

Fig. 4. Variation in % transmittance with radiation dose of Unipac-PA-30 samples after gamma irradiation doses up to 100 kGy.

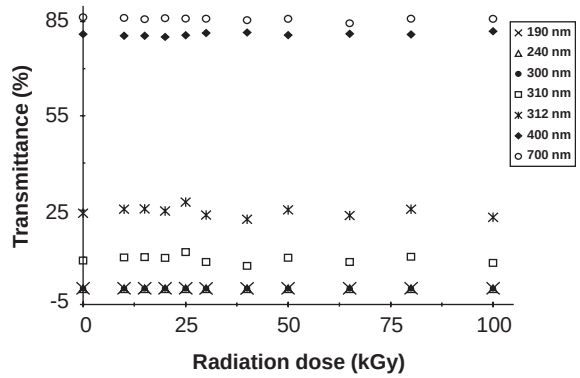

Fig. 5. Variation in % transmittance with radiation dose of Unipac-PET-12 samples after gamma irradiation doses up to 100 kGy.

samples increases displaying an inconsistent behavior at doses of 5, 10 and 65 kGy. As shown in Fig. 4, % transmittance becomes reduced with increasing radiation dose at low wavelengths, except for Unipac-PA-30 in the 15–25 kGy dose range. These changes could be due to the formation of imide groups, unsaturations, and carbonyl and hydroxyl compounds.

3.3. Unipac-PET-12 film

After irradiation, Unipac-PET-12 samples presented no significant changes in light absorption or transmission at the doses tested (Fig. 5).

4. Conclusion

The irradiated Unipac-PET-12 samples presented no changes in color or optical properties one week after irradiation. It is known that color changes of irradiated

polymers can be reversible; therefore, our observations may indicate either that no changes occurred within the 1-week period or that, if any occurred, they were reversible and were no longer detectable after 1-week. On the other hand, after the same post-irradiation time period, the two other films (Unipac-PE-60 and Unipac-PA-30) presented changes in optical properties that varied according to the increase in radiation dose. Such changes are likely to be caused by the cross-linking and degradation processes that irradiated polymers undergo.

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