Applied Magnetic Resonance (2020) 51:1041–1047
https://doi.org/10.1007/s00723-020-01244-8

Applied
Magnetic Resonance

ORIGINAL PAPER

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EPR Investigation of Mix of Sucrose and Ascorbic Acid Irradiated with γ-Rays

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Received: 29 June 2020 / Revised: 31 July 2020 / Published online: 28 August 2020

Abstract
Mixes of sucrose and various proportions of ascorbic acid were irradiated with γ-rays and studied by an electron paramagnetic resonance (EPR) spectroscopy. Before irradiation no EPR signals have been recorded. After irradiation an EPR spectrum of sucrose has been observed from all samples independently of the quantity of ascorbic acid. The influence of the microwave power and the modulation amplitude on the EPR intensity was reported. It has been found that the EPR signal intensity of sucrose decreased when the ascorbic acid is added to it. This result suggests that ascorbic acid play role of free radical scavenger because of its antiradical activity.

1 Introduction

In the recent past it is known that sucrose and ascorbic acid showed good results as dosimeter using EPR technique [1–7]. However, there is still considerable interest in improving the accuracy and precision of the existing systems as well as in developing new systems with improved characteristics. Use of unstable organic radicals in a matrix of an inorganic material is an innovative idea of Sato and Ikeya for dosimetry [8]. Similar to this idea, in the present study was mixed two organic compounds such as sucrose and ascorbic acid and the mixture was investigated in two directions: as a potential dosimetric material and as matrix for studying the radio-protected properties of ascorbic acid. Sucrose and ascorbic acid separately show stable EPR spectra which made them useful dosimetric materials. Mixing of the substances may lead to following effects: synergism, additivity and antagonism of their dosimetric properties. Because of the good dosimetric characteristics of sucrose the addition of ascorbic acid gives us a reason to expect additivity or synergism effect of the dosimetric properties of the new substance with one single aim to increase the sensitivity of sucrose as a dosimeter. With regard to the radio-protected capability of ascorbic

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acid, there are only a few works that have studied this capacity of the ascorbic acid [9–11]. To our best knowledge, the EPR technique has not been used for that aim up until now. The all mentioned up to here determinate the purpose of the present work, namely study of the mix material sucrose/ascorbic acid with EPR spectroscopy and finding its future applications.

2 Experimental

2.1 Sample Preparation and Irradiation

Sucrose and ascorbic acid (AA) were bought from Sigma Aldrich. The samples were prepared by mixing of ascorbic acid with saturated water solutions of sucrose followed by co-precipitation of the solution. Different proportions of ascorbic acid were used—2, 5, 30 and 50%. Three samples for each mixture were prepared and were irradiated with gamma rays (^{137}Cs source, dose rate of 200 Gy/h, doses 20 kGy). For control of the absorbed dose distribution alanine dosimeters (Kodak BioMax) were used, measured by an ESR spectrometer E-scan Bruker and calibrated in units of absorbed dose in water. The irradiation was performed in air and at room temperature. After irradiation all samples were kept in closed plastic bags in a desiccator at room temperature.

2.2 EPR Measurements

The EPR spectra were recorded by JEOL JES-FA 100 EPR spectrometer operating in the X-band with standard TE_{011} resonator at room temperature. The experimental data from three consecutive measurements of the EPR spectrum of each of the samples including inserting–removing–inserting just in the center of the EPR cavity were averaged. In that way the reproducibility of the EPR response was found to be within ± 2% (SD = 0.01).

3 Results and Discussion

3.1 EPR Spectra

Non-irradiated sucrose and ascorbic acid do not exhibit EPR spectra. Irradiated individual samples of sugar and ascorbic acid have an EPR spectrum typical for each of them (Fig. 1).

3.2 Dependence of the Signal Intensity of Sugar and Ascorbic Acid on the EPR Parameters

In order to make the measurements instrumentally independent, the influence of the parameters as microwave power and modulation amplitude was studied. With that

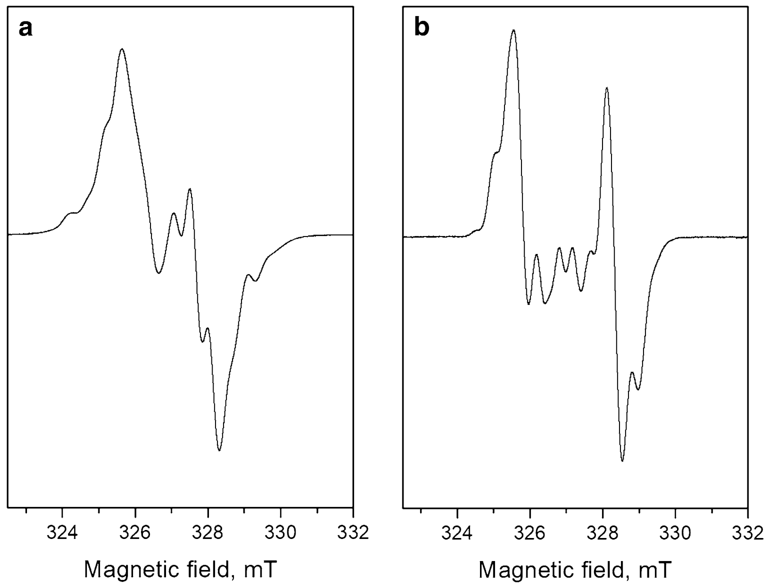

Fig. 1 EPR spectra of irradiated sucrose (**a**) and ascorbic acid (**b**) recorded 72 h after irradiation with γ-rays

aim irradiated samples were positioned in the center of the cavity and EPR spectra were recorded at different instrumental settings.

The influence of the applied microwave power on signal intensity on the recorded EPR spectra of sucrose and AA is given in Fig. 2a. As can be seen, the EPR intensity sharply increases with increase of the microwave power from 0.1 to 1 mW for sucrose and from 0.1 to 0.25 mW for AA. With respect to the modulation amplitude (Fig. 2b), the EPR signal intensity increased linearly to 0.4 and 0.6 mT for AA and sucrose, respectively. Thus having in mind that in the present investigation both substances are simultaneously recorded 1 mW microwave power and 0.4 mT modulation amplitude were used.

The EPR spectra of the mixed sucrose and ascorbic acid are given in Fig. 3.

As can see from the figure in the spectrum of mixed material, the EPR spectrum of sucrose dominates and no EPR spectrum due to ascorbic acid is recorded. The possible reasons could be the overlapping of the signals or interaction between the free radicals of ascorbic acid and sucrose. Because of the radical scavenging ability of ascorbic acid, it catches the free radicals in sucrose and leads to decreased number of radicals in it and therefore of the intensity of the signal in comparison with the pure sucrose.

3.3 EPR Response

Figure 4 shows the changes in the EPR signal intensity of sucrose when it is irradiated simultaneously with different percent content of ascorbic acid. S means pure

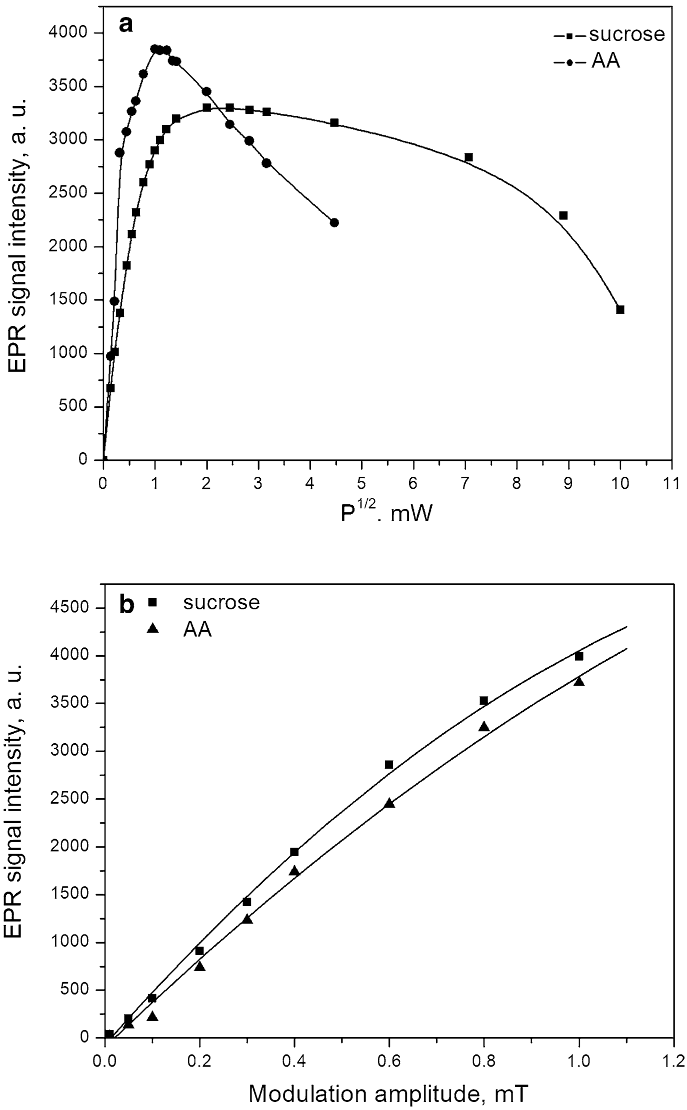

Fig. 2 Dependence of the EPR signal intensity of the square root of microwave power (**a**) and the modulation amplitude (**b**)

sucrose, AA—pure ascorbic acid, whereas content of ascorbic acid in the mixed materials is shown in percent under every bar.

For that study, three samples from every kind are used and the spectrum is recorded three times for every sample. The mean values of the intensities are summarized in Fig. 4. It is seen from Fig. 4 that the EPR intensity of sugar is decreased not proportional to its content in the mixture with AA. This decrease most probably is due on the one hand to the decrease of sucrose content in the

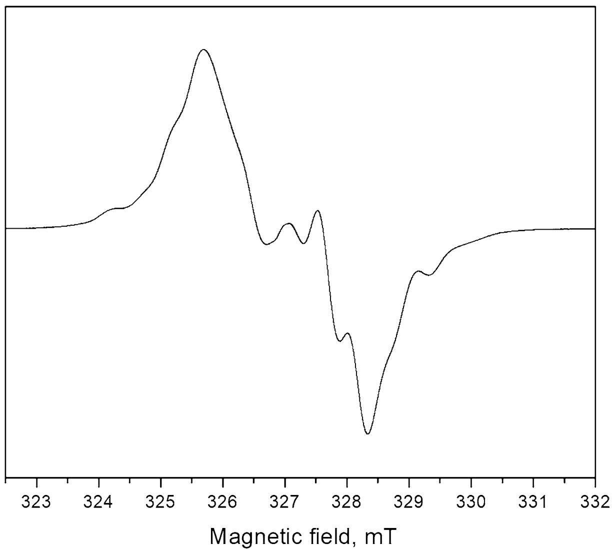

Fig. 3 EPR spectrum of mix of sucrose and ascorbic acid

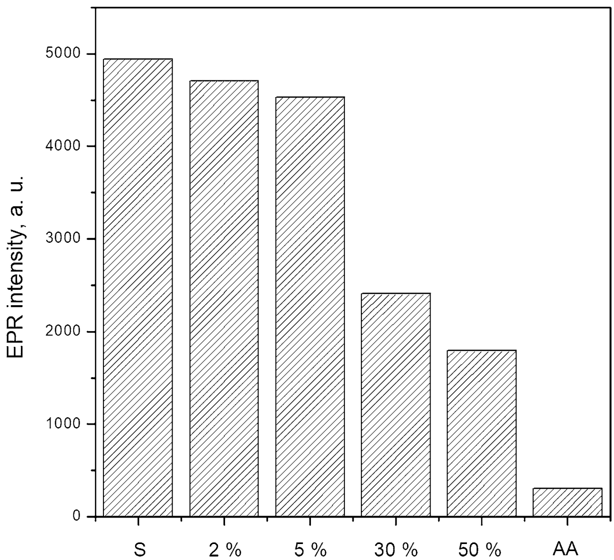

Fig. 4 EPR signal intensity of irradiated sucrose, ascorbic acid and sucrose/AA mixes

sample when prepared, and on other hand to the radical-scavenging capacity of AA. It is known that depending on the medium conditions, AA acts as an antioxidant or oxygen scavenger. The results show that with a 50% decrease of sucrose content, the EPR intensity decreased by 63.7% for a 20 kGy absorbed dose. For the samples with contents of 30% AA the EPR response decreased with 51.6%.

For every sample is observed to decrease in the EPR intensity bigger than the decrease content of sucrose in it. This decrease is more than the frame of the error of measurements and therefore it is due to presence of AA.

3.4 Application of the System Sucrose/Ascorbic Acid

The aim of that study was to investigate mixed solid material obtained with various proportions of sucrose and ascorbic acid in two directions: as a dosimetric material with more high sensitivity than each of the separate component, or in opposite, having in mind that sucrose is tissues equivalent materials and it is part of DNA as potential radio protector. The obtained results show that the mixture of sucrose and ascorbic acid has lower intensity than a pure sucrose and therefore is not a good dosimetric material. The decrease in the intensity of the EPR signal is related to decrease of the free radicals induced during irradiation with gamma rays when AA is added to the mixture. Therefore, from the investigation it may be concluded that the mixture sucrose/AA can be used as a radio protector. It would be interesting to study the behavior of these mixtures at low doses of ionizing radiation and at different radiation dose rates. Also would be nice to see if there is a difference in the results for various kind of radiation (X-rays, heavy particles, neutrons and so on). There is a study which shows that ascorbic acid gives different protective effects on human cells when it is exposed to X-rays and heavy ions [10]. However, this requires additional studies and can be object of future investigations.

4 Conclusion

The present EPR studies on gamma-irradiated mixture of sucrose and different concentrations of ascorbic acid show that independently of the concentration of ascorbic acid, only the spectrum of sucrose is recorded. The intensity of sucrose decreased with increase of the ascorbic acid contents in the mixture. This result suggests that ascorbic acid plays the role of free radical scavenger effect with respect to sucrose.

Acknowledgments The authors gratefully acknowledged financial support by the Bulgarian National Science Fund (Contract Number KP-06-N39/12).

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