Available online at www.sciencedirect.com
ScienceDirect
NUCLEAR SCIENCE AND TECHNIQUES
Nuclear Science and Techniques, Vol.18, No.3 (2007) 141–144

Aqueous solution of basic fuchsin as food irradiation dosimeter

Hasan M. KHAN* Shagufta NAZ

(Radiation Chemistry Laboratory, National Centre of Excellence in Physical Chemistry, University of Peshawar, Peshawar 25120, Pakistan)

Abstract Dosimetric characterization of aqueous solution of basic fuchsin was studied spectrophotometrically for possible application in the low-dose food irradiation dosimetry. Absorption spectra of unirradiated and irradiated solutions were determined and the decrease in absorbance with the dose was noted down. Radiation-induced bleaching of the dye was measured at wavelengths of maximum absorption λ_{max} (540nm) as well as 510nm and 460 nm. At all these wavelengths, the decrease in absorbance of the dosimeter was linear with respect to the absorbed dose from 50 Gy to 600 Gy. The stability of dosimetric solution during post-irradiation storage in the dark at room temperature showed that after initial bleaching during first ten to twenty days, the response was almost stable for about 34 days. The study on the effect of different light and temperature conditions also showed that the response gradually decreased during the storage period of 34 days, which shows that basic fuchsin dye is photosensitive as well as thermally sensitive.

Key words Basic fuchsin, Food irradiation, Dosimeter, Absorbance

CLC numbers TL818, TQ615.3

1 Introduction

Food irradiation can play an important role in Pakistan in overcoming food shortage and preventing food losses. Substantial quantities of food materials of different types, such as grains, fresh fruits, vegetables and dry fruits are damaged or lost during post-harvest storage in Pakistan.[1] Since gamma radiations will be used more widely for insect control, seed and vegetable sprouting inhibition, vegetable and fruit shelf-life extension,[2] standardization and quality assurance in these technologies require quantitative determination of amount of radiation absorbed by the material.[3,4]

Radiation dosimetry deals with dosimeter-reading, dose distribution inside the material and dose rate at any point of interest in the radiation field. Dosimetry is used in the development, commissioning and control of radiation processes. It is consequently essential for the successful commercial exploitation of this new industry. And it is consequently accepted methodology that is applied to ensure that a radiation process meets specification and also to ensure that results obtained in the laboratory can be reproduced elsewhere, either in another laboratory or in commercial radiation facility.

The objective of the present work is to measure quantitatively the absorbed dose using aqueous chemical dosimeter, such as dyes, and to compare their dosimetric characteristic pertinent to concentration of dye and post-irradiation storage. In this regards, the dosimetric characteristics of aqueous basic fuchsin dosimeter has been studied. Spectrophotometric response of aqueous solutions of basic fuchsin has been investigated as gamma ray dosimeter. Radiation induced response is coloration or fading of colour in different parts of UV-visible or IR spectrum, usually analysed by spectrophotometer or densitometer.

2 Experimental

Aqueous solution of basic fuchsin (3.13×10^{-5} mol/L) was prepared by dissolving 0.01 g of basic fuchsin (Aldrich) in 1 litre of triply distilled water. Similarly 6.5×10^{-5} mol/L aqueous solution of basic fuchsin was prepared by dissolving 0.021 g of basic

* Correspondence author: hmkhan3@gmail.com
Received date: 2007-03-06

fuchsin in 1 litre of triply distilled water. The triply distilled water was prepared in the laboratory from singly distilled water, which was re-distilled first in basic potassium permanganate followed by in acidic potassium dichromate solutions.[5,6] All the chemicals used in the present study, such as sulphuric acid (Merck), potassium dichromate (Merck), potassium permanganate (Merck), ferrous sulphate (B.D.H.) and basic fuchsin (Aldrich) were of reagent grade.

The dosimetric solutions were protected from light before and after irradiation by using aluminium foil. Irradiations were carried out with ^{60}Co gamma ray source at the Nuclear Institute for Food and Agriculture (NIFA), Tarnab, Peshawar. Fricke dosimeter was used to find the dose rate at fixed irradiation position.[7]

Spectrophotometric measurements were made using a calibrated double beam UV-visible scanning spectrophotometer (Shimadzu model 160A), using 1 cm path length cell. For studying the post-irradiation stability of response, the dosimetric solutions in glass-stoppered test tubes were irradiated to desired dose level and were stored in the dark at room temperature. Absorbance measurements were made at the selected wavelengths (540, 510, and 460 nm) at different intervals of time.

3 Results and discussion

The absorption changes in 3.13×10^{-5} mol/L and 6.5×10^{-5} mol/L aqueous basic fuchsin solutions at pH 5 when irradiated by the gamma rays have been studied in detail in order to investigate its possible use as radiation dosimeter.

3.1 Absorption spectra of unirradiated and irradiated solutions of basic fuchsin dosimeter at pH 5.0

To select suitable wavelengths for the dosimetric characterization, the absorption spectra of unirradiated and irradiated solutions were determined in the spectral range of 250 nm-800 nm. The spectra showed that there was the decrease in absorbance around the maximum absorption wavelength, i.e. around 540 nm (λ_{max}), with the formation of small peak at 290 nm as the absorbed dose increased. The wavelength of maximum absorption (540-555 nm) should be the most suitable wavelength for studying the dosimetric properties of the basic fuchsin dosimeter at pH 5.0. However, in principle any wavelength in the range studied (200-600 nm) can be used for the dosimetry. In the present study the absorbance was measured at 540 nm as well as at 510 and 460 nm. For irradiations the dye solutions were held in the 10 mL stopper glass test tubes. The irradiations were carried out in the central position of a ^{60}Co gamma ray irradiator at NIFA. The absorbed dose rate was 450 Gy/h. The temperature during the irradiation was 25℃. The optical absorption spectra and the values of absorbance at specified wavelengths were measured by a spectrophotometer using the band pass setting of 1.0 nm. The absorbance of solution was determined in 10 mm path length quartz cell with reference to distilled water. The radiation-induced loss in the absorbance of dye was measured at selected wavelengths at different absorbed doses. The absorption spectra of unirradiated and irradiated basic fuchsin solutions are shown in Fig.1.

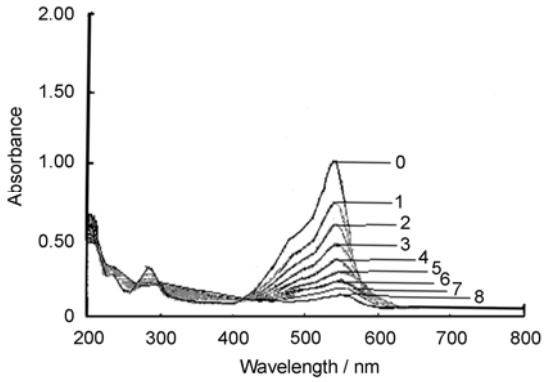

Fig.1 Absorption spectra of 6.5×10^{-5} mol/L basic fuchsin aqueous solution before irradiation (0) and after irradiation to different doses (1=100, 2=200, 3=300, 4=400, 5=500, 6=600, 7=700 and 8=800 Gy).

3.2 Response curve and useful dose range of basic fuchsin dosimeter

Response curve is essential to finding useful dose range of the dosimeter. Response curve is the plot showing change in absorbance of the irradiated dosimeter at selected wavelength against the absorbed dose.

Response curves at 540 and 510 nm have been plotted for 3.13×10^{-5} mol/L aqueous basic fuchsin solution at pH 5.0 as shown in Fig.2. The response of the dosimeter was found to be linear in the dose range of

50 to 600 Gy at 540 and 510 nm. The results are similar to those found earlier for aqueous solutions of coumarin and ferrous-cupric sulphate.[8,9] The response curves deviate from linearity at higher doses.

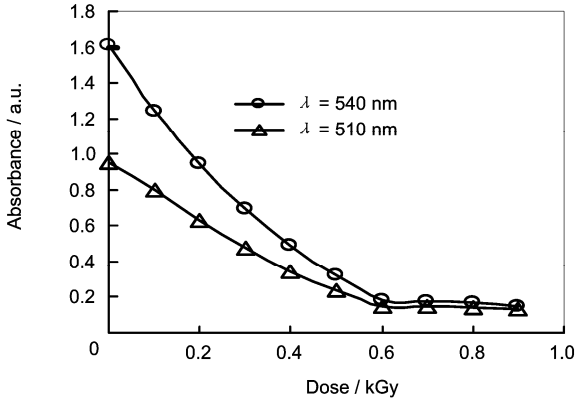

Fig.2 Response curve for 3.13×10^{-5} mol/L aqueous basic fuchsin solution at pH 5.0 showing absorbance versus absorbed dose at 540 and 510 nm.

A similar change in absorbance (i.e. ΔA= absorbance of unirradiated – absorbance of irradiated solution) for 3.13×10^{-5} mol/L was also plotted versus the absorbed dose. The response was also found to be linear in the dose range of 50 to 600 Gy at 540 and 510 nm at pH 5.0. Results are shown in Fig.3. This dose range is useful for food irradiation dosimetry, for the purpose such as inhibition of sprouting in potatoes, garlic and onions.

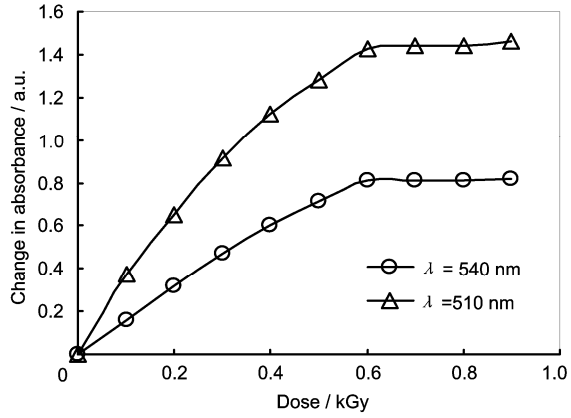

Fig.3 Response curve for 3.13×10^{-5} mol/L aqueous basic fuchsin solution at pH 5.0 showing change in absorbance versus absorbed dose at 540 and 510 nm.

According to well-known Beer's law, it is possible to express the radiation response as follows.[10]

$$D = - k \log A$$

Therefore, the response function for 3.13×10^{-5} mol/L aqueous basic fuchsin solution was also tried in terms of (-log A) versus absorbed dose (D). Results at 540 and 510 nm are shown in Fig.4. The figure showed a linear response in the dose range of 50 to 600 Gy. These results are similar to those shown in Figs.2 and 3 and those found earlier for several dye solutions, such as for aryl sulfonic substituted para diethyl amino triphenylmethane dye solution.[10]

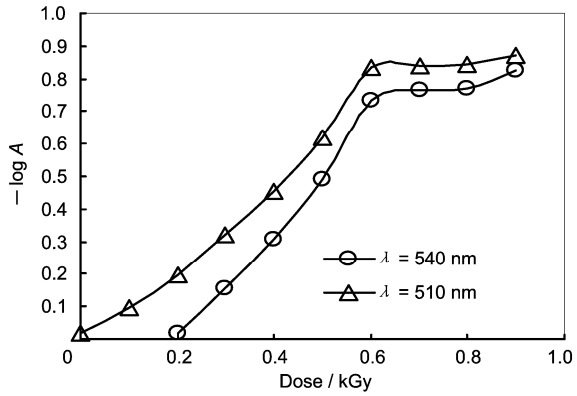

Fig.4 Radiation response function for aqueous solution of basic fuchsin (3.13×10^{-5} mol/L), in terms of negative Logarithm of absorbance measured at the absorption peak (540 nm) and 510 nm at pH 5.0 as a function of absorbed dose.

In order to check the effect of concentration on the response curve, the response curves for 6.5×10^{-5} mol/L aqueous basic fuchsin solution at pH 5.0 were determined at 540 (λ_{max}), 510 and 460 nm by plotting the absorbance versus absorbed dose. The results are presented in Fig.5 showing linearity in the dose range of 50 to 600 Gy. Therefore, increasing the concentration of dye by two folds has no effect on the useful dose range of aqueous basic fuchsin solution when analysed at 540 (λ_{max}), 510 and 460 nm. These results are comparitive to those found for coumarin and ferrous-cupric sulfate dosimeters.[8,9]

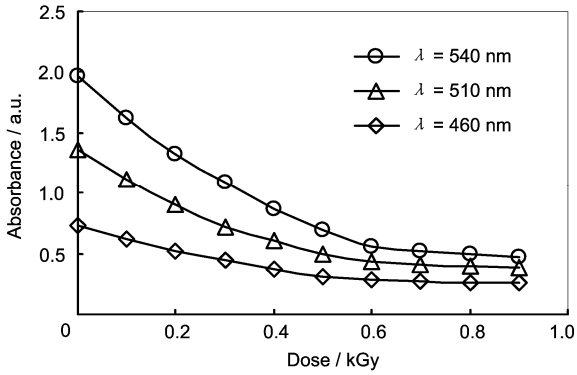

Fig.5 Response curves for 6.5×10^{-5} mol/L aqueous basic fuchsin solution at pH 5.0 showing absorbance versus absorbed dose at 540, 510 and 460 nm.

3.3 Post-irradiation stability

To study post-irradiation stability of the dye solutions, the irradiated solutions (100 Gy) in stopper test tubes were wrapped in aluminum foil to protect them from light and stored at 25℃. The stability of the response during post-irradiation storage was studied for about one month. The spectrophotometric measurements of absorbance were made at a number of wavelengths, such as 540 and 460 nm as shown in Fig.6. The results showed that the irradiated basic fuchsin dosimeter is not stable and the absorbance of the dosimeter decreased rapidly till 10-20 days. These results show that the responses of dosimetric solution are not stable during storage at room temperature and the response should be measured as soon as possible.

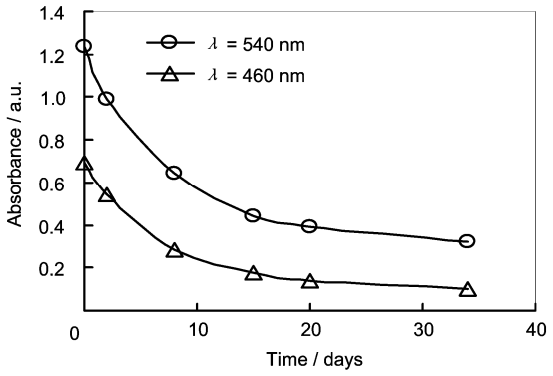

Fig.6 Post-irradiation stability of 6.5×10^{-5} mol/L aqueous basic fuchsin solution irradiated to 100 Gy stored at room temperature (25℃) in the dark.

4 Conclusions

In the present work the dosimetric characteristics of aqueous solutions of basic fuchsin has been investigated spectrophotometrically at pH 5.0. It can be concluded from the present work that the basic fuchsin aqueous solution absorbs UV-Visible light with maximum absorption around 540 nm. On irradiation the absorbance at 540 nm decreased while a peak around 290 nm was formed and its absorbance increased with absorbed dose. The response curves for the basic fuchsin dosimeter at pH 5.0 suggests that the dosimetric solution can be useful in the dose range of 50 to 600 Gy and changing the concentration of the dye solution from 3.1×10^{-5} to 6.5×10^{-5} mol/L does not increase the useful dose range for the dye solution. The dye solution after irradiation is not stable and the response should be measured immediately after irradiation or provision for post-irradiation decay should be made.

References

1 Banaras M. Research & development for maintaining post-harvest quality of fruits and vegetables & safety of their food products, in Proceedings of the National Executive Symposium on Technologies Developed for Commercialisation Challenges & Opportunities (Ihsanullah and SanaUllah, Eds.), NIFA, Peshawar, 2003: 234.

2 McLaughlin M L, Hussmann E K, Eisenlohr H H, *et al*. International Journal of Applied Radiation and Isotopes, 1971, **22**: 135.

3 Mahesh K. Introductory aspects of radiation, in Techniques of radiation dosimetry (Mahesh K, Vij D R, Eds.), New Delhi: Wiley Estern Limited, 1985.

4 Nofel M. IAEA Bulleten, 1987, **29**: 43.

5 Allen A O. Radiation chemistry of water and aqueous solution. New York: D. Van Nostrand Company, Inc., 1961: 18.

6 Holm N W, Zagorski Z P. Aqueous chemical dosimetry, in Manual on radiation dosimetry (Holm N W, Berry R J, Eds.), New York: Marcel Dekker, 1970: 83.

7 Sehested K. The fricke dosimeter, in Manual on radiation dosimetry (Holm N W, Berry R J, Eds.), New York: Marcel Dekker, 1970: 313.

8 Khan H M, Anwar M. J Radioanal Nucl Chem Letters, 1993, **175**: 199.

9 Khan H M, Anwar M. J Radioanal Nucl Chem Letters, 1993, **175**: 191.

10 Elssy N B, Dung C Y, Walker M L, *et al*. Radiation Physics and Chemistry, 1995, **46**: 1189.