COMMERCIAL SFG YELLOW CRL DYE AQUEOUS SOLUTIONS FOR GAMMA DOSIMETRY

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Aqueous solutions of the SFG Yellow CRL commercial dye can be used as chemical dosimeters in the absorbed dose range 200-1000Gy. The standard aqueous solutions were scanned by T80 UV/VIS spectrophotometer for the determination of maximum wave length ($\lambda_{max)}$ which was found to be 448 nm. At this value, the absorbance (A) of irradiated samples was measured in UV region. The plot between concentration C and A gave a linear relationship and hence verified Beer's Law which proved that these dye solutions can satisfactorily be used as the dye dosimeters in 200-1000Gy gamma dose range.

Keywords: Aqueous solutions; the SFG Yellow CRL dye; dosimetry; gamma irradiation; optical density (OD); radiolytic bleaching

INTRODUCTION

The knowledge about the amount of energy absorbed from the gamma radiation is known as radiation chemistry. In radiation chemistry, a quantitative estimation of the absorbed energy deals with its branch known as dosimetry and the system employed to do this job is known as dosimeter. Further, a setup that measures the amount of energy absorbed from the gamma radiations with respect to the chemical changes produced in the system on exposure to the radiation is called chemical dosimetry which requires calibration in order for its use as dosimeter and is termed as secondary dosimeter (Parwate *et al*., 2007).

There are numerous dosimeters such as ionization chambers, thermo-luminescent detectors (TLDs), radiographic films, silicon diode dosimeter, alanine dosimeter, plastic scintillators, diamond dosimeter, gel dosimeter, Fricke dosimeter and so forth, and are used for the evaluation of ionizing photons. However, dye dosimeters are well documented and different researchers used various colours such as congo red (Parwatea *et al*., 2007), brilliant green (Khan *et al*., 2002), anionictriphenyl- methane dye solutions (Nasef *et al*., 1995), methylene blue (Kovács *et al*., 1998) chlorantine fast green BLL (El-Assy, *et al*., 1991) and methyl red (Ajji, 2006) to make dye dosimeters. However, in this study the suitability of commercial SFG Yellow CRL dye is tested for the first time to be used as dye dosimeter. It is well known that the ionizing radiations cause bleaching of the aqueous dye solutions. This property of decolorization of dye can be used for dosimetry as the decomposition of the dye is linear with respect to the amount of dose absorbed (Parwate, *et al.*, 2007).

The aim of the present work was to explore that the synthetic commercial dye can be used as a dosimeter. It is known that commercial dyes contain pigmentations (coloring substances) which are used to impart color to the fibers. However, these dyes also have other uses like as chemical dosimeters for high gamma radiation doses (Khan *et al*., 2002). The corresponding chemical changes caused to the irradiated aqueous dye solutions by the ionizing radiations can be observed by the respective fading of the dye and hence is the measure of the incident γ-radiations (Nasef *et al*., 1995).

The dye used in this study was a commercial dye (SFG Yellow CRL), available with the Sandal Dyestuff Industries Pvt. Ltd. Faisalabad and is a cheap dye costing only Rs 300/kg. The chemical structure of the dye available with the company is presented in Figure 1.

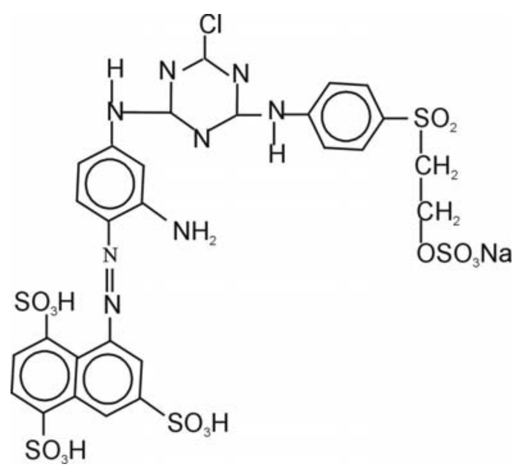

Fig. 1. The structure of SFG Yellow CRL

The overall objective of this work was to check for this commercial dye to respond to gamma radiation like as a dosimeter. Furthermore, the other parameters studied were the effect of dye concentration on the gamma response and the verification of Beer's law in order to find the suitability of this commercially available dye to be used for dosimetric studies in 200-1000Gy dose range.

MATERIALS AND METHODS

The stock solution of SFG Yellow CRL dye was prepared by preparing the dye concentration (0.125gm/L) in de-mineralized water that was collected from Steam Power Station, Faisalabad and had electrical conductivity less than 1μSiemens/cm. The pH of this solution was found to be nearly 7.0. The dye was readily dissolved in water at room temperature, 30^0C, because of its high solubility. From the stock solution, different concentrations of the dye such as C_1=136 μmol/L, C_2=68 μmol/L and C_3=4 μmol/L were prepared at different pH values. In dosimetric studies, those dye dosimeters are considered to be satisfactory which show a linear relationship between the concentrations (C) of the dye in the solutions and absorbance (A) measured at the primary absorption peak maxima that is actually verification of Beer's Law (Nasef *et al*., 1995).

For irradiation, the dye solutions were placed in 5 ml glass ampoules having internal diameter 1.03 cm and thickness 0.18 cm with fit in ground stoppers. Co^{60} gamma radiation source (Mark IV Irradiator) available at Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad and having dose rate of 12 Gyh^{-1} was used to irradiate the samples. All the samples were irradiated at room temperature (25^oC) by placing them inside the irradiation chamber at fixed positions in the gamma flux with the help of a fixed stand. The samples were irradiated according to pre-selected doses, i.e. 200Gy, 400Gy, 600Gy, 800Gy and 1000Gy. The samples were scanned for optical wavelength (λ_{max}) and the absorbance (A) measured by double beam T80 UV/VIS spectrophotometer having band pass setting of 1mm. The solutions were placed in the object beam in quartz glass, 10mm path lengths cuvettes, along with the reference beam cuvette containing the de-mineralized water.

RESULTS AND DISCUSSION

Figure 2 shows a linear relationship between absorbance (A) and concentration (C) and hence verifies Beer's Law which reveals that this dye can be used as a dosimeter.

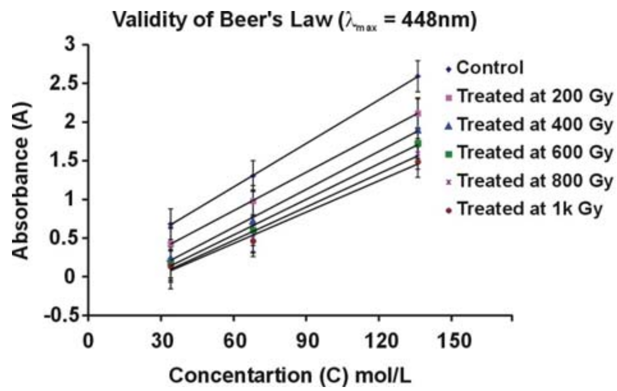

Fig. 2. The linear relationship between absorbance and concentration of the dye solutions

A_C = 0.018C+0.035; R^2=0.9999 (1)
A_{200} = 0.016C -0.142; R^2=1.0000 (2)
A_{400} = 0.016C -0.346; R^2=0.9976 (3)
A_{600} = 0.015C -0.380; R^2=0.9954 (4)
A_{800} = 0.014C -0.390; R^2=0.9910 (5)
A_{1k} = 0.0135C-0.380; R^2=0.9907 (6)

where A_C, A_{200}, A_{400}, A_{600}, A_{800} and A_{1k} stand for the absorbance of control and irradiated samples at 200, 400, 600, 800 and 1000Gy gamma dose respectively. The fitted lines show linear relationship between concentration (C) of the samples and absorbance (A). The slopes of all the fitted lines are almost the same whereas their Y-intercepts decrease gradually from higher to their lower values. Further, it is obvious from the values of Y-intercepts, that the value of intercept for the control response line is the highest of all other response lines and is the lowest of the line for A_{1k}. The reason of this decline seems to be that upon irradiation N=N double bond of this dye breaks which is actually responsible of pigmentation of dye and hence the absorbance of the sample solutions is decreased. Rauf and Ashraf (2009) have reported that upon irradiation of aqueous dyes, because of the radiolysis of H_2O molecule, $^{\bullet}OH$, $^{\bullet}H$ radicals and hydrated electron (e_{aq}^-) were produced such that e_{aq}^- added to the –N=N– double bond and produced the hydrazyl radical [–N–N–(OH)] and led to the destruction of the intense colour of the dye. Thus, the breakage of –N=N– double bond resulted in the fadedness of the pigmentation of the dye solutions (Solpan, *et al.*, 2003).

The absorption spectra of un-irradiated (control) and irradiated dye solutions were recorded in the range 330-570nm using demineralized water as blank. The absorption spectra of SFG Yellow CRL were recorded for the range of absorbed dose (200-1000Gy) of gamma rays is shown in Figure 3. Khan *et al.* (2002) studied the absorption spectra of un-exposed and gamma exposed samples of un-irradiated and irradiated aqueous solution of brilliant green dye in the range of 350-750nm and in the response spectra for the dye, they found two absorption peaks one at 427 and the other at 626nm. In our study, the spectra of control and irradiated samples also showed two absorption peaks one at 380 and the other at 448nm. Thus, wavelengths of maximum absorption (i.e. 380 and 448nm) should be the suitable wavelengths for the characterization of this dye dosimeter. Further, these spectra also showed that about 448nm wavelength, the absorbance decreased with the increase in the irradiation dose which confirmed the occurrence of bleaching of dye about both the regions of maximum wavelengths as the absorbed dose is increased. Hence, 448nm was chosen as the λ_{max} (the absorption peak). Ajji (2006) observed the similar behavior of the spectra while studying aqueous solution exposure of methyl red as dye dosimeter for gamma radiation.

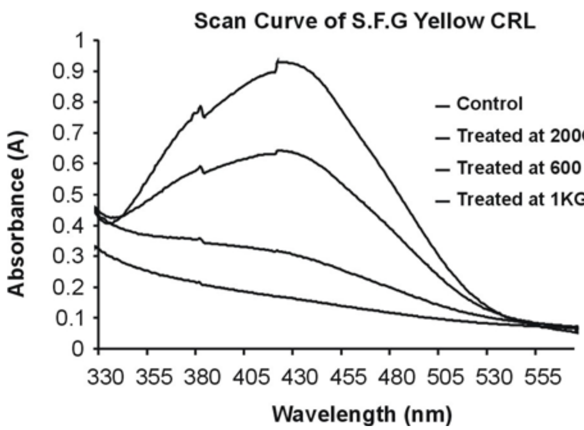

Fig. 3. Absorption spectra of control and treated samples of SFG Yellow CRL

The absorbance (A) at λ_{max} (448nm) versus absorbed dose (D) is represented in Figure 3. It is obvious from the figure that for all the cases there is a logarithmic relationship between the absorbance and absorbed dose. Ajji (2006) found similar exponential decline in the absorbance versus gamma dose response plotted for methyl red dye dosimeter. Further, applying fits of exponential decay (first order) for the decrease of the absorbance with respect to the gamma absorbed dose results in correlation coefficients (R^2) as shown below that all are in good agreement for the dose range between 200-1000Gy. Ajji (2006) had also reported similar behavior of methyl red dye dosimeter for the gamma dose ranging from 50-6000Gy.

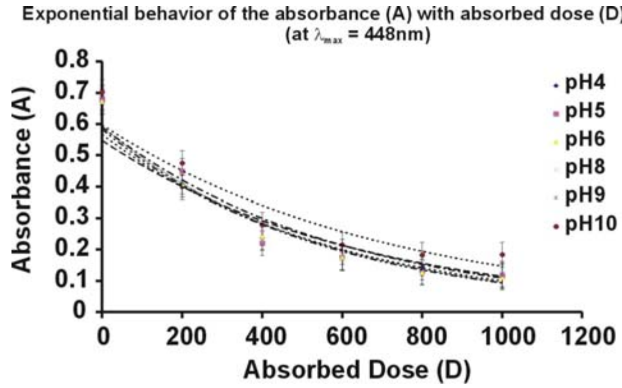

Fig. 4. Response of absorbance as a function of absorbed dose

$A_4 = 0.5662e$	$R^2 = 0.9522$	(7)
$A_5 = 0.5913e$	$R^2 = 0.9383$	(8)
$A_6 = 0.5831e$	$R^2 = 0.9641$	(9)
$A_8 = 0.5472e$	$R^2 = 0.8999$	(10)
$A_9 = 0.5903e$	$R^2 = 0.9628$	(11)
$A_{10} = 0.5969e$	$R^2 = 0.8984$	(12)

CONCLUSION

The decoloration and degradation of SFG Yellow CRL commercial dye in aqueous solution by gamma radiation has been demonstrated. The linear relationship found between absorbance and concentration verified Beer's Law which confirmed that SFG Yellow CRL commercial dye can be used as a dosimeter over a small range of gamma dose ranging from 200-1000 Gy. However, additional studies are still required to increase the radiation doses up to 10000 Gy, to evaluate the dose rate and energy dependency.

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