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Mechanical and thermal properties of irradiated films based on Tilapia (*Oreochromis niloticus*) proteins

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Abstract

Proteins are considered potential material in natural films as alternative to traditional packaging. When gamma radiation is applied to protein film forming solution it resulted in an improvement in mechanical properties of whey protein films. The objective of this work was the characterization of mechanical and thermal properties of irradiated films based on muscle proteins from Nile Tilapia (*Oreochromis niloticus*). The films were prepared according to a casting technique with two levels of plasticizer: 25% and 45% glycerol and irradiated in electron accelerator type Radiation Dynamics, 0.550 MeV at dose range from 0 to 200 kGy. Thermal properties and mechanical properties were determined using a differential scanning calorimeter and a texture analyzer, respectively. Radiation from electron beam caused a slightly increase on its tensile strength characteristic at 100 kGy, while elongation value at this dose had no reduction.

Keywords: Electron beam radiation; Fish protein; Films

1. Introduction

Food packaging is usually made from synthetic materials due to exceptional properties, but with environmental deterioration concerns. A new trend to minimize this problem consist in studies about films based on natural polymers from renewable raw materials, among them polysaccharides, proteins, cellulose derivatives, starches, waxes and others (Krochta et al., 1994).

The mechanical and barrier properties of protein-based films are generally better than those of polysaccharide-based films (Monterrey and Sobral, 2000). Contrary to polysaccharides which are homopolymers, proteins have a specific structure (based on 20 different monomers) which confers a wider range of potential functional properties, especially high intermolecular binding potential (Cuq et al., 1995). Several studies evolving thermal treatment, use of cross-linking agents, adjustment of pH and exposure to radiation, were carried out in order to improve the film (Kester and Fennema, 1986).

Radiation of plastics is a way to induce their cross-linking and to improve considerably their performance. As the cross-linking process changes a linear network into a three-dimensional one, consequently it evolves a relevant modification of the characteristics of the material (Rouif, 2004). In fact, a certain degree of anchorage avoids intermolecular movements and makes possible the elastic deformation under stress (Van Vlack, 1964).

When gamma radiation is applied to protein film forming solution (FFS) it resulted in an improvement in mechanical properties of whey protein films. The radicals formed during radiolysis, especially $OH^{\bullet}$ promote a binding between two adjacent tyrosine molecules forming a bityrosine. Possibly, this cross-linking is responsible for an improvement in a better resistance to tensile strength (Mezgheni et al., 1998). Others papers showed the improvement in soy protein films based on physical cross-linking using gamma radiation

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(Sabato et al., 2001, Lacroix et al., 2002) and also in starch-based plastic sheets due to the formation of intact network structure (Zhai et al., 2003).

The objective of this work was the characterization of mechanical and thermal properties of irradiated films based on muscle proteins from Nile Tilapia (*Oreochromis niloticus*). In Brazil, this fish is commercialized at competitive prices comparative to these practiced in developing country and presents a fast grow and good handling that represents interesting productivity (Monterrey and Sobral, 2000, Paschoalick et al., 2003). Besides, myofibrillar protein from Nile Tilapia has 3.43 g of tyrosine/100 g of protein, a potential cross-linking site under radiation process.

2. Methodology

2.1. Preparation of films

An FFS was prepared with freeze-dried protein extracted from Nilo Tilapia containing 80.98% of protein (Paschoalick et al., 2003). Films were obtained according to a casting technique, consisting dehydration of the FFS (1% protein m:v) in a Plexiglas support with two levels of plasticizers: 25 and 45 g of glycerol/100 g of protein. pH was kept in 2.7 with glacial acetic acid, using a Tecnal, TEC-2 pHmeter. The FFS were treated thermally at 40 °C during 30 min (Tecnal, TE184). The films were dried in an oven at 35 °C, with circulation of air, during 24–48 h. The thickness of each film was measured in a digital micrometer (probe of 6.4 mm diameter, Mitutoyo) in nine different random points. The films were conditioned at 58% relative moisture and 25 °C in a dessicator containing saturated aqueous NaBr solution during 4–7 days before the characterization.

2.2. Irradiation

The films were irradiated at room temperature by EB, with beam current of 2.01 mA and acceleration energy of 0.550 MeV, generated by the Radiation Dynamics Inc. (USA). Irradiation doses varied from 25 to 200 kGy. Dosimeter was carried out using cellulose triacetate (CTA) (Fuji Photo Film Co., Tokyo, Japan).

2.3. Mechanical properties

Mechanical properties of films were determined by tensile tests using rectangular samples of 100 mm × 16 mm, initial grips separation of 80 mm and crosshead speed of 0.9 mm/s (Paschoalick et al., 2003). The tensile strength (force/initial cross-sectional area) and elongation at break ($\Delta l/l_o$) were determined with the software Texture Expert V.1.15 (SMS) directly from the stress × strain curves. A total of 12 specimens were tested for each film and dose type.

2.4. Thermal properties

To verify the state of proteins, the films were hydrated with the same amount of water and thermal analyzed using a DSC 2010 (TA Instruments). The samples (~10 mg) were conditioned in hermetic TA aluminum pans and heated at 10 °C/min, between 0 and 130 °C, in inert atmosphere (48 ml/min N_2) (Monterrey and Sobral, 2000).

3. Results and discussion

Tensile strength showed a slight increase with the increment of radiation dose (Fig. 1). Tensile strength value reached the major value for film with 45% glycerol at 100 kGy ($p < 0.05$), followed by values at 50 and 150 kGy (statistically different from values at 0 kGy). This tendency also occurred for films with 25% but the maximum value at 100 kGy was not statistically different from values at 150 and 200 kGy. Similar results were observed concerning the elongation at break of films (Fig. 2).

Comparing plasticizer concentration effect, the major values for tensile strength and lower values for elongation at break were obtained for films containing 25% glycerol, as expected, because the increasing in plasticizer concentration increased the mobility of protein network (Cuq et al.,

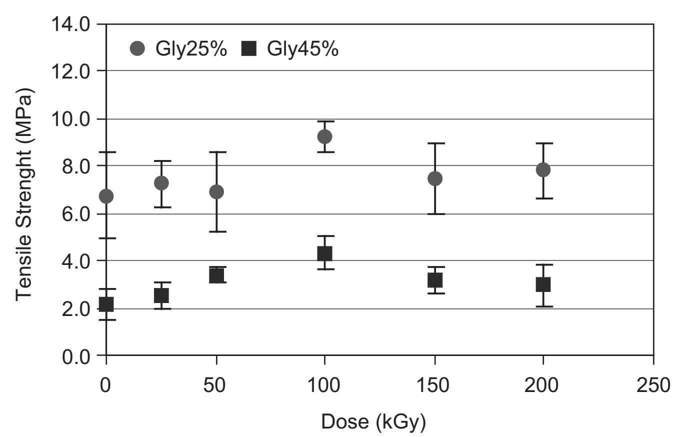

Fig. 1. Effect of radiation doses on tensile strength of Tilapia muscle based films with two concentrations of plasticizer.

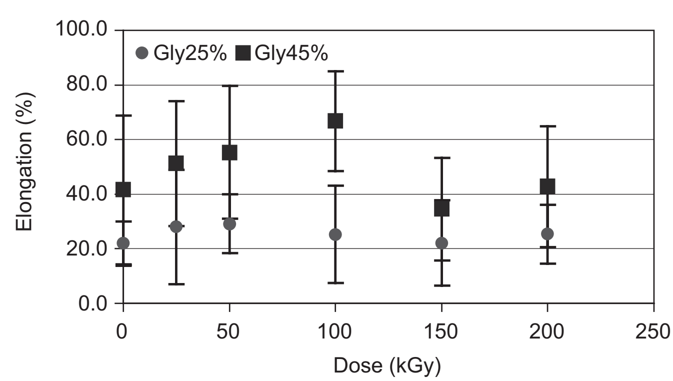

Fig. 2. Effect of radiation doses on elongation at break of Tilapia muscle based films with two concentrations of plasticizer.

1995). Moreover, the resistance of these radiated films was slightly higher than similar films produced without radiation (Garcia and Sobral, 2005).

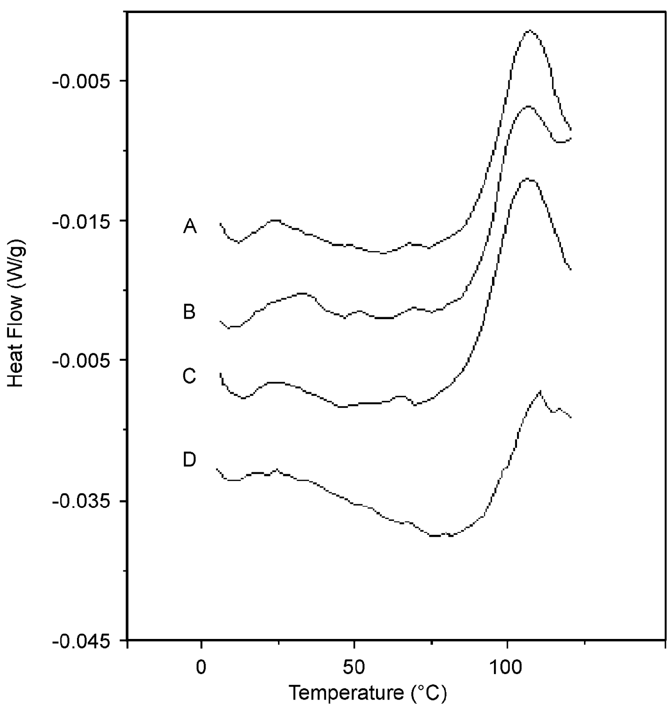

Fig. 3. DSC thermograms of irradiated Tilapia muscle based films (45% glycerol) in different doses ($A = 50$ kGy; $B = 100$ kGy; $C = 150$ kGy; $D = 200$ kGy).

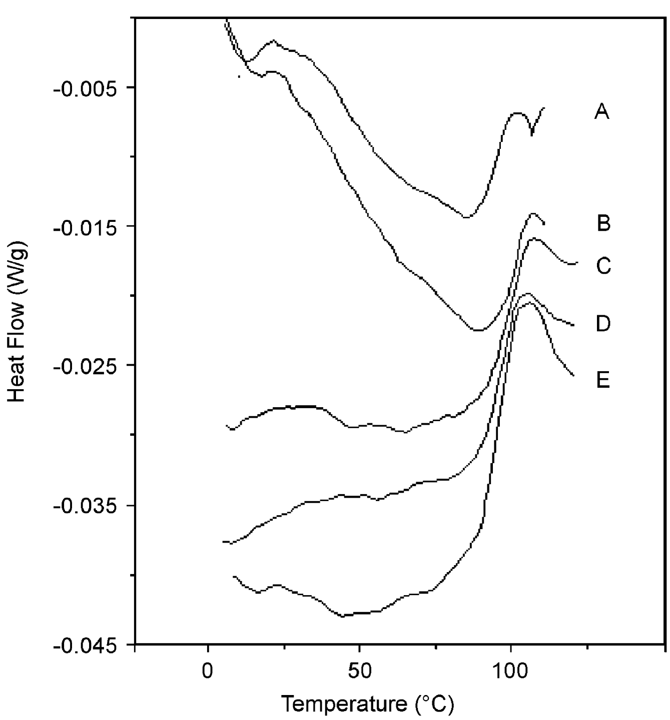

Fig. 4. DSC thermograms of irradiated Tilapia muscle based films (25% glycerol) in different doses ($A = 25$ kGy; $B = 50$ kGy; $C = 100$ kGy; $D = 150$ kGy; $E = 200$ kGy).

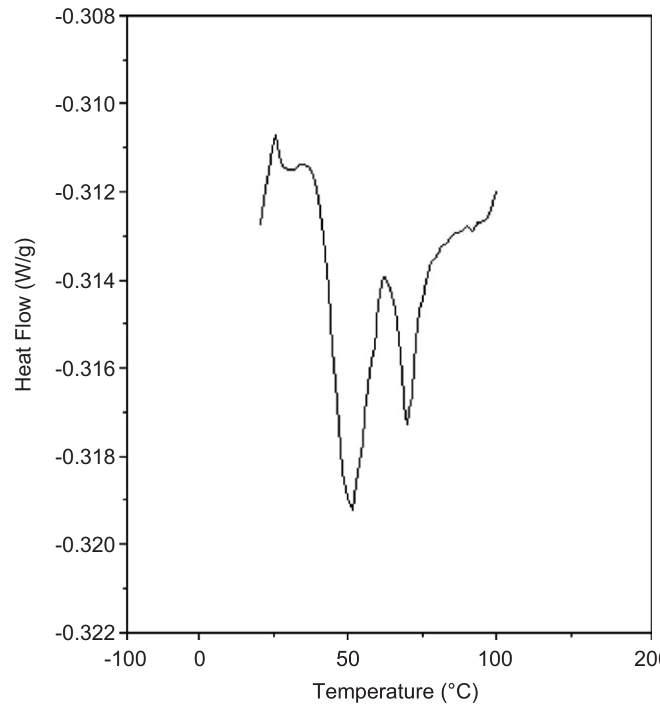

Fig. 5. DSC thermograms of native Tilapia muscle proteins.

According to the results of thermal analysis, the proteins in irradiated films could not be in the native state, because no endothermic peaks were visible in thermograms (Figs. 3 and 4). Normally, native proteins present two endothermic peaks at around 51 and 69 °C (Fig. 5) due to denaturation of myosin and actin fractions, respectively (Monterrey and Sobral, 2000). In this case, the protein denaturation could be caused not only by dehydration of proteins, but also by irradiation. In this sense, some exothermic peaks appeared around 100 °C in thermograms of films that also demonstrated a more reactive behavior of irradiated films. An explanation to this can be attributed to free radical formed during the irradiation.

4. Conclusion

Radiation from electron beam on films based on muscle protein caused a slightly increase on its tensile strength characteristic in an absorbed dose of 100 kGy, while elongation value at this dose had no reduction. Thermal analysis demonstrated that the proteins were in denaturated state in films without visible effect of radiation doses.

Acknowledgments

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