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CONTENTS

COMPARTMENT MODELLING IN DRYING OF GAMMA IRRADIATED CHESTNUT FRUITS

Amilcar L. Antonio[1,2,3]
Elsa Ramalhosa[1]
Albino Bento[1]
[1]CIMO-ESA - Instituto Politécnico de Bragança, Bragança, Portugal
E-mail: amilcar@ipb.pt

Mauro Trindade[4]
Guillermo Sanchez[5]
[4] Departmento de Radioterapia, Centro Hospitalar de Trás-os-Montes e Alto Douro, Vila Real, Portugal.
[5]ENUSA – Industrias Avanzadas S.A., Salamanca, Spain.

M. Luisa Botelho[2]
Begoña Quintana[3]
[2]GTRPP/Unidade de Física e Aceleradores, ITN, Sacavém, Portugal.
[3]Departamento de Física Fundamental, Universidad de Salamanca, Spain

KEYWORDS
Chestnut fruits; Gamma irradiation; Drying; Compartment modelling.

ABSTRACT

The main objective of this work was to understand how irradiation processing influences the drying of chestnut fruits. Herein, based on the fruit characteristcs and Computational Tomography (CT) images, we proposed a compartment-model for the kinetic drying curves. The preliminary results seemed to indicate that one-compartment modelling gives good fitting results for the modelization of the drying curves. In this way, this model could be a good approach to the drying process.

INTRODUCTION

Food irradiation is a non-thermal processing technology for food preservation, to increase shelf-life, for disinfestation (insects elimination) or sterilization. Irradiation appears in chestnut fruits as a possible phytosanitary treatment, to meet the international trade laws, without affecting significantly the nutritional value (Antonio et al. 2011; Fernandes et al. 2011; Kwon et al. 2004). In these fruits one of the main problems is water loss, causing loss of weight, with changes of some physical characteristics, like texture, affecting the incomes of the producers. Otherwise, the drying itself is another food industry process available to obtain other sub-products, like flour for cooking and for bakery products. In this way, understanding how irradiation processing influences the drying of this fruit is an important goal.
Herein, based on the fruit characteristcs and Computational Tomography (CT) images, we proposed an alternative approach, compartment-modelling for the drying kinetics. This kind of modelization is used in different areas, namely in pharmacokinetics for modeling drugs administration in the human body (Sanchez 2007). This modelization consists in dividing the human body, seen here as the sample, in compartments that interact between each other transfering matter, in this case water. Herein, we had considered the initial concentration of water in the fruit similar as one intake of a drug.

MATERIALS AND METHODS

Samples

Chestnuts samples (*Castanea sativa* Mill., Judia variety) were obtained directly from a local producer of Trás-os-Montes, in the northeast of Portugal. They were divided in four groups to be exposed to different radiation doses (0, 1, 3 and 6 kGy) with 27 units per group (about 0.5 kg) placed into polyethylene bags, being 0 kGy the non-irradiated samples (control).

Irradiations

The irradiation of the samples were performed in a Co-60 experimental chamber with four sources, with a total activity of 267 TBq (6.35 kCi) in November 2011. The dose rate for the positions of irradiation was estimated using an ionization chamber dosimeter (model FC60-P, from IBA dosimetry company). During the irradiation processing 4 routine dosimeters were used for each group, in the corners of the sample bag (Amber Perspex dosimeters, from Harwell company, U.K.). The samples were rotated up side down (180°) at half of the time, to increase the dose uniformity. The dosimeters were read in a UV-VIS Spectrophotomer (model Specord 200, from Analytik Jena) at 603 nm, two readings for each, to estimate the dose according to a previous calibration curve.

Drying process

In order to determine the moisture contents of chestnuts subjected to different irradiation doses, three chestnuts from each group were triturated and dried in an oven at 105 °C till constant mass. Another group of samples (four for each dose) were dried in an air forced oven at 50 °C measuring the fruits mass along time, till 29 h (Fig. 1).
The water content per dry matter (W) is

$$W = (\text{mass of water}) / (\text{mass of dry matter}) \quad (1)$$

Fig. 1: Chestnut samples used in the present work.

Modelization

To model the drying of the fruits, a one-compartment model was used (Fig. 2), that interacts with the exterior transfering matter, in this case water. The initial water content in the fruit, b_0, was considered similar as one intake of a "drug" and its behaviour along the time (drying process), corresponded to the water loss by the fruit. The equation that describes this model is

$$dq_1(t) / dt = -k_{10}\, q_1(t) \qquad (2)$$

The k_{10}, elimination constant, is the transferring coefficient from the compartment 1 (fruit) to compartment 0 (outside).

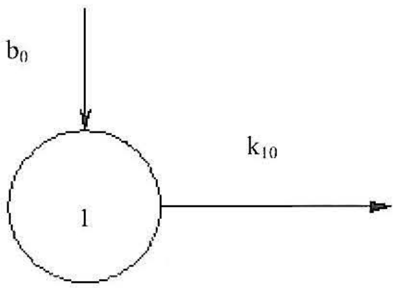

Fig. 2: One-compartment model.

The solution of this equation, used for fitting the drying process is:

$$q_1(t) = b_0\, e^{-k10\ t} \qquad (3)$$

For determining the elimination constant, k_{10}, for each group of samples the *Mathematica* software was used, version 8 (from Wolfram company).

Computed tomography (CT) images

CT images of the fruit were taken in a Philips machine (model Brilliance CT Big Bore, from the Philips company), at 120 kV, 50 mA and 2.1 seconds of exposition.

RESULTS AND DISCUSSION

The estimated doses, after photometric reading of the dosimeters, were 1.0 ± 0.1, 3.2 ± 0.7, 6.3 ± 0.9 kGy.

For simplicity, from now on, in the graphs we considered the values 1, 3 and 6 kGy.
The dose rate was 2.5 ± 0.1 kGy h^{-1} and the average dose uniformity ratio (D_{max}/D_{min}) was 1.4 ± 0.3.
As could be seen from the CT images the fruit had some inhomogeneities, inner and outer skins, and some inside heterogeneity (Fig. 3).

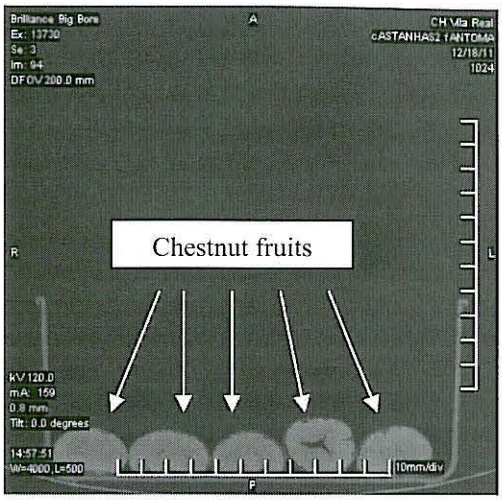

Fig. 3: Computed tomography image of chestnut fruits.

Good fits with the one-compartment model were obtained, with R squared values higher than 0.996 (Fig.4).

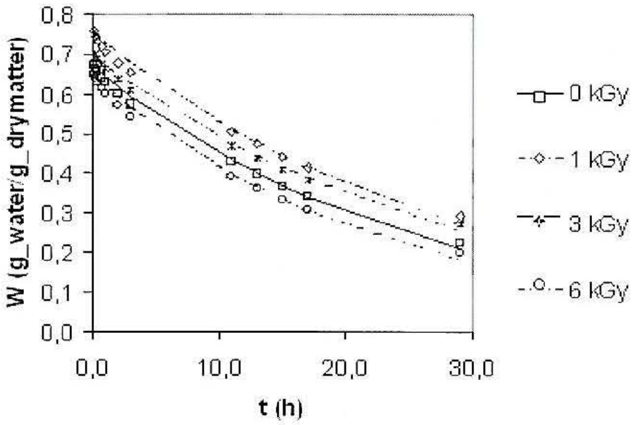

Fig. 4: Drying experimental data and fitting curves for one-compartment model.

The drying curves for the different doses followed a similar behavior, including control (non-irradiated samples).

CONCLUSIONS

The drying curves for the irradiated samples were similar to the non-irradiated chestnuts, up to 6 kGy. The results also indicated that one-compartment modelling gave a good description of drying process. In the near future we intend to compare these results with those obtained in a multi-compartment model, in order to take into account the inhomogeneities of this fruit.

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AUTHOR BIOGRAPHIES

AMILCAR L. ANTONIO research interests are related to food irradiation. E-mail: amilcar@ipb.pt

ELSA RAMALHOSA research interests are related to food engineering. E-mail: elsa@ipb.pt

ALBINO BENTO research interests are related to pest control. E-mail: bento@ipb.pt

MAURO TRINDADE research interests are related to different radiotherapy thecniques and medical physics. E-mail: MAUROPT@chtmad.min-saude.pt

M. LUISA BOTELHO research interests are related with microbiology, ionizing radiation and development of radiation applications for industry: environment, healthcare, pharamaceutical and others. E-mail: mlb@itn.pt

GUILLERMO SANCHEZ research interests are related with Nuclear Safety, Health Physics, Radioprotection, Environmental and Radiological Engineering, Planning, and Computer Modelization. E-mail: guillermo@usal.es

BEGOÑA QUINTANA research interests are related with Radiation Protection mainly in the field of environmental surveillance, Monte-Carlo simulations and Gamma spectrometry with Ge detectors. E-mail: quintana@usal.es