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Full Length Research Paper

A study on the response of natural dye to Gamma radiation as a dosimeter

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Red Cabbage (*Brassica oleracea*) contains a pigment called anthocyanine which changes color over different pH ranges. We examined spectrophotometrically the effects of gamma irradiation on aqueous solutions of red cabbage dye to facilitate industrial applications. Samples were exposed to Cs-137 γ source from 0-100 kGy. Irradiation greater than 60 kGy clearly affected the major colorant in extracts of red cabbage leaves. Dosimetric characterization on basis of dye concentration and pH values was also described which showed that these dye solutions can satisfactorily be used as dye dosimeters in gamma dose range of 60-100 kGy.

Key words: Aqueous solutions, red cabbage dye, gamma irradiation, optical density (OD), decolouration.

INTRODUCTION

The passage of ionizing radiation in many chemical compounds may produce chemical changes and if the change can be quantified, it can be used as a technique to quantify absorbed dose. Many dye solutions are used for this purpose. Since most dyes are colored in nature, it is relatively easy to monitor their color change during the course of experiment. It is well known that there are several aqueous solutions of chemical compounds which are used as gamma radiation dosimetry (Ahmad and Pausa, 2007; Barakat et al., 2001; Ebraheem et al., 2003; Hasan et al., 2002). The research work on aqueous solution of brilliant green used as low dosimeters was carried out by Galante et al. (2006). Radiation effects on different type of dosimeters (Farah et al., 2004; Hussain et al., 2009: 46(1): 78-81) and in some polymeric films (Baker et al., 2007; Buenfil et al., 2002; El-Assy et al., 1991; Hussain et al., 2009: 46(3): 224-227) have been reported. To date there is limited information on chemical dosimetry using natural dyes (Davies et al., 2010). Hence, in this paper, the development of a new γ-ray dosimeter was reported based on the use of natural dye extracted from red cabbage leaves. Its leaves are of red/purple color but changes color according to the soil pH value. Anthocyanine pigment is responsible for this color change. Because of this property, red cabbage juice is used to monitor levels of ionic hydrogen in solutions, for dying purpose and also as pH indicator. The overall objective of this work is to check for this natural dye to respond to Gamma radiation as a dosimeter. Furthermore, the other parameters studied were the effect of dye concentration, effect of pH and degree of discoloration. Structure of cyanidin, the type of anthocyanin in red cabbage is given in Figure 1.

MATERIALS AND METHODS

Red Cabbage leaves were dried at room temperature and ground to make fine powder. Red Cabbage powder (3.0 g) was boiled for 20 min in 400 ml of water at 80°C temperature to make a solution of 7.5 g/L concentration. The prepared solution color was blue and pH was 7.0. The solution was filtered and different concentrations of the solution were prepared such as: NDc1 = 7.5 g/L, NDc2 = 3.75 g/L, NDc3 = 1.875 g/L at different pH values by using 1 molar solution of Sodium Hydroxide (NaOH) and Hydrochloric acid (HCl). At pH 5, the solution color

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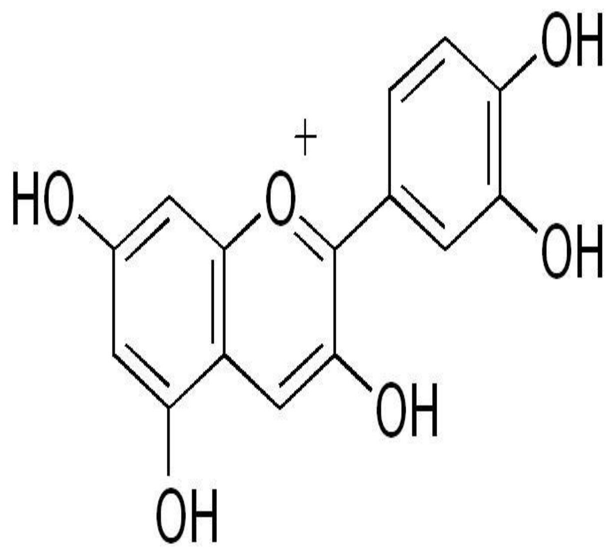

Figure 1. Structure of cyanidin, type of anthocyanin in red cabbage.

turned into light purple and at pH 10, the color turned into green due to Red Cabbage pH indicator characteristic. 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 (Emi et al., 2007). For irradiation, the dye solutions were placed in 5 ml glass ampoules having internal diameter of 1.03 cm and thickness of 0.18 cm with fit in ground stoppers (Shahid et al., 2013). Cs-137 gamma radiation source (Mark IV Irradiator) available at Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad and having dose rate of 1 kGy/1.5 h was used to irradiate the samples. All the samples were irradiated at room temperature by placing them inside the irradiation chamber at fixed positions in the gamma flux with the help of a fixed stand (Shahid et al., 2012). The samples were irradiated according to pre-selected doses, that is, 60, 70, 80, 90 and 100 kGy. The samples were scanned for optical wavelength (λ_{max}) and the absorbance (A) measured by T80 UV/VIS spectrophotometer having band pass setting of 1 mm. Beer's Law was verified by plotting the absorbance (A) versus concentration (C).

RESULTS AND DISCUSSION

Decoloration on the basis of absorption spectra

UV/VIS comparative images of red cabbage dye before and after irradiation were recorded in the range of 380-700 nm. Absorption band maxima (λ_{max}) for controlled acidic samples were found to be 520 nm and for alkaline solutions λ_{max} was shifted to 430 nm, while the value of absorbance decreased with increasing absorbed dose.

Radiation induced color changes found in red cabbage dye solutions indicated its structural changes which may be due to electron movement or confinement in a double bond. Upon irradiation, the electrons of the ring structures interact with incoming light and absorb various frequencies (Farah et al., 2004). As the side groups vary, the frequencies of electrons vary, more confinement makes the light absorbed bluer (shorter wavelength), and less confinement makes it red (longer wavelength). Also the cyanidin molecule in solution having hydroxide groups (OH) upon irradiation gives up their hydrogen atoms, as ions, into the surrounding water. When they lose the H, their resonant frequency shifts a bit towards shorter wavelengths.

Dose dependent response curve

Aqueous solutions of red cabbage dye having different concentrations and different pH values were exposed to gamma radiations. The absorbance of the irradiated samples decreased with increasing absorbed dose. Negative logarithm of absorbance (- log A) was plotted against absorbed dose for each concentration as shown in Figures 2, 3 and 4, which showed that for certain concentrations, this relationship gives a linear response function (Shahid et al., 2013). Useful dose range found for dosimetric applications was 60-100 kGy.

Concentration based dosimetric behavior

Three different concentrations of the solution were prepared: NDc1 = 7.5 g/L, NDc2 = 3.75 g/L and NDc3 = 1.875 g/L. It was found that with increase of concentration, absorbance increased thus verifying

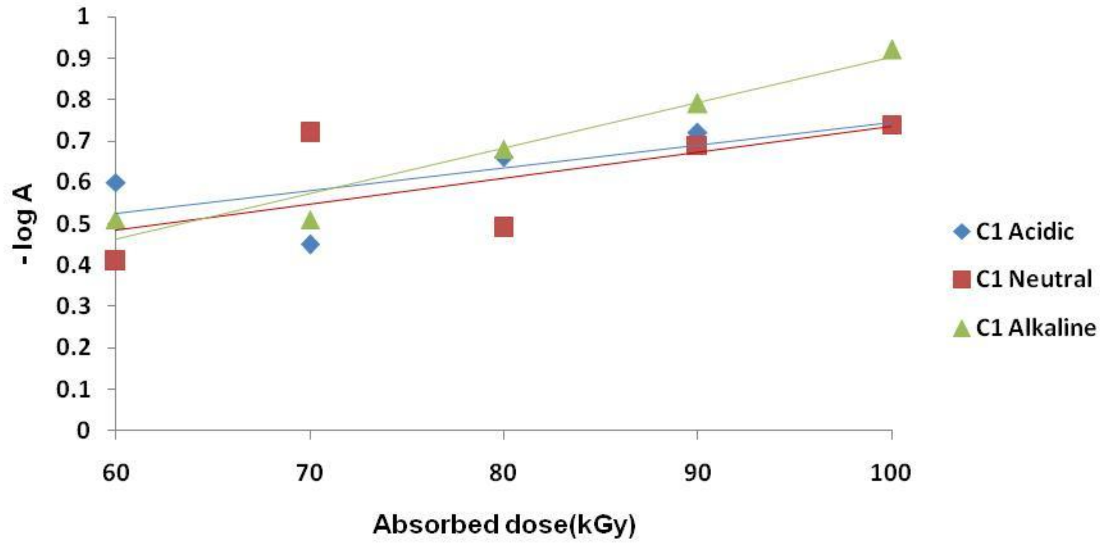

Figure 2. Absorbed dose versus negative logarithm of A for C1=7.5 g/L.

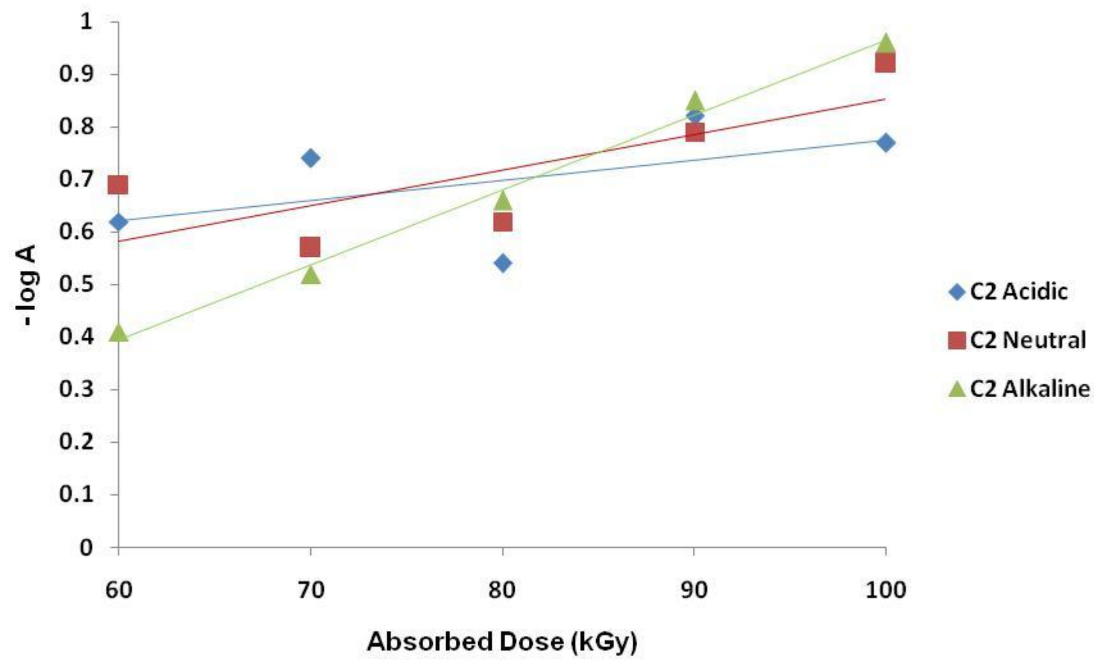

Figure 3. Absorbed dose versus negative logarithm of A for C2=3.75 g/L.

Beer's law.

It can be observed in Figures 2, 3 and 4 that the dose response curve of samples of concentration NDc1 = 7.5 g/L and NDc2 = 3.75 g/L, followed a linear relationship as compared to that of concentration NDc3 = 1.875 g/L. Dosimetric dependency on the aforementioned concentrations is clearly shown in Figure 5 where c1 and c2 show exponential decay as compared to the c3 concentration. Therefore, the solutions of the first two concentrations gave ideal results and can be used for dosimetric purposes in the dose range of 60-100 kGy.

Effect of pH value

Effect of absorbed dose and decoloration of natural red cabbage dye was studied at different pH value solutions. pH versus % decoloration was plotted as shown in Figure 6. Results showed that maximum decoloration was

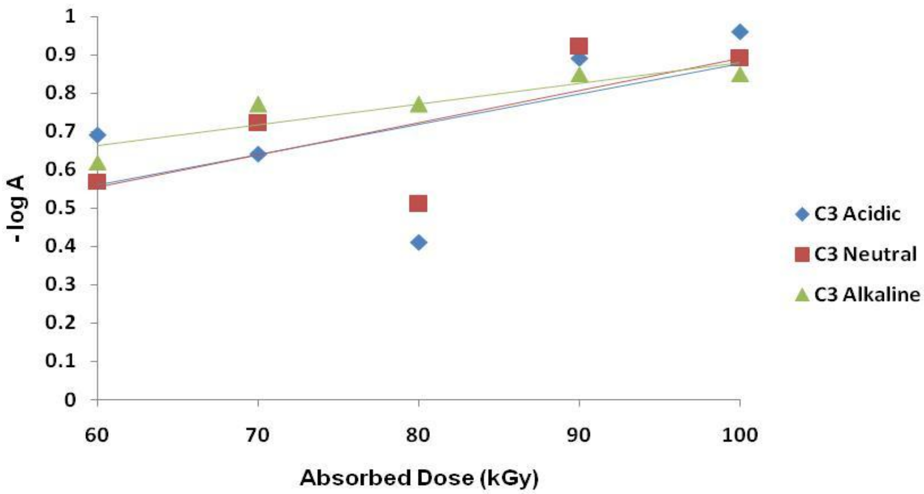

Figure 4. Absorbed dose versus negative logarithm of A for C3=1.8 g/L.

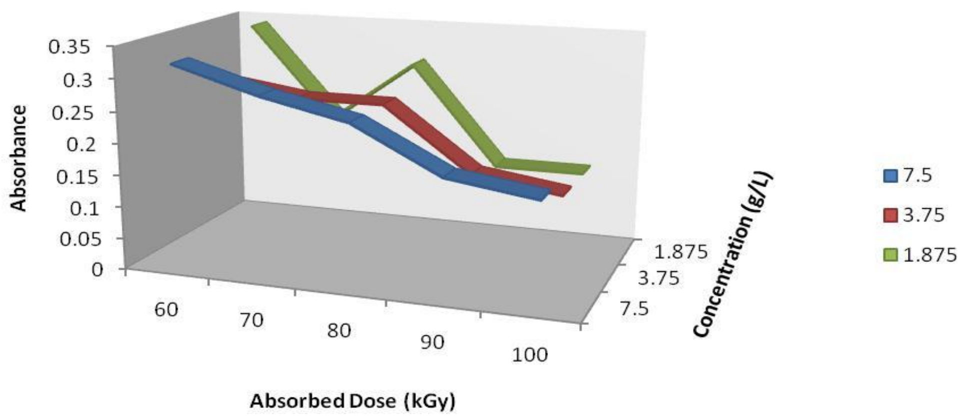

Figure 5. Graph between absorbed dose, absorbance and concentration.

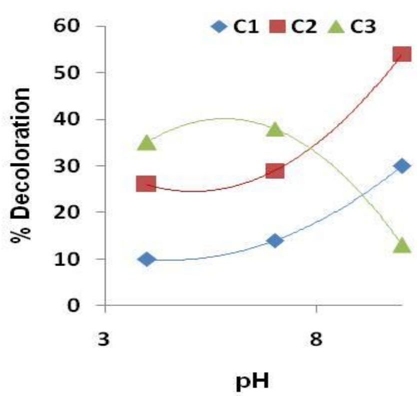

Figure 6. pH versus % decoloration for all three concentrations.

Obtained for alkaline samples as compared to neutral or acidic sample solutions. More than 50% decoloration was achieved for NDc2 = 3.75 g/L sample solution which was highest among all concentrations. So the alkaline nature of this dye dosimeter would give the best results.

APPLICATIONS

In this study, chemical dosimeters were applied for high gamma radiation doses.

Conclusions

The spetrophotometric analysis and gamma radiation response of a natural dye (red cabbage dye) was investigated. Decoloration of dye, effect of concentration, change of absorbance spectra and pH values were demonstrated. This natural dye was found useful for the routine dosimetry purposes in the dose range of 60-100kGy. Maximum delcoloration achieved was 54% providing the fact that large absorbed dose is required to completely degrade dye molecules of natural dyes as compared to the synthetic dyes. The dose range can be increased by varying the concentration of dye solute. The alkaline samples showed linear dose response and high decoloration as compared to acidic or neutral ones. In order to avoid light effects on the dye response, their storage in dark room was suggested before and after irradiation. These solutions were found to be highly stable for longer period of time before and after irradiation and have negligible humidity effects as well. They are easy to prepare in laboratory and do not require toxic solvents in their preparation. On the basis of properties, it was suggested that these dyes will be most suitable for large scale production and application for routine monitoring.

FUTURE RECOMMENDATIONS

Sensitivity of dye solutions may be increased by using aqueous alcoholic solvents instead of only demineralised water and also by applying high humidity environment. The response of the dye may be affected by increasing irradiation temperature or the greater dose rate than the present (that is, 1kGy/1.5 h). However, additional studies are still recommended to evaluate the dose rate and energy dependency. Moreover, physio-chemical environment of the lab may also be controlled during study.

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