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INVESTIGATIONS OF THE FRICKE GEL (FXG) DOSIMETER DEVELOPED AT IPEN IRRADIATED WITH ^{60}Co GAMMA RAYS

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ABSTRACT

Different dosimetric systems (radiochromic films, chemical solutions, calorimeter and semiconductors) are used to radiation dose determination in radiotherapy processes. However, they do not present good response for 3D dose distribution measurements. The Fricke gel (FXG) system obtained by means of modifications on standard Fricke dosemeter presents some advantages: easy preparation, fast response, good reproductibility, tissue equivalence, geometric dose information and can be used to determine dose inside of human body cavity. A gelatinous agent (gelatin) that supplies molecular structure to avoid the ions diffusion for enough time to measurements and xylenol orange, a metal ion indicator, are added to the Fricke solution. The dosimetry is based on the oxidation process of ferrous ions in ferric ions when the dosimeter is exposed to the ionizing radiation. In this work porcine gelatin 270 bloom was used to modify the conventional Fricke solution. The irradiation were carried out free in air at electronic equilibrium conditions using a ^{60}Co Gammacell source. The ferric ion concentration after irradiation was measured by spectrophotometry in the wavelength of 585 nm using the spectrophotometer Shimadzu UV-2101PC. Characteristics such as absorption spectrum, dose response between 5 and 50 Gy and signal stability were evaluated. The developed material presented good performance to be applied to measurements of spatial distribution of gamma dose using magnetic resonance imaging.

1. INTRODUCTION

Radiotherapy is the medical use of ionizing radiation as part of treatment of diseases like cancer. The planning of radiotherapy treatment has been enhanced and optimized using dosimetric techniques, i.e., tissue equivalent simulators are irradiated in the same irradiation conditions of patients, minimizing the damage caused to errors in the radiation application; improving the patient life quality and increasing the public acceptance in general.

The Fricke conventional dosimeter, aqueous solution of ferrous ammonium sulphate, whose dosimetry is based in the oxidation process of ferrous ions (Fe^{+2}) to ferric ions (Fe^{+3}) has been used to determine both absorbed dose and dose distribution.

Change in the conventional Fricke solution with adition of gelatin allow to stabilize the spatial dose distribution information [1-4].

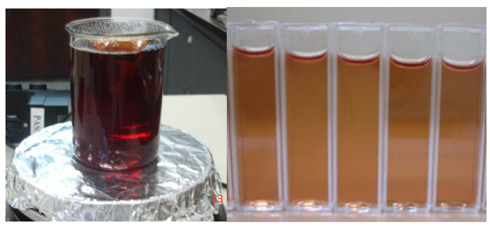
In this work porcine gelatin 270 bloom was used, considering the easiness to obtain in the national market and low cost compared with gelatin 300 bloom used in other works, that is imported and very expensive. The results has been excellent and the spectrophotometry is a fast, cheaper, sensitive and convenient measurement technique [5].

The solution characterization was made in the wavelength of 585 nm in samples non-irradiated and irradiated with ^{60}Co gamma radiation. Characteristics such as absorption spectrum, dose-response between 5 and 50 Gy and signal stability were evaluated.

2. MATERIAL AND METHOD

2.1. FXG solution preparation

A conventional Fricke solution was optimized adding gelatin 270 bloom (gelatinous agent) and xylenol orange (metal ion indicator) for 3D dose information. The final FXG solution consist of 1 mM ferrous ammonium sulphate; 50 mM sulphuric acid; 1 mM sodium chloride; 0.1 mM xylenol orange, 5% gelatinous agent and tri-distillated water. The FXG solution preparation consist of three parts: gelatin dissolution in 75% of total water and incorporation in the gel matrix of the chemical compounds dissolved in 25% of remainder water; transference to acrylic cuvettes of 10 mm optical path, 45 mm height and 1 mm wall thickness and maintenance under refrigeration at 5^{o}C and darkness during 12 h, Fig. 1.



Fricke gel solution ***Acrylic cuvettes filled with FXG solution***

Figure 1. Preparation of FXG solution.

2.2. Irradiation and measurement procedures

A ^{60}Co source (Gammacell) that belong to the Radiation Technology Center CTR / IPEN-CNEN/SP was used for gamma irradiation, the samples were irradiated in air at electronic equilibrium with doses between 5 and 50 Gy. The irradiation position and dose rate were certified by the dose guarantee program IDAS / IAEA (International Dose Assurance Service / International Atomic Energy Agency) with conventional Fricke dosimeter.

The absorbances before (A_o) and after (A) irradiation were measurements using a spectrophotometer Shimadzu UV-2101PC at maximum absorption wavelength of 585 nm; the FXG solution conditioned in sealed acrylic cuvettes were maintained at room temperature during 30 min before irradiation.

3. RESULTS AND DISCUSSION.

3.1 Absorption spectrum

The absorption spectrum of the Fricke gel solution were measured scanning over the wavelength range between 190 - 900 nm in the Fig. 2 are shown the results obtained in samples irradiated with dose range between 5 and 50 Gy. The increasing of absorbance values are related with the absorbed dose.

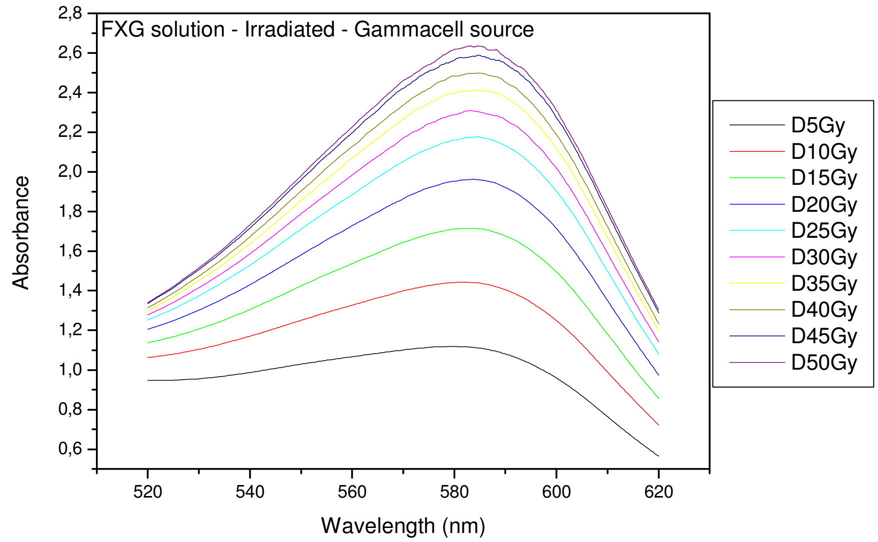


Figure 2. Absorbance values of FXG solutions irradiated in the dose range between 5 and 50 Gy.

3.2 Signal Stability

The Fricke gel solution suffers a natural oxidation process increasing its absorbance values with the time after the solution preparation. It was observed that for solutions kept in low temperatures (5^{o}C) this process is minimized. Solutions maintained at laboratory normal conditions, i.e., natural and artificial light and temperatures of approximately 25^{o}C, presents an accented increase in the absorbance values and it is maximum after one week of storage, about two times greater than the solutions kept under refrigeration in the same period. In the Fig. 3 are showed the results obtained for non-irradiated solutions at 585 nm.

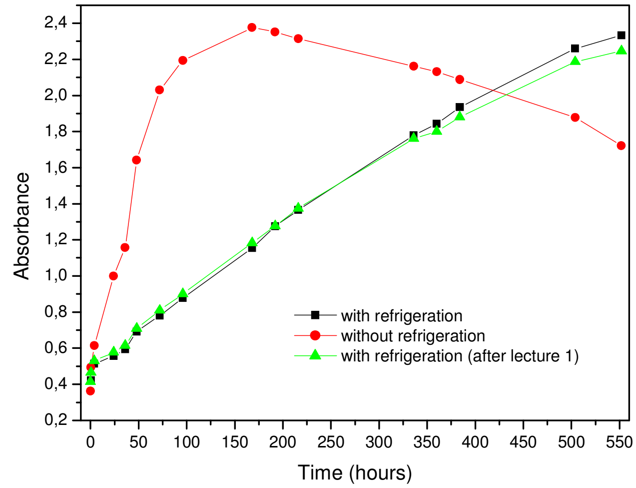


Figure 3. Response stability as a function of time after preparation of FXG solution non-irradiated exposed to ambient conditions and low temperature;

3.3 Calibration curve

In the dose response curve, Fig. 4, is observed a linear dose range response between 5 - 25 Gy and a saturation effect after 25 Gy due to chemical changes and reagents consumption. The spectrophotometric measurements were performed at 585 nm

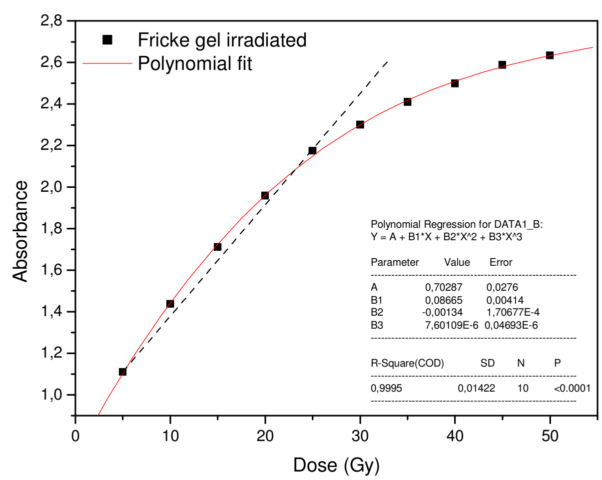


Figure 4. FXG dose response, gamma radiation and absorbance measurement at 585 nm.

4. CONCLUSIONS

These results indicate that the FXG solution is sensitive to light and temperature ambient conditions, due to auto-oxidation process. In this way the solution must be maintained at low temperatures and the increase in the absorbance values known to be corrected of the contribution radiation induced result.

The radiation measurements with FXG dosimeter is a sensitive technique and can be used in medical applications such as radiotherapy to obtain special dose informations. The useful dose range is compatible with the applied in the malignant diseases treatment.

Considering that the FXG dosimeter is prepared in liquid form and is tissue equivalent it can be confectioned in any format to simulate human body organs.

The spectrophotometry technique is adequate, cheap and provides a very sensitive and convenient analysis method.

Breast simulators were prepared, irradiated with gamma rays and are being studied using in nuclear magnetic resonance technique, the results will be presented in future work.

ACKNOWLEDGMENTS

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