Investigation of the gelling agent effect on response of Fricke gel dosimeters

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Abstract
Purpose of this study is to test if applying of the various gelling agents have consequences on the dosimetric properties of Fricke gel dosimeters. Therefore, dose response curve of Fricke gel dosimeters prepared using three different gel matrices, PVA, agarose and agar were investigated by optical absorbance measurements. The absorbance of the dosimeters grows linearly with the dose up to 30 Gy. Also, the findings suggested that PVA-GTA Fricke gels with lower diffusion coefficient are promising tools for radiaton therapy dosimetry applications.

Keywords: Fricke gel dosimeters, Gelling Agent, Dosimeter Response

Introduction
Quality assurance procedures required in modern radiation therapy would greatly benefit from the development of the dosimeters able of rendering three dimensional dose profiles with high spatial resolution. One of the common dosimeters is based on the Fricke gel system which contains a gelling agent in addition to the ferrous ions. In Fricke gel dosimeters, ionizing radiation induces radiolysis of water, followed by reactions oxidizing ferrous ions to ferric ions, with a yield proportional to the absorbed dose up to saturation. The distribution of the resulting ferric ions is used to produce a 3D image of the absorbed dose by Magnetic Resonance Imaging or by optical imaging, provided if a metal ion indicator is employed. The most used metal ion indicator is xylenol orange. Xylenol orange molecules absorb light around 430 nm. After irradiation, the produced ferric ions are chelated by xylenol orange and the resulting complexes give light absorption above 500 nm. So, it is possible to assess the dose absorbed by Fricke gel dosimeters by evaluating the variation of their absorbance.
Some disadvantages of Fricke gel dosimeters are still challenging, making the systems an interesting topic of research. Firstly, irradiated Fricke gel dosimeters suffer from a gradual blurring over time due to the diffusion of ferric ions, which eventually destroys the information on 3D dose distribution. Secondly, the dose response of Fricke gel dosimeters depends significantly on several parameters that characterize their manufacture, including purity and composition of chemicals. Various additives were proposed to improve the radiation sensitivity of Fricke gel dosimeters to radiotherapeutic doses (Jin etal.,2012). Recently, formulations based on gel matrices of Poly Vinyl Alcohol (PVA) chemically crosslinked with glutaraldehyde (GTA) have shown improvements as compared to Fricke gels with common gelling agents.
In this work, we studied effects of the gelling agents on the radiation sensitivity and dosimetric performance of Fricke gel dosimeters by means of absorption spectroscopy measurements. In addition to PVA, two common gelling agents were investigated, agarose and agar.

Experimental
Samples of Fricke gel dosimeters based on three gelling agents, PVA, agarose and agar were fabricated. Fricke PVA gel dosimeters were prepared from a 10% w/v aqueous solution of hydrolyzed 99% purity PVA with molecular weight between 85000 and 124000 (Sigma Aldrich), 1% w/v GTA, H_2SO_4 25 mM (Merck), and 1.5 mM ferrous ammonium sulfate hexahydrate and 0.165 mM xylenol orange. The gel was fabricated following the procedure described in [1].
Then, Fricke agarose gel dosimeter was prepared using agarose at 1% (Sigma Aldrich), 25 mM H_2SO_4 (Merck), 0.5 mM of ferrous ammonium sulphate hexahydrate (Sigma Aldrich) and 0.165 mM of xylenol orange (Sigma Aldrich). The gel was fabricated following the procedure described in [2]. Afterthat, Fricke agar gel dosimeter was prepared using agar at 3% (Sigma Aldrich), 25 mM H_2SO_4 (Merck), 0.5 mM of ferrous ammonium sulphate hexahydrate (Sigma Aldrich) and 0.165 mM of xylenol orange (Sigma Aldrich). The gel was fabricated following the procedure described in [3]. The prepared gels were poured into the cuvettes and stored in the dark in order to minimize possible autooxidation of ferrous ions. Figure 1 represents samples of the prepared Fricke gel dosimeters. Fricke gel samples were irradiated up to 50 Gy with a gamma cell 220 unit. The optical analyses of the dosimeters

were carried out using a spectrophotometer (BECKMAN COULTER-DU-800).

(a)

(b)

Figure 1. (a) Samples of the prepared Fricke gel dosimeters. (b) Color change of samples with dose increase.

Fricke infused gels suffer from spontaneous oxidation and diffusion of ferric ions after irradiation.. This is the main reason we added xylenol orange to the gels, however it can also change the color of samples as it can be seen in Figure2 (b).

Results and discussion

Absorbance spectra collected at consecutive times post irradiation showed that a time of approximately thirty minutes is sufficient to reach a stable value of the absorbance, indicating the achievement of a chemical equilibrium in the complexation processes between ferric and xylenol orange. The wavelength used for the absorbance measurements was chosen 585 nm (peak of the spectrun). Absorbances at this wavelength for different gelling agents and different doses were used to obtain dose response curves (relation between dose and optical absorbance). For each point of the curves, three samples were analyzed. Figure 2 shows the dose response curve of the fabricated Fricke gel dosimeters. As it can be seen, the absorbance at 585 nm of the dosimeters grows linearly with the dose up to 30 Gy. However, oxidation of ferrous ions continues even after the end of irradiation, which shifts the dose response function with time. Sensitivity of the dosimeters is, in fact, the slope of the dose response curve. As it can be seen in Figure 2, Fricke PVA gel dosimeters have more dose sensitivity compared to the Fricke gels with agarose and agar. Poor stability of Fricke gels due to the diffusion of ferric ions within agar and agarose Fricke gel dosimeters, imposes constraints upon the time between the irradiation and readout process whereas PVA-GTA Fricke gels with lower diffusion coefficient are promising tools for three dimensional dose measurements.

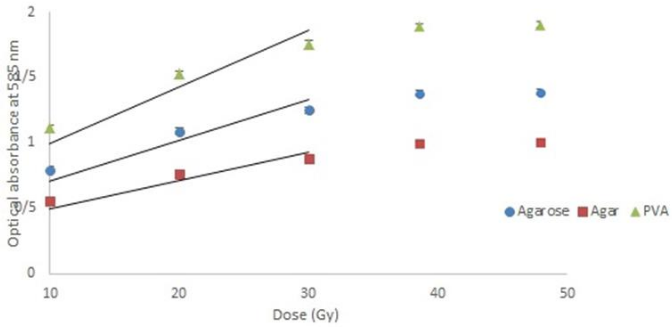

Figure 2. Dose response Curve of the fabricated Fricke gel dosimeters

Conclusions

In this work, we investigated effects of the gelling agents on response of Fricke gel dosimeters by means of absorption spectroscopy measurements. Three gelling agents were surveyed, PVA, agarose and agar. Formulations based on gel matrices of PVA chemically cross linked with GTA have shown improvements as compared to Fricke gels with the other gelling agents. The results showed that the diffusion process is slower in PVA-GTA gels than in agar and agarose ones. Also, Fricke PVA gel dosimeters have more dose sensitivity compared to the Fricke gels with agarose and agar. Determination of the diffusion coefficient of the gels is doing by the authors.

References

[1] F. Errico, et al. *Novel GTA-PVA Fricke gels for three-dimensional dose mapping in radiotherapy*, Rad. Meas. 106, 612 (2017).
[2] S. Gallo, et al. *Does the gelation temperature or the sulfuric acid concentration influence the dosimetric properties of radiochromic PVA-GTA Xylenol Orange Fricke gels?*, Rad. Phys. and Chem. 160, 35 (2019).
[3] C. Baldock, et al., *Investigation of temperature dependence of diffusion in agar fricke gel for MRI dosimetry*, Proc. ISMRM, 22, 1103, (1994).