Radiation Technologies: Processes and Products

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Radiation Technologies: Processes and Products is an interdisciplinary group that uses the holistic approach as the key to conceptualize a research or a service. This interdisciplinarity, using Biology, Chemistry and Physics science, allows the study of a subject from various angles and methods unified by a common goal: the validation of methodologies to understand the subject of study, which core is ionizing radiation.

The group *modus operandi* permits a constant connection with Industries, Universities and other Research groups applying its "way of knowing" in response to requested services, as a collaborator in a research project or in the transmission of knowledge.

The group activities focus on the delineation, development, validation and application of technologies and processes in various fields, such as Environment, Food and Pharmaceutics. As a fundamental part of the validation studies, Risk Analysis is being applied as a process management tool either in production lines of studied products (*e.g.*: food, devices and pharmaceuticals) or in environmental control (*e.g.* hospitals rooms, pharmaceutical industries and buildings energetic certification).

In the scope of ITN mission the group is requested by the authorities or private industries to undertake a consultant role on sterilization and decontamination procedures mainly applying ionising radiation. The group also develops work with the National and International normalization, standardization and certification bodies (IPQ, CEN and ISO).

The Group's main R&D activities are focused at employing ionising radiation technologies to new processes and applications in Agriculture, Food, Pharmaceutical, Wastewater Treatment, Art and other areas. In order to improve our understanding of the Radiation effects in products integrated methodologies composed by Analytical Methods of Biology, Microbiology, Chemistry and Physics are being used. Molecular Biology new trends based on PCR technique are being developed as a diagnostic tool (*e. g.:* potential pathogenic micro-organisms) and as well as fingerprinting methods to assess the biodiversity profile of environmental samples. Furthermore, R&D in environmental virology is being carried on, namely the inactivation of enteric viruses (e.g. norovirus and adenovirus) by ionizing radiation for disinfection purposes.

In 2010 two FCT projects were initiated both focusing ionizing radiation applications taking advantage of IRIS and LETAL infrastructures. One (Pulse Radiolysis - PTDC/QUI-QUI/104229/2008) is related with the implementation of a pulse radiolysis system at the LINAC Accelerator to study the mechanistic details of the degradation of chemicals compounds. The other project (RADIART - PTDC/HIS-HEC/101756/2008) deals with art objects and the potentiality of gamma radiation as a decontamination tool. An ionizing process treatment with gamma and electrons radiation is being studied for food preservation (e.g. chestnuts) in the scope of a collaboration project (CHESTNUTSRAD - QREN nº 13198/2010) with School of Agriculture of IPB.

Training and "know-how" diffusion are one of the main issues of this Group reflecting in the attainment of academic degrees (Graduation, M.Sc. and Ph.D.) and in the dissemination of obtained results in the scientific community (publications, workshops and conferences).

The financial support of the group is based on projects, sponsored by National (e.g. FCT, AdI) and International (e.g IAEA) science foundations and expertise services to Industrial Companies.

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IRIS up to date

P.M.P. Santos, A. A. Amílcar[1], R. Melo, S. Cabo Verde, T. Silva, H. Marcos, I. Nunes, M. Oliveira, V. Dores and M. L. Botelho

Objectives

Dosimetric studies are being carried out in the ionizing radiation facility IRIS, using the radiation equipments: ^{60}Co experimental source Precisa22 and the Linear Accelerator (Linac). These studies intended to dose map both equipments for further ionizing radiation treatment processes optimizations.

Results

The difficulty in obtaining agreement between simulations and experimental results has been a permanent stimulus to achieve optimal conditions for radiation treatment processes. A model based in the Monte Carlo simulation using the irradiation equipments available at IRIS – an experimental gamma irradiation chamber (Precisa22, Graviner Ltd, UK) and a Linac – will be applied in this study. A dosimeter mapping of Precisa22 and preliminary dosimeter measures in the Linac were performed.

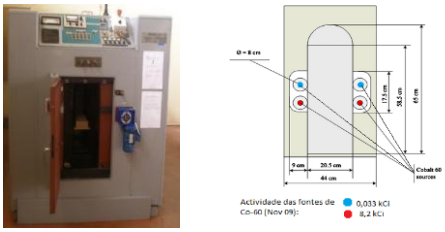

Fig. 1 – Precisa22 irradiation chamber: activity of sources and dimensions.

The ^{60}Co irradiation facility (Fig. 1) consists of a 65 cm x 50 cm x 20 cm (h x d x w) rectangular cavity surrounded by a lead protection barrier. Four ^{60}Co sources, with an activity of 305 TBq (8.233 kCi) in November 2009, are positioned in stainless-steel tubes located in the lateral walls of the chamber, in positions directly facing each other, about 30 cm above the chamber floor. The movement of the sources in the 50 cm long tubes is controlled by an automatic mechanism. The dosimetric study was performed using Fricke solution as reference dosimeter, within the range of 40 to 400 Gy. The irradiation geometry is composed by a four level steel frame that delimitates the irradiation chamber and supports four wood racks with 27 positions each. The higher estimated dose rate was 4 kGy/h obtained in the level 2 of the irradiation geometry (second upper level near the sources). In opposition, the lower dose rate achieved was 0.080 kGy/h at the bottom level 4, close to outside door.

The Linac (Fig. 2) can operate both in electron and in photon mode and deliver an energy comprised between 4 and 12 MeV. A magnetron working at a frequency of about 3 GHz and triggered between 10 and 300 Hz delivers pulses of several ms.

Fig. 2 – Linac: bunker; modulator; accelerating structure and electron/photon beam exit (270° loop).

A preliminary dosimetric study was conducted in the Linac using Fricke dosimeter. The accelerator set up was 10 MeV; 50 mA; 2.28 μs in the electron mode. Fricke solution amilon bags (9.5 x 3.5 cm; n = 3) were placed in the irradiation tray (28.5 cm x 9.5 cm) and irradiated at a distance of 30 cm of irradiation head. For the selected irradiation geometry and Linac configurations, the higher obtained dose rate was 1.12 ± 0.03 kGy/h in the center position (bellow irradiation head), and the lower was 0.48 ± 0.06 kGy/h in the left side of the tray.

The dose mapping for both equipments is being accomplished and further evaluated by simulation and routine dosimetry.

This R&D work is the theme of a PhD Thesis (FCT SFRH/PROTEC/67398/2010).

Influence of gamma radiation on the antioxidant properties of edible chestnuts – In food irradiation the dose distribution inside the chamber and the dose uniformity ratio must be well characterized to control the irradiation process. An estimation of dose was performed using Fricke chemical dosimeter solution, obtaining a dose rate of 0.27 ± 0.04 kGy, for the selected geometry inside the irradiation chamber. The dose uniformity ratio obtained was similar to one (D_{max}/D_{min} = 1.3). The dose uniformity ratio obtained is in conformity with the good practices for food irradiation that should be less than 3. In this preliminary study the results suggested that a variation of 0.27 kGy affected the skin and fruit properties in different ways, maybe due to different chemical composition of these parts. However, along storage time the control and irradiated samples follow the same tendency. Further studies will be done in order to elucidate the influence of irradiation in chemical composition and nutritional value of chestnuts fruits. This R&D work is under a Protocol between several entities and is supported by "ON.2 - Programa Operacional Regional do Norte" with the Project CHESTNUTSRAD - QREN nº 13198/2010.

Published work

A. L. António, I. C. F. R. Ferreira, A. Bento, P. Teubig, M. Luísa Botelho *"Influence of gamma radiation on the antioxidant properties of edible chestnuts*" Isotope Technologies and Applications – New Horizons. NAARRI International Conference – NIC 2010; Vol. II: pp. 170-175.

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Cork wastewater chemical evaluation

R. Melo, J.P. Leal[1], T. Silva, S. Cabo Verde and M. L. Botelho

The effects of ionizing radiation in the degradation of cork wastewater pollutants are being studied. Among the several complex present in cork wastewater, phenolic compounds play an important role on the wastewater toxicity. Radiolytic degradation of acetovanillone, as model compound, has been studied. Acetovanillone is known for its anti-inflammatory capabilities which are attributed to its ability to selectively prevent the formation of free radicals, oxygen ions and peroxides in the body. Acetovanillone is a NADPH oxidase inhibitor and it is effective in preventing the superoxide in human white blood cells. However, its presence in cork wastewater increases its toxicity. Irradiations were performed in the Co-60 experimental source (IRIS) at 2.1 kGy/h for the absorbed doses of 2 and 41 kGy. The obtained results show that almost all acetovanillone was degraded (~93%) at 41 kGy. The radiolytic products were identified by GC-MS with previous derivatization of samples. The main detected products were malonic acid, benzoic acid, oxalic acid and succinic acid.
In other point of view, phenolic content, antioxidant activity and the presence of gallic acid, ferulic acid and hydroquinone were determined in cork wastewater samples due to the potentiality reuse of phenolic compounds as antioxidants. Samples were collected in the cork boiling process and in the end of cork process. The obtained results show that phenolic content is higher in the cork boiling wastewater; however there is no difference between the samples concerning the antioxidant activity. Gallic acid was the only phenolic compound detected. Further studies will be done to better understand the cork wastewater samples as well as the potentiality of antioxidants extraction to reuse.

Xanthines scavenging capacity towards superoxide radical anion

P.M.P. Santos, A.J.S.C. Vieira[2] and M.L. Botelho

Oxidative stress in living tissues has been well characterised as the result of chemical changes in biological molecules (e.g. proteins, lipids and DNA) induced by endogenous or exogenous oxidising species. The agents of oxidative stress are UV or ionising radiations (γ- and X-rays) or chemical agents such as metabolites, xenobiotics and, mainly, free radicals, in particular the so-called reactive oxygen species (ROS) and reactive nitrogen species (RNS). Among the several classes of antioxidants studied to protect biological molecules against oxidative stress, xanthines play an important role. These compounds are found in human tissues and fluids (xanthine, xanthosine) or present in several beverages and foods like coffee, tea, chocolate and cola (e.g., caffeine, theobromine and theophylline) and their significant antioxidant effect can protect biological targets against damage by ROS, namely HO• hydroxyl radical. Other N-alkyl xanthines are used as cardiovascular and anti-inflammatory drugs, and their pharmacological activity is supposed to be related, at least partially, to their ability to scavenge ROS. Under oxidative stress conditions, dismutation of O2•− superoxide anion radical (a mild reactive species) leads to the formation of H2O2 which is known to produce HO• via Fenton reaction. Therefore, studies were conducted in order to evaluate the scavenging capacity of several N-methylated xanthines towards O2•−. This radical was produced by irradiating O2 saturated aqueous solutions of the studied xanthine and NaHCOO in the experimental 60Co chamber irradiation Precisa22 (10 kGy). Under these conditions, all primary radiolytic species are converted into O2•−. In each case, a predominant oxidation product different from the well-known corresponding uric acids was detected by HPLC-DAD. Further studies are in progress to characterize these products and to evaluate the influence of the methyl groups number and position of these compounds in the O2•− scavenging capacity.

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Microbial growth and inactivation patterns in art objects

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The assessment of bioburden is a major factor for a reliable evaluation of microbial inactivation. Facing different materials (e.g. ancient tiles, books and parchments), and the need to study the inactivation profile of its microbiota without damaging the sample, several methodologies were developed. The bioburden determination methodologies were outlined based on swab sampling technique and validated using artificial contamination with known microbial inoculums. For tiles, the bioburden ranged between 1 – 100 cfu/cm^2 and the microbial population dynamics were closely dependent of the exposition environment. The parchments bioburden were mainly composed by fungi with an average concentration of 10^4 cfu/m^2. The ancient book presented a bioburden ranging 100 – 1000 cfu/page depending of sampling site (cover, interior and back cover). Preliminary inactivation studies were performed at the Co-60 experimental source (IRIS) only after the complete knowledge of samples bioburden. Sub-lethal doses (1 – 5 kGy) were applied to verify microbial population inactivation profiles. Considering the applied low radiation doses it was achieved approximately 20% of population inactivation for the tested ancient art objects. Being aware of the historical value of the referred art objects, the study milestones were the microbial decontamination (not sterilization) for preservation proposes and the conservation of its characteristics. Higher radiation doses are being tested to guarantee a stable decontamination preservation and conservation of the ancient art objects. These studies are under the scope of the projects RADIART (1 BIC) and MYCHOARCHIVE (1 PhD; 1 McS).