Preliminary Results on Energy Dependence of the Fricke Gel Dosimeter for Low Energy X-Radiation

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Abstract. The conventional Fricke dosimeter have been commonly used for calibration of various procedures that use ionizing radiation and the Fricke gel dosimeter, which consist of the modification of conventional dosimeter by the addition of gelatinous agent, have been studied for radiotherapy application. The present study was carried out with the purpose of to investigate the energy dependence of the Fricke gel dosimeter response for low energy X-radiation, in order to know the properties of this dosimeter for future application other than radiotherapy. The Fricke gel dosimeters were irradiated using a PANTAK SEIFERT X-rays systems model ISOVOLT 160 HS with absorbed dose of 1 Gy with different X-rays beam qualities. The Fricke gel response was evaluated by optical absorption spectrophotometry technique. The absorbance values correspond to the wavelength of 550 nm. The energy dependence of the Fricke gel dosimeter response for low energy X-radiation relative to ^{60}Co corrected to cuvettes wall absorption increases between 0.107 ± 0.162 to 7.38 keV until 1.000 ± 0.192 to 30.48 keV.

KEYWORDS: Fricke gel dosimeter; energy dependence; low energy X-radiation; spectrophotometry technique.

1. Introduction

The accurate determination of absorbed radiation energy is of great importance in applications of ionizing radiation in medicine, industry and research [1-2]. Among the dosimetry methods [3] the gel systems have been enough studied [1,4-8] by many researchers because it can be used to measure three-dimensional (3D) radiation dose distributions using magnetic resonance imaging [9] of way non-destructive and non-invasive [1,10]. The Fricke gel system has presented satisfactory results for this purpose [3,8,11,12]. In this technique, ferrous (Fe^{2+}) ions are oxidized to ferric (Fe^{3+}) ions by free radicals produced by ionizing radiation [10,13] that is proportional to absorbed dose [9].

The aim this work is to obtain results on energy dependence response of the Fricke Xylenol Gel (FXG) dosimeter developed at IPEN for low energy X-radiation in order to verify possible applications of this dosimeter other than radiotherapy using 270 Bloom gelatin.

2. Materials and Methods

2.1 Fricke Gel Solution Preparation

The FXG solution was prepared using 5% by weight 270 Bloom porcine gelatin (commercial gelatin gel powder used in the pharmaceutical industry), tri-distilled water, 50 mM sulphuric acid (H_2SO_4), 1 mM sodium chloride (NaCl), 1 mM ferrous ammonium sulphate hexahydrate $[Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O]$ and 0.1 mM xylenol orange-sodium salt ($C_{31}H_{28}N_2Na_4O_{13}S$) [2,14].

Immediately after preparation the dosimetric solution was conditioned in acrylic cuvettes (optical path length of 10 mm), the optical measurements of non-irradiated solution were achieved and then the FXG samples were maintained under refrigeration (4° C ± 1° C) and light protected during 17 h before irradiation.

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2.2 Samples Irradiation

The FXG samples were maintained at room temperature (~ 25° C) thirty minutes before irradiation. The dosimeters were irradiated in the same cuvettes in the PANTAK SEIFERT X-radiation system model ISOVOLT 160 HS (Current range = 0.1 to 45 mA; voltage range = 1 to 160 kV) pertaining to Instruments Calibration Laboratory of IPEN-CNEN/SP with absorbed dose of 1 Gy with beams of radiotherapy quality with different effective energies: 7.38, 11.88, 13.93, 22.08 and 30.48 keV.

The irradiations were achieved in a field of 8 cm, in a Source-to-cuvette-volume-center Distance (SD) of 50 cm and in free air. Thirty minutes after irradiation the spectrophotometric measures were performed.

The parameters of X-rays system used in irradiation of the FXG dosimeters are presented in Table 1.

Table 1: Parameters of the X-radiation system used for FXG dosimeters irradiation [15].

X-Radiation Quality	Additional Filter (mmAl)	Applied Voltage (kV)	Half Value Layer (HVL)		SD (cm)	Air Kerma Rate (mGy/s)	X-Radiation Effective Energy (keV)
			1ª. (mmAl)	2ª. (mmAl)			
T-10	-	10	0.043	0.052	50	3.130 ± 0.0130	7.38
T-30	0.2	30	0.185	0.320	50	9.638 ± 0.0420	11.88
T-25	0.4	25	0.279	0.410	50	2.762 ± 0.0110	13.93
T-50(b)	1.0	50	1.079	1.690	50	4.027 ± 0.0160	22.08
T-50(a)	4.0	50	2.411	2.890	50	0.821 ± 0.0036	30.48

2.3 Optical Absorption Evaluation

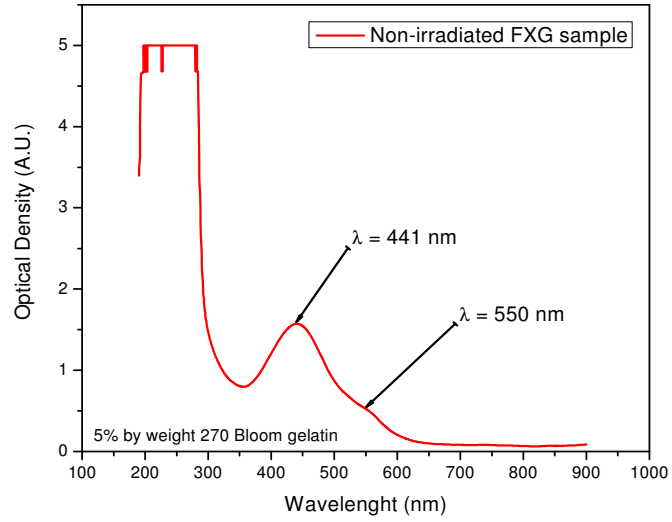
The FXG dosimeter response was evaluated by the well established optical absorption spectrophotometry technique [16-17] immediately after preparation and thirty minutes after irradiation.

The optical measurements were achieved using a UV-visible SHIMADZU spectrophotometer model UV-2101PC operating in absorbance mode in the optical range of 190 to 900 nm.

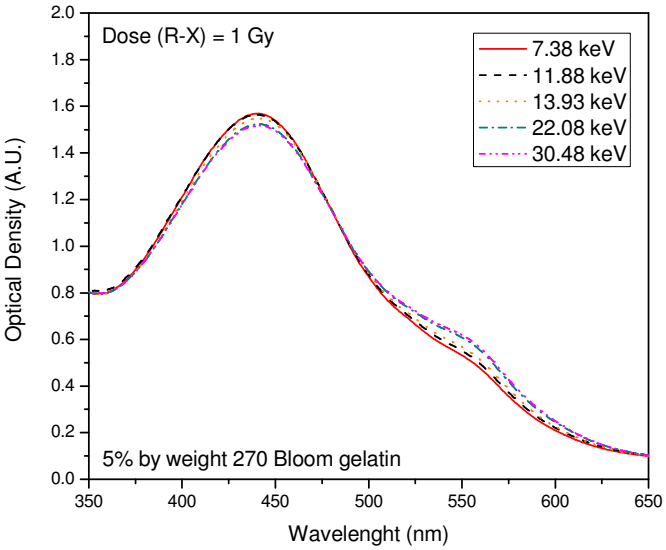
3. Results and Discussions

The optical absorption spectra of the Fricke gel dosimeters are presented in Fig. 1.

Figure 1: Optical absorption spectra of non-irradiated (A) and irradiated (B) Fricke gel dosimeters with different X-rays energies.



A

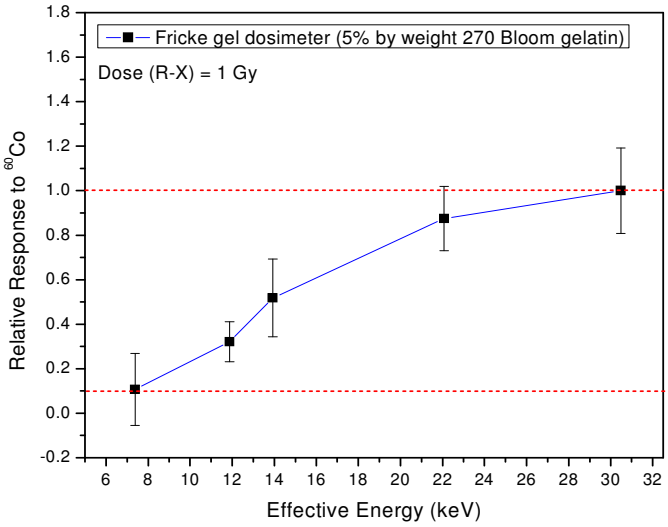


B

The FXG dosimeter presents two absorption bands; one at 441 nm related to Fe^{2+} ions and other at 550 nm related to Fe^{3+} ions.

The energy dependence of the of spectrophotometric response FXG dosimeter for low energies X-radiation relative to ^{60}Co gamma radiation and corrected to the radiation absorption ($e^{-\mu x}$) in the cuvettes wall is presented in Fig. 2. The presented data correspond to the arithmetic average of five FXG samples for each X-ray energy studied and presented uncertainties based in the standard uncertainty times coverage factor k = 3 providing a reliable level of 99% approximately.

Figure 2: Energy dependence of the optical response of the Fricke gel dosimeter for low energy X-radiation.



The energy dependence of the Fricke gel dosimeter response for low energy X-radiation relative to ^{60}Co change strongly from 0.107 ± 0.162 to 7.38 keV to 1.000 ± 0.192 to 30.48 keV and presents energy independent behaviour to energies higher than 30 keV. The relative response to ^{60}Co corresponds to the wavelength of 550 nm.

4. Conclusion

The obtained results shows that the Fricke gel dosimeter prepared using 5% by weight 270 Bloom gelatin presents strong energy dependence for X-ray energies between 7.38 until 22.08 keV and can be considered energy independent for effective energies higher than 30 keV.

These results can be improved evaluating the FXG optical response for energies in the range between 30 and 670 keV (^{137}Cs).

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