Effect of bloom strength on radiochromic gel dosimeters

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Abstract. The Fricke gel dosimeter has been the widely used dosimeter among the gel dosimeters because of its dose response characteristics and easy preparation. The ferrous to ferric conversion that happens in this gel dosimeter on irradiation, corresponds to the absorbed dose of radiation. Gel dosimetry in India is not moving forward because of the import restrictions on the commercially available high bloom strength gelatin (imported 300 bloom). The feasibility of using Fricke gel dosimeter prepared with the locally available gelatin of 240 bloom and 200 bloom were compared with the 300 bloom gelatin taken as standard. The gel samples were prepared with 5% gelatin by weight and irradiated with $^{60}$Co gamma radiation for a dose range from 0-3 Gy used clinically. The optical absorption of gel samples were analyzed using spectrophotometer at 585 nm and dose response curves were generated. The results indicate that Fricke gels prepared with 240 bloom have linear dose response and comparable with those prepared with 300 bloom but the use of gels prepared with 200 bloom was found to be limited because of its poor optical transmittance.

1. Introduction
Fricke and Polymer gel dosimeters are manufactured from radiation sensitive chemicals, which upon irradiation polymerize as a function of the absorbed radiation dose [1]. These gel dosimeters which record the radiation dose distribution in three-dimensions (3D) have specific advantages when compared to one-dimensional dosimeters and two-dimensional dosimeters [2]. These 3D dosimeters are radiologically soft-tissue equivalent [3, 4] with properties that may be modified depending on the application. The 3D radiation dose distribution in polymer gel dosimeters may be imaged using magnetic resonance imaging (MRI) [5, 6], optical-computerized tomography (optical-CT) [7, 8], x-ray CT [9, 10], ultrasound [11, 12] or vibrational spectroscopy [13, 14].

Gelatin is the key ingredient in the gel dosimeter that holds the radiation induced change by holding it in its matrix for determination of dose [15-19]. The strength of the gel is often given in terms of “bloom strength”. Bloom strength is defined as the ability of the gelatin to swell when dissolved in water to form a matrix generally termed as gel strength. Though there are various bloom strengths of gelatin commercially available, the restrictions imposed by the government due to misuse of gelatin by anti-social elements have created an artificial non-availability of higher bloom strength gelatin in India. Hence the need arises to investigate the use of different bloom strengths of gelatin and their limitations when radiochomic gels are prepared with them.

The dose response of Fricke gel prepared with 270 bloom strength of gelatin has been reported [20] as good performance when compared with 300 bloom gelatin that is usually recommended for preparation of gels. However 270 bloom is also considered to be a higher bloom strength when looking for gelatin available in the local market. Further the non-availability of Type A gelatin at this bloom strength requires the use of Type B gelatin as an alternative. Studies on gelatin obtained from...
manufacturers in India (Rama industries, Mumbai, India) have showed that the source of gelatin whether it is from Porcine (Type A) or Bovine (Type B) did not alter the quality of gel prepared but bloom strength did affect the outcome [21]. Various researchers have investigated Fricke gel dosimeter, the role of various combinations of components and their influence on the optical properties [22-25].

The purpose of this study is to analyze the spectrophotometric response of Fricke gel dosimeter prepared with gelatin (300 bloom) and to compare the outcome with the cost effective 240 and 200 bloom gelatin locally available, belonging to Type B category.

2. Materials and Methods

Three different bloom strengths of gelatin 300 (Sigma), 240 (SD-fine), 200 (Raymon) were chosen for the experiments.

2.1. Preparation of Fricke Gel Dosimeter

Fricke gel dosimeter was prepared using 5% gelatin by weight. Gelatin was added to triple distilled water and stirred well for 1 hour inside a water bath maintained at 45°C. After 1 hour the gelatin solution was allowed to cool down to 25°C and required quantities of Xylenol Orange, Ferrous Ammonium Sulphate and 1 M H$_2$SO$_4$ were added. The final gel consisted of 50 mM H$_2$SO$_4$, 0.05 mM Xylenol Orange and 0.3 mM Ferrous Ammonium Sulphate. The gel solution was then transferred to cuvettes of 3.5 ml capacity and path length 1cm. The samples as gel solution were kept in the refrigerator for 12 hours maintained at 4°C.

2.2. Irradiation setup

The gel samples were irradiated on a $^{60}$Co gamma irradiation unit (Theratron-780C) for clinical range of doses ranging from 0-3 Gy for Fricke gel. The gel samples were placed in a water (23°C) bath kept on acrylic sheets for sufficient backscatter. The irradiation setup is shown in figure 1.

![Figure 1. Irradiation setup of Fricke gel samples in a water bath on $^{60}$Co Tele gamma unit.](image)

2.3. Evaluation of Gel samples

The samples were evaluated after 1 hour of irradiation using a UV-1800 spectrophotometer (Shimadzu, Japan) in the optical range of 200 – 900 nm. The wavelength for photometric measurement was fixed at 585 nm. Un-irradiated gel sample readings were subtracted from all measurement to account for pre-irradiation data from gel dosimeter.
2.4. Parameters studied
The cuvettes with the Fricke gel were analyzed for the optical absorption per path length of the gel (1 cm). The room temperature was at 28°C when the samples were measured. The physical condition of the gel samples at this temperature was also noted.

3. Results and Discussions
Dose response curves were generated from arithmetic mean of data from five samples of the gel dosimeter. The temperature during the preparation, irradiation and measurement of data using spectrophotometer was noted.

![Figure 2. Dose response of Fricke gel dosimeter prepared with 300, 240, 200 bloom gelatin evaluated at a wavelength of 585 nm.](image)

3.1. Fricke Gel – 300 Bloom
The Fricke gel dosimeter prepared with 300 bloom gelatine was taken as the reference. The measurements were performed at a wavelength of 585 nm (figure 2). Considering the uncertainties associated with the gel samples, the evaluation of $R^2$ value from the graph showed 99.77% reliability level for the gel dosimeter.

3.2. Fricke Gel -240 Bloom
The gel samples were stable at room temperature (28°C) and were similar to the physical condition of the samples of 300 bloom gelatin during irradiation and measurements. The transparency of the gel prepared with the 240 bloom gelatin was little lower than the 300 bloom gelatin when prepared as a bulk gel (~1 L) but did not seem to affect the dose response as it was similar to the linear dose response of gels prepared with 300 bloom gelatin.

3.3. Fricke Gel – 200 Bloom
Fricke gel dosimeters prepared with 200 bloom gelatin were less transparent than the 300 and 240 bloom gelatin. Moreover the gel samples were not affected at the temperature (28°C) but showed signs of melting when the room temperature increased more than 30°C. Though there were limitations, the gel samples prepared with 200 bloom showed linearity in dose response but poor optical transmittance when a larger quantity (~ 1 L) was prepared.

4. Conclusions
The obtained results indicate that the gels prepared with 240 bloom gelatin exhibit similar linearity in dose response when compared with 300 bloom gelatin and a potential substitute that is locally available at a low cost if the bloom strength can be improved further. Though the 200 bloom gelatin showed good dose response its use as a bulk gel is limited because of its lower optical transmittance.
Further studies on improving the gel strength of locally available 240 bloom gelatin should be performed to remove the limitations of its use.

5. References

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