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INVESTIGATION OF RADIATION SENSITIVITY OF SOME TARTRATE COMPOUNDS

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Potential electron spin resonance (ESR) dosimetric application of different compounds of sodium tartrate, such as sodium tartrate dihydrate, sodium bitartrate monohydrate and potassium sodium tartrate tetrahydrate, was investigated in the range of 0.74–25 Gy. While the radiation-induced intermediates produced in these compounds are similar, their radiation yields are different. It is found that the radiation yield of sodium tartrate dihydrate is higher than other compounds of sodium tartrates. Comparison of the radiation yields were also made between well-known samples of ammonium tartrate, alanine and lithium formate. It is found that the radiation yields of sodium tartrate dihydrate, sodium bitartrate monohydrate and potassium sodium tartrate tetrahydrate have the values of 1.22, 0.18 and 0.13, respectively.

INTRODUCTION

Electron spin resonance (ESR) spectroscopy has been successfully used in the determination of the radiation dose. Due to reasonable radiation sensitivity, stable-free radical signal, excellent tissue equivalence and a linear dose–response curve alanine is chosen as ESR dosemeter[1–9]. Although studies carried out on alanine hold promise at low dose[10–14], there is still a need for alternative materials sensitive to <5 Gy, if ESR/dosimetry is to become a serious alternative to existing methods. In this respect, such materials should have a high radical yield, a linear dose dependency, narrow linewidth, stable radicals at room temperature[15, 16] and that show simple ESR spectra. In this regard, smartphone screen glass, sugar, ammonium tartrate, 2-methylalanine, compounds of formic acid and dithionate salts have been evaluated in the literature[15–31].

Because of their high radiation yield, many groups were focused on the radiosensitivity of the tartrates such as DL-tartaric acid[32, 33], ammonium tartrate[21–23, 34–37] and potassium tartrate[38, 39]. The dosimetric potential and kinetic features of sodium tartrate dihydrate (NaTA) in the intermediate dose range (0.5–20 kGy) were also reported[40]. The high radiation response of tartrates, especially sodium tartrate compounds led one to investigate their dosimetric potential <25 Gy. Therefore, the aim of the present work is to investigate the dosimetric potential of different compounds of sodium tartrate such as sodium tartrate dihydrate (NaTA), sodium bitartrate monohydrate (Na-bTA) and potassium sodium tartrate tetrahydrate (KNaTA) in the range of 0.74–25 Gy. The dosimetric features of these compounds are also compared with DL-alanine (AL), lithium formate (LiFo) and ammonium tartrate (AmTA).

MATERIALS AND METHODS

The crystalline powder of NaTA, Na-bTA, KNaTA, AmTA, AL and LiFo was provided from Aldrich and used without any further treatment by keeping it in sealed polyethylene vials at room temperature (290 K) before irradiation. All irradiations were performed at room temperature (290 K) on powder samples by using a ^{137}Cs gamma cell supplying a dose rate of 0.18 Gy s^{-1} as an ionising radiation source at the Sarayköy Establishment of the Turkish Atomic Energy Agency in Ankara. Samples irradiated in the dose range of 0.74–25.0 Gy were employed to construct the calibration dose–response curves.

EPR measurements were carried out on samples transferred to quartz ESR tubes of 4-mm inner diameter using a Bruker EMX-131 X-band ESR spectrometer operating at ~9.8 GHz and equipped with a high-sensitive cylindrical cavity at the Department of Physics Engineering, Hacettepe University, Ankara, Turkey. The same operation conditions were applied for all samples (microwave power, 0.5 mW; receiver gain, 1.0×10^4; modulation frequency, 100 kHz; modulation amplitude, 0.2 mT; time constant 327.68 ms; sweep time, 83.89 s; number of scan, 5) except the central field and the sweep width. The results were given as the average of the data collected using three different samples for each radiation doses. The ESR measurements are done after ~60 min of the irradiation. Signal intensities were measured directly from the recorded first derivative spectra (Figure 1), and the spectrum area below the absorption curves, which is proportional to the number of the radicals present in the sample, was calculated by the double integration technique that described by Barr *et al.*[41] using the Bruker WINEPR program.

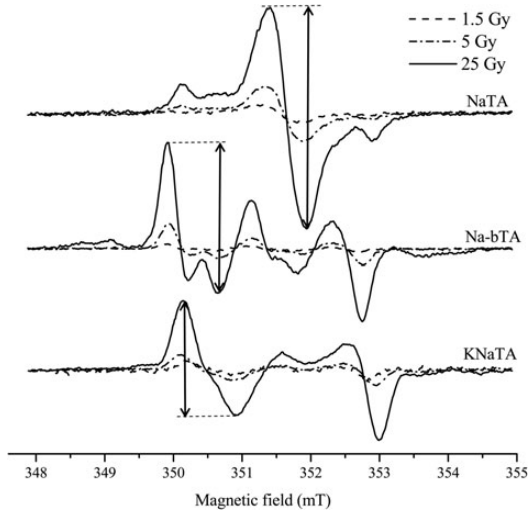

Figure 1. ESR spectra of sodium tartrates compounds normalised to the mass of the samples irradiated at three different radiation doses.

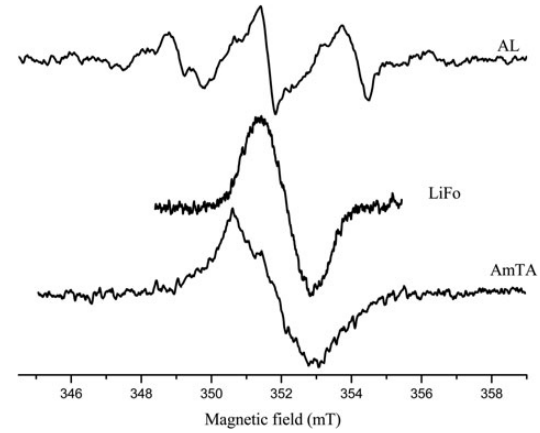

Figure 2. Normalised ESR spectra of AL, LiFo and AmTA samples irradiated at 2.2 Gy, and have a modulation amplitude of 0.2 mT.

The radiation yield of the material is given by the *G*-value[6], and is defined as the number of radicals produced by radiation energy of 100 eV. Ikeya[6] accepted that if a material having the *G*-value equal to 1, the number of the radiation-induced radicals per kg are $\sim 6.3 \times 10^{16}$ Gy^{-1}, and also Ikeya accepted the *G*-value of alanine as 1[6]. In the present work the spectrum area data of each sample are normalised to the area of AL at all radiation doses to make a comparison easer, and used to determine the radiation yield of the interested materials.

RESULTS AND DISCUSSION

EPR spectra of irradiated samples

While before the irradiation none of the samples showed any ESR signal, the irradiated samples presented ESR spectra easily distinguished even at ~1.5 Gy. While the spectra of NaTA and LiFo were easily followed, the other samples did not have a significant ESR spectra at the lowest radiation dose (0.74 Gy) that reached in the present work. Thus, it is concluded that the detection limit for NaTA and LiFo is 0.74 Gy. Although LiFo, AL and AmTA start to saturate at high microwave (MW) power value, the MW power was set to be 0.5 mW to avoid the saturation effect, especially for NaTA[40]. The ESR spectra of irradiated NaTA, Na-bTA and KNaTA at three different radiation doses (1.5, 5 and 25 Gy) were given in Figure 1 to make it easy following the spectrum changes. The ESR spectra of LiFo, AmTA and AL, at the same operation conditions, were also given in Figure 2. As it is clearly seen from the figures, ESR spectra of NaTA consist of one main singlet with narrow linewidth (~0.6 mT), and has two shoulders at both sides (Figure 1). The ESR spectra of Na-bTA and KNaTA have relatively complex pattern compared with the spectra of NaTA (Figure 1). In Figure 2 it is seen that the AmTA, which is another family member of tartrates, and LiFo have almost singlet ESR spectra with ~1.1 and 1.5 mT linewidth, respectively.

Dosimetric features

Samples irradiated at the dose of 0.74, 1.5, 2.2, 5.0, 10.0 and 25.0 Gy were used to construct the calibration dose–response curves. All ESR measurements are recorded at the same spectrometer condition, and normalised to the mass of the sample and to the receiver gain. The calibration curve of the sodium tartrate compounds and samples that are well known from the literature (AL, LiFo and AmTA) are given in Figure 3. A linear function has the form of $I = a + b \cdot D$ is used to determine the experimental data. As it is seen from the figure the normalised signal intensity of LiFo has the highest slope, NaTA and AmTA have very similar values. Nevertheless, each of the sodium tartrates compounds (NaTA, Na-bTA and KNaTA) have a good radiation response and thus hold promise to be a potential dosimetric material <10 Gy, especially NaTA.

From the point of view of the radiation yield, the picture is slightly different for NaTA. The normalised spectrum areas under the absorption curve (given as the *G*-value) and the slope of the calibration curves are given in Figure 4. It is found that the *G* values of the LiFo, NaTA, AmTA, Na-bTA and KNaTA are to be 1.31, 1.22, 1.05, 0.18, and 0.13, respectively. Almost the same values are found from the slope of the

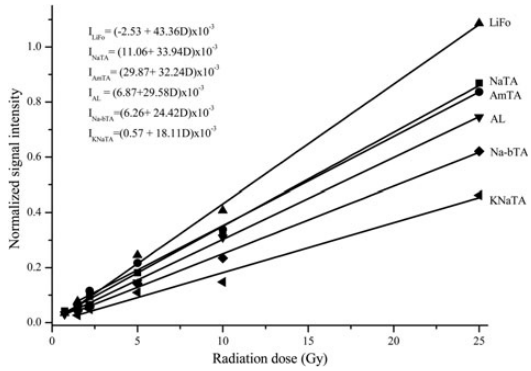

Figure 3. Calibration dose–response curves of interested samples (filled squares, NaTA; filled diamonds, Na-bTA; filled side triangles, KNaTA); filled circles, AmTA; filled triangles, LiFo; filled inverted triangles, AL.

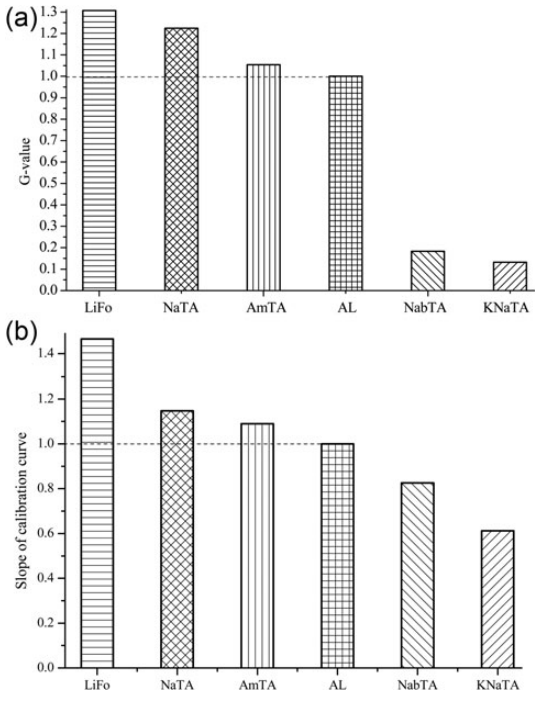

Figure 4. (**a**) The average of the radiation yield (normalised spectrum area) of all radiation doses and (**b**) the slopes of the calibration curves of interested samples (all data are normalised to spectrum area of the AL).

calibration curves, except NabTA and KNaTA. These differences are concluded to be due to the complex ESR spectra, and this causes difference between the signal intensity measurement and the spectrum area data.

CONCLUSION

Sodium tartrates (NaTA, Na-bTA and KNaTA) and AmTA presented good response to the radiation <10 Gy. By using NaTA, it is able to detect radiation doses <5 Gy. Beside other good dosimetric materials, the narrow linewidth (0.6 mT), simple ESR spectrum and relatively good radiation yield make NaTA a good candidate to be a dosimetric material in a low radiation dose range. However, its low microwave power saturation value and radical transformation in the period of 1 month[40] are the negative features of NaTA. More studies on NaTA should be performed in order to investigate its potential usefulness as a dosemeter in the low radiation dose range.

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