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Irradiation dose control of chicken meat processing with alanine/ESR dosimetric system

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Abstract

Irradiation of foodstuff is a well-known food preservation technique. In Brazil spices are already irradiated for sanitary and preservation reasons. Chicken meat is an important commodity; Brazil is the second largest world producer and the largest world exporter. The shelf-life of chicken meat is limited by the presence of micro-organisms and enzyme activity and together with other preservation techniques irradiation seems to be an attractive option. In this study the dose delivered to frozen chicken cuts was measured and compared with the prescribed value. Chicken breast cuts were analyzed for 39 days for their microbiological activity, chemical and organoleptic properties.

Cylindrical dosimeters were prepared using the weight composition of 80% of DL-alanine (Sigma Co), used without any further treatment except drying, and 20% of paraffin. The dosimeters having 4.7 mm diameter and 12 mm length were inserted in a build-up cap. Dosimeters were placed inside cardboard boxes containing frozen chicken breast cuts, packed in styrofoam trays wrapped with plastic film. The boxes were irradiated in an industrial ^{60}Co irradiator (Nordion JS 7500) with a dose rate of 4 kGy/h. First derivative ESR signals were obtained in a VARIAN E-4 spectrometer operating at X-band ($\nu \approx 9$ GHz) and equipped with a rectangular cavity (TE-102, model E-231). The cavity was constantly purged with dry nitrogen and modulated at 100 KHz with 0.5 mT peak to peak. A calibration curve was made for a few dosimeters from the same batch and used to obtain the dose from the ESR signal intensity.

A batch of six boxes was irradiated at each experiment with prescribed doses of 1.5, 3.0 and 7.0 kGy. Considering that the larger the radiation dose the greater is the probability of finding a product with its sensorial characteristics altered (odor of burned meat), we conclude that a dose of 3 kGy would be more adequate, taking into account the microbiological and sensorial aspects.

Keywords: Chicken meat; Food irradiation; Shelf-life; Microbiology; Sensorial evaluation; ESR; X-band; DL-alanine; Radiation dose; Dosimetry

1. Introduction

Radiation processing is an expanding technology with numerous applications such as: medical products sterilization, hospital waste and sewer treatment, modification of some polymers properties, and irradiation of foodstuff (Deeley, 2004).

Foodstuffs are irradiated in order to inhibit buds in products such as potato, onion and garlic; to disinfect agricultural products (to kill insects, larvae, etc.); and to decontaminate and preserve foods (Rodrigues Jr., 2000). An important aspect in the process of food irradiation is to establish levels of radiation dose that significantly reduce the microbial load without compromising the sensorial and nutritional quality of the product. However, optimizing the process depends on the appropriate radiation dose having been applied and measured, in order to correlate with the laboratory analyses. The typical doses for this type of activity vary from 100 Gy until hundreds of kGy (Farrar IV, 2000; International Atomic Energy Agency, 1999). Some countries (Argentina, Belgium, Chile, Denmark, United States, France, Hungary, Holland, Japan and others), are using irradiation to diminish the risk of alimentary toxic infections and to increase the shelf-life of foods (International Consultive Group on Food Irradiation, 1995). In the United States of America a renewed interest

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in food irradiation exists as phytosanitary treatment for disinfecting fruits and fresh vegetables, to eliminate plagues from imported agricultural products and, to control the bacterium *E. coli 0157: H7* in bovine meat, because all these factors could affect the viability of these products' economy (Ross and Engeljohn, 2000). In 1990, the irradiation of chicken meat was approved to control the *Salmonella* bacterium (Adams, 2000).

The history of food irradiation began in Brazil more than 20 years ago when the irradiation of poultry meat was approved in 1985 (Del Mastro, 1999). The current regulations on this subject are argued in Oliveira (2000). In the case of Brazil, the second largest world producer and the largest world exporter of chicken meat, one of the sanitary requirements at international level is that the chicken meat must be irradiated. The maximum radiation dose allowed for chicken meat was established at 7.0 kGy with the intention to increase the shelf-life and to promote decontamination (Oliveira de, 2000). In the United States, minimum doses of 1.5 kGy and maximum of 3.0 kGy are established for chicken meats (Ross and Engeljohn, 2000).

The objective of this work is to determine an adequate value for radiation dose sighting to increase the shelf-life of the chicken meat based on the evaluation of its microbiological and sensorial characteristics after irradiation. The radiation dose delivered to the chicken meat samples was measured with the alanine/ESR dosimetry technique. This technique has gained wide acceptance in many calibration laboratories as a standard dosimetry method for high radiation doses like those used in industrial radiation processing applications (ASTM, 1997; McLaughlin and Desrosiers, 1995; Mehta, 1996; Farrar IV, 2000). One important aspect to be considered is the dose homogeneity over the volume occupied by the chicken meat samples in the irradiation process. In the ideal irradiation situation the entire product receives an identical dose and, a criterion to establish the homogeneity of the process is based on the concept of an overdose ratio OR (maximum dose to minimum dose ratio), that would be near to 1 (Farrar IV, 1995; Deeley, 2004). The minimum dose should be enough to attain the desired effect and the maximum dose must be below that which would jeopardize the nutritious properties and the sensorial attributes of the food (Farrar IV, 1995).

2. Materials and methods

2.1. Chicken meat samples packing and transport

Samples of frozen chicken breast cuts without bone and skin, approximately 200 g each, were prepared and packed in styrofoam trays and covered by polyethylene film. The dimensions of each tray were: 24 cm length, 18 cm width, 3 cm height. The trays were placed in cardboard boxes (approximately 10 trays/box) of dimensions: 1 m length, 50 cm width, 9 cm height. After preparation and packing, the boxes were stored in a refrigerated truck with controlled temperature of 4 ± 1 °C, for transportation to the irradiation facility.

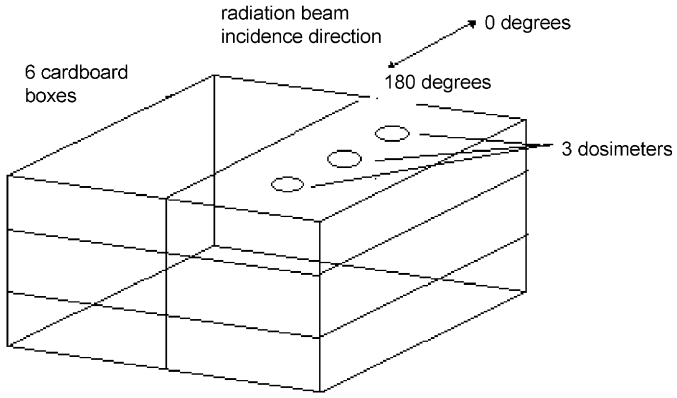

Fig. 1. Cardboard boxes configuration for irradiation.

2.2. Sample irradiation

Six boxes (placed as shown in Fig. 1) were irradiated at the same time in an industrial ^{60}Co irradiator (Nordion JS 7500) in the static modality, at a dose rate of 4 kGy/h. The irradiation time was varied to obtain dose values of 1.5, 3.0 and 7.0 kGy. The boxes were irradiated with half of the total dose delivered on one side (0° in relation to the radiation beam direction) and the other half dose value in the opposing side (180°, see Fig. 1) in order to obtain a more homogenous dose distribution (Farrar IV, 1995). The irradiation was carried out twice, called experiment A and experiment B.

2.3. Dose distribution and ESR measurements

In order to determine dose control in the irradiation process, alanine/ESR dosimeters were used for dose measurement. Three dosimeters were placed in each cardboard box (Fig. 1). Each dosimeter consisted of a mixture of 80% DL-alanine plus 20% paraffin, with a nominal mass of 240 mg and dimensions of 4.7 mm diameter and 12 mm length. The ESR signal intensity reading corresponding to each dosimeter was transformed to the dose value received through a calibration curve that was constructed irradiating a group of 15 dosimeters to a dose range of 1–10 kGy (three dosimeters per dose value). Each dosimeter was placed inside a PVC build-up cap with 5 mm thick to provide electronic equilibrium.

First derivative ESR signals were obtained in a VARIAN E-4 spectrometer operating at X-band (9.5 GHz) and equipped with a rectangular cavity (TE-102, model E-231). The spectrometer parameters settings used were: central magnetic field H_0 of 325 mT, scan range ΔH of 20 mT, 2 min of scan time, microwave power of 50 mW and 0.5 mT and 100 kHz for modulation amplitude and frequency, respectively. For a precise positioning of the dosimeter into the resonance cavity, the dosimeter was placed inside a double-walled quartz sample holder. All measurements were made at ambient temperature.

2.4. Sensorial and microbiological analyses

After irradiation, all the samples (including non-irradiated samples) were stored in a refrigerated chamber at 5 ± 1 °C