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Study of the possibility of using food salt as a gamma ray dosimeter

Kassim A.R. Khazal, Riyadh Ch. Abul-Hail *

University of Basrah, College of Education, Department of Physics, Basrah, Iraq

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ABSTRACT

For the possibility of using table salt as a dosimeter to measure the dose of gamma rays, the characteristics of thermoluminescence have been studied in detail for (3) different salt samples represented by Iraqi, Iranian and English salts (BDH limited, Poole, England) because they are affordable, available in the markets and equivalent to human body tissues.

On obtaining the results, it is possible to use table salt as a dosimeter to measure the dose of gamma rays within the range 0–10 Gy according to the following conditions:

1. Pre-irradiation annealing at temperatures 400 °C/h, 100 °C/2 h.
2. Post-irradiation annealing at temperature 100 °C/20 min.

Also, it is possible to use the samples mentioned above as gamma ray dosimeters within the range 0.01–50 Gy without the use of annealing depending on the high temperature peaks; thus it is possible to use salt as accidental dosimeter.

1. Introduction

In the past, sodium chloride has been claimed as suitable candidate for TL dosimetry (1980–1983) . Heywood and Clarke [1,2]used pure NaCl and NaCl:Ca in order to understand the TL properties after exposure to gamma rays. Some recent TL studies on alkali halides including those of Purohit and Joshi [3], Davidson et al. [4], Ortiz et al. [5] and Davidson et al. [6] have discussed the TL glow curves and the effect of impurities on TL of NaCl crystals. In this work we report some dosimetric aspects of the different salt samples brought from different sources. Some of them are Iraqi food salts, the others include English salt, which has high purity, obtained from the College of Engineering, University of Basrah, and Iranian salt brought from the market. We suggest food salt to be used because of its availability, low cost and equivalence to human tissue.

2. Materials and methods

The samples mentioned above are prepared in the form of powder; therefore, they are ground very carefully using a porcelain mortar. Then the powder is passed through two sifting nets, with sizes 63 and 45 μm. The choice of grains falls on those with similar sizes between 45 and 63 μm. The purpose of grinding in this way is to make the amount of thermoluminescence resulting from mechanical exertion (breaking) negligible. All the samples are kept in a dissicator that contains silica gel to absorb the moisture. The specimens have been irradiated with gamma rays from a Cs-137 gamma source mark (IV TLD dosimeters irradiator), made by JL Shepherd and Associates Company, California. The strength of the Cs-137 low-dose source was 3.7×10^{10} Bq in 1985 and the strength of the Cs-137 high-dose source was 44.4×10^{10} Bq in 1982. In every experiment that requires irradiation, the sample is put in a container made of plexiglas so as to obtain the electronic equilibrium and to guarantee absorption of the sample in the same irradiation dose.

The TL-reader used in the present work is a Toledo 654 manufactured by the English Pitman company; the food salt samples reading is registered by the thermoluminescence reader at a heating rate of 5 °C/s and up to a temperature of 350 °C.

3. Characteristics of TL of food salt samples

In order to use food salt in this research as a dosimeter to measure the radiation doses of gamma rays, the thermoluminescence characteristics of this material must be studied. They include the following.

3.1. Glow curve

The glow curve has a great importance in identifying the extent of utility of the material to be used in measuring the

* Corresponding author.
E-mail address: riydh2009@yahoo.com (R.C. Abul-Hail).

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radiation doses. A suitable peak is selected from this curve to conduct the measurements. Three different samples of table salt under study are used. After preparing them according to Section 2, these samples are given a random fixed dose. Then the thermoluminescence is read by the TL-reader by raising their temperature from room temperature to 350 °C and with a linear heating rate of 5 °C/s. This experiment is conducted under the same conditions in relation to the sample weight, which reaches 1 mg, and the linear heating rate of 5 °C/s in order to uncover the qualities of the thermoluminescence curves of salt samples mentioned earlier. As a result, we obtained thermoluminescence curves, which are illustrated in Figs. 1–3, where we notice the following:

1. The appearance of two clear peaks for all salt samples at high temperature peak (HTP) and low temperature peak (LTP).
2. The emergence of sensitivity difference in Iraqi food salt, Iranian salt and English salt.
3. The behaviors of the thermoluminescence curves of salt samples under study are generally similar to the behavior of the thermoluminscence curve of sodium chloride crystal in relation to the number of peaks [3,7].

The slight differences among thermoluminescence curves are attributed to the differences in type and the amount of impurities, which depend on the places from which the samples are obtained. These impurities have strong influence on thermoluminescence [8].

The reason for the appearance of two clear peaks for all table salt samples is because salt is considered a non-organic, ionic crystal. Thus, when it is exposed to an ionizing radiation there appear in the spectrum of these crystals absorption bands in both the visible and the ultraviolet regions and even in the infrared region where the ultraviolet absorption corresponds to electronic transitions, while the infrared absorption is related to the vibration of the ions composing the solid [9]. It is worth mentioning that the appearance of the high-temperature peaks supports the use of salt samples in radiation dosimetry on using these peaks.

3.2. Dose–response

The samples studied are exposed to different doses of gamma rays from the radiation source, which has an activity of 44.4×10^{10} Bq. The doses are between 1.22 and 5.60 Gy for Iraqi salt sample. The radiation doses are between 1.68 and 8.40 Gy for English salt and between 2.80 and 14.00 Gy for Iranian salt. Using the thermoluminescence reader where the temperature is raised from room temperature to 350 °C with a linear heating rate of

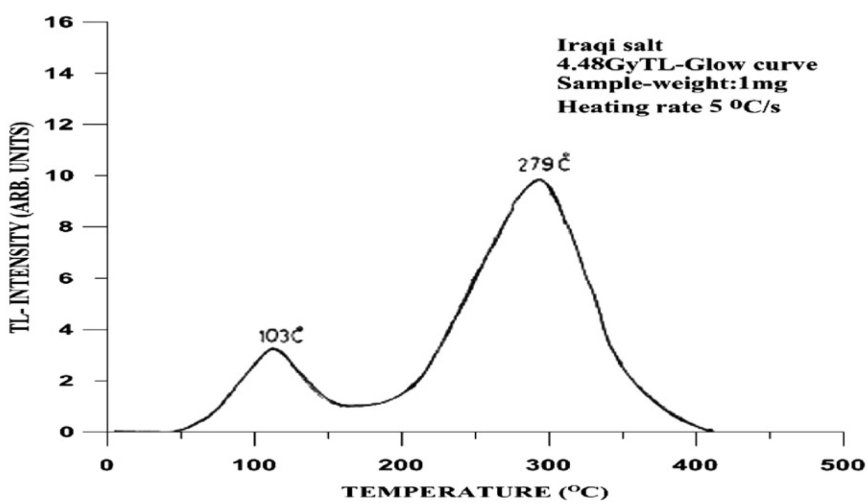

Fig. 1. TL glow curve of Iraqi salt.

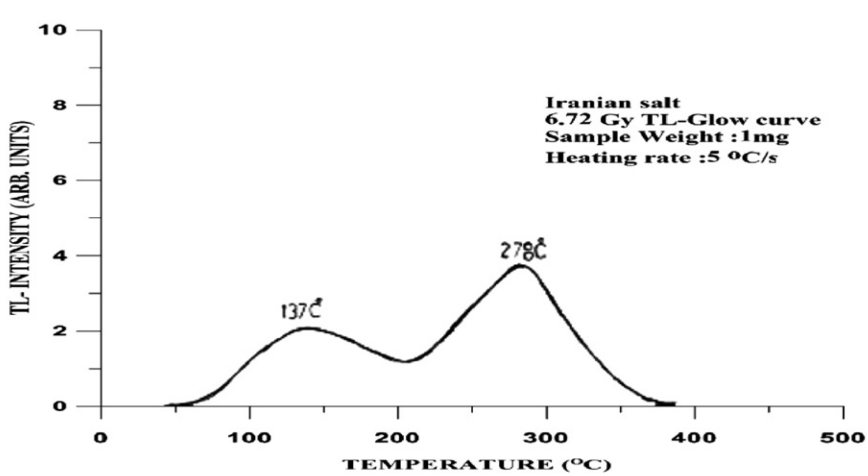

Fig. 2. .TL glow curve of Iranian salt.

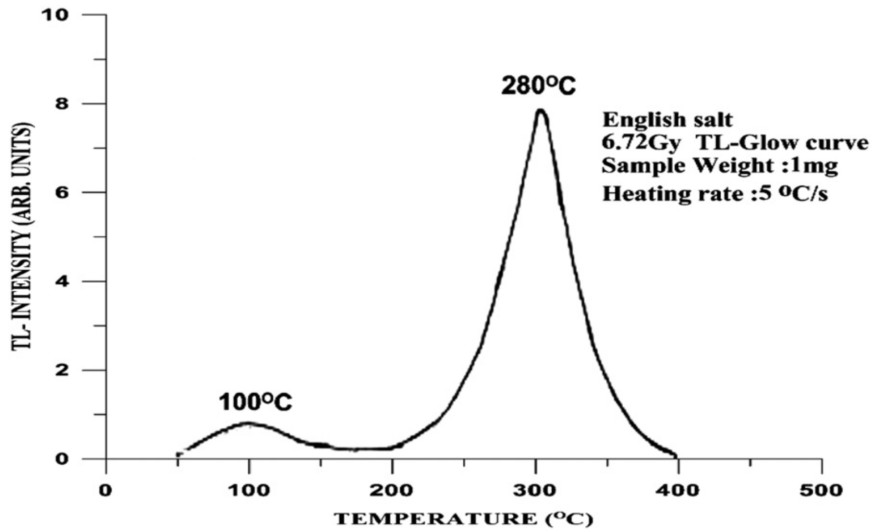

Fig. 3. TL glow curve of English salt.

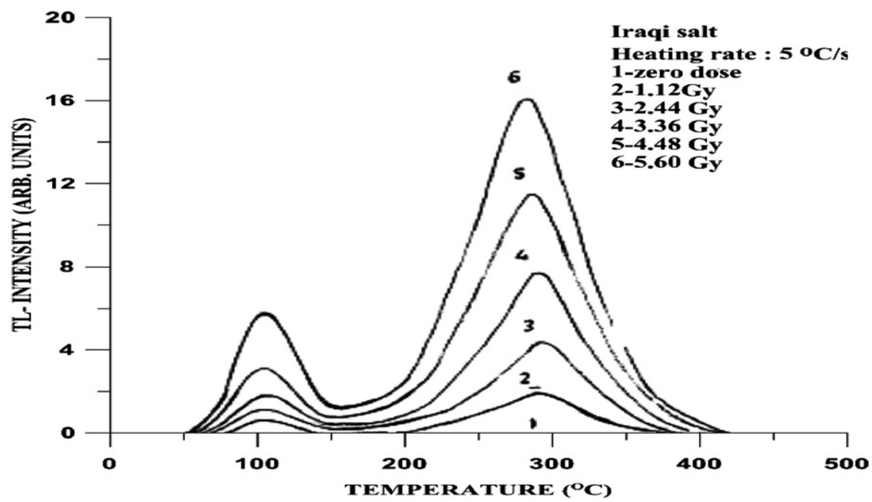

Fig. 4. Variation of TL glow curve with gamma dose.

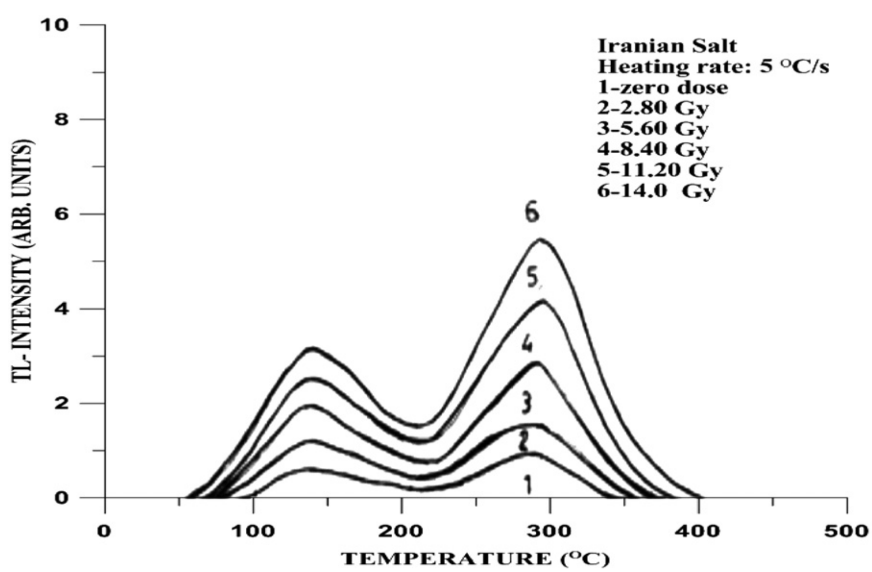

Fig. 5. Variation of TL glow curve with gamma dose.

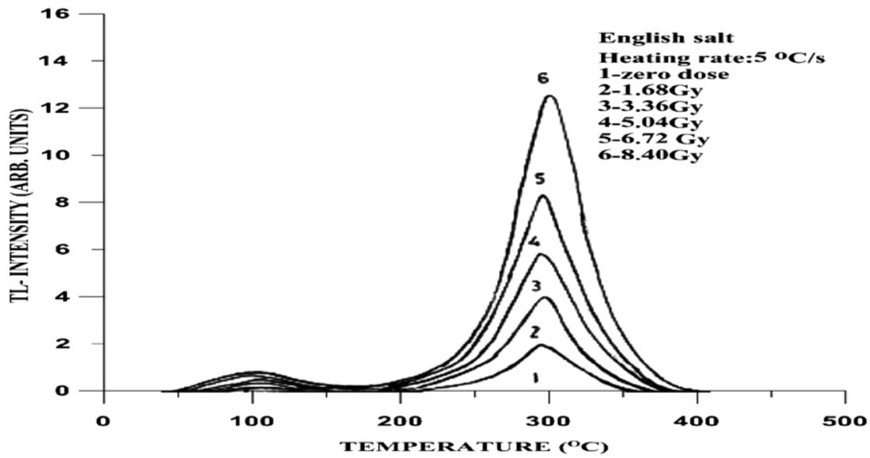

Fig. 6. Variation of TL glow curve with gamma dose.

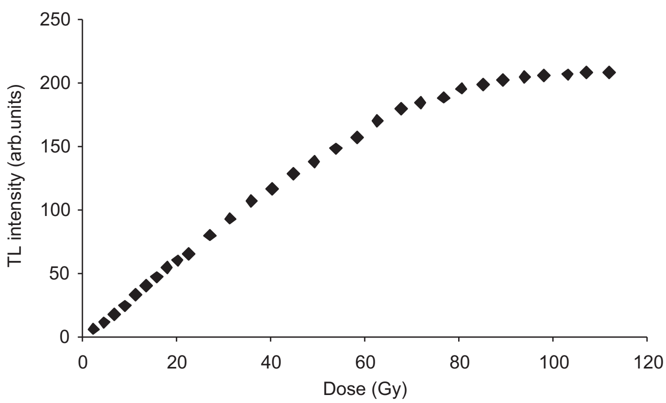

Fig. 7. TL growth curve and saturation level of Iraqi salt.

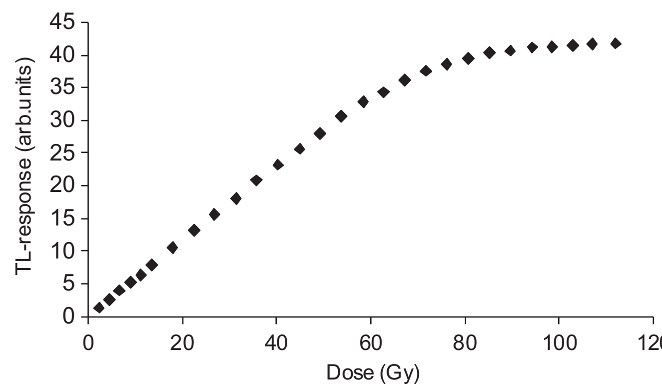

Fig. 8. TL growth curve and saturation level of Iranian salt.

5 °C/s and under the same conditions, we obtained Figs. 4–6. Studying these figures, we notice the following:

1. The high-temperature peak (HTP) being on the higher side of the temperature scale involves deeper traps in the TL process. This leads to long storage of trapped electrons at normal working temperature. Furthermore, it is observed that the position of the HTP does not shift with the increase in the radiation dose.
2. There is a difference in sensitivity between all samples of Iraqi food salt, English salt, and Iranian salt .
3. The effect of ionizing radiation is to detach an electron from its parent atom or ion so that it is free to diffuse about the crystal until trapped at a defect, i.e.,saturation.Nearly all the traps filled in the TL output have been found to start at about 50 Gy for all samples under study, as shown in Figs. 7–9.

The presence of a linear relationship between the dose and the response of the samples under study and for the high-temperature peak justifies their use in radiation dosimetry with range 0–50 Gy. See Figs. 10–12.

The difference in the response of food salt samples studied above is attributed to the difference in the degree of purity and the type of impurity in the samples. These factors play a great role in creating trapping centers of different depths and have a great effect on the production of thermoluminescence when the sample is heated. As is known, sample sensitivity is equal to the thermoluminescence resulted divided by the given dose. In addition, the concentration and size of the impurities within the crystal compound of the samples studied have an effect on sample sensitivity [4].

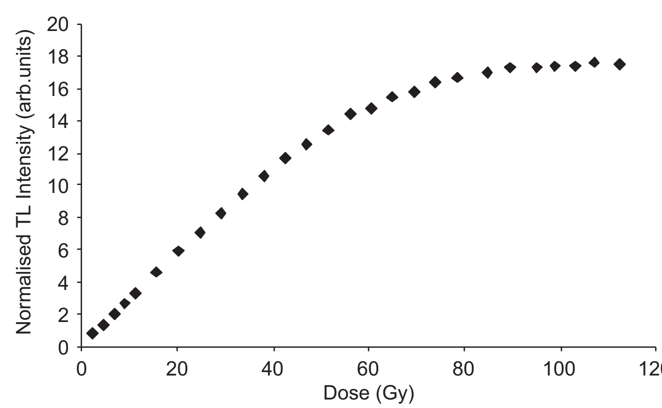

Fig. 9. TL growth curve and saturation level of English salt.

3.3. Thermal fading

The study of the thermal fading characteristics of the TL glow curve of table salt is considered one of the important factors that enable its use as a radiation dosimeter to measure radiation doses of gamma rays [10]. The experiment conducted to study the thermal fading is summarized as follows.

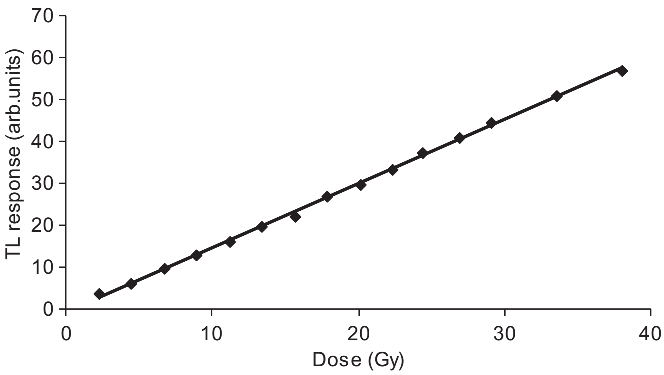

Fig. 10. Dose–response relationship for Iraqi salt at HTP for temperature interval 150–360 °C.

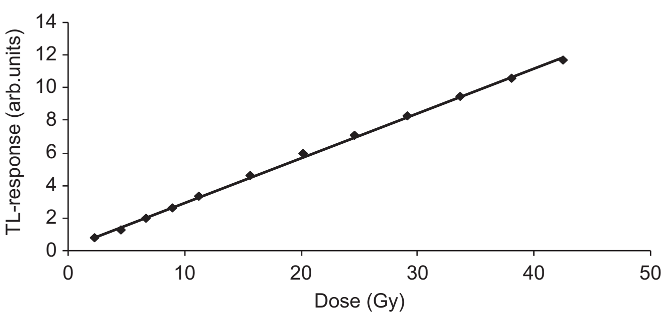

Fig. 11. Dose–response relationship for Iranian salt at HTP for temperature interval 150–360 °C.

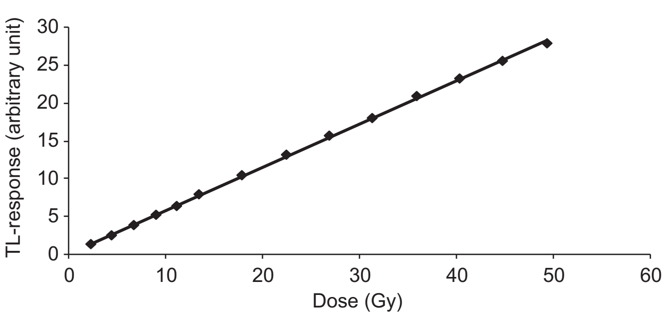

Fig. 12. Dose–response relationship for English salt at HTP for temperature interval 150–360 °C.

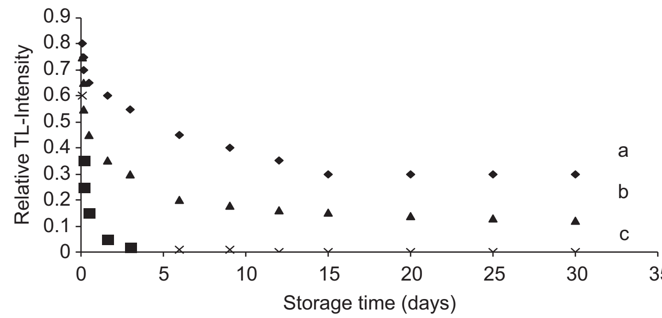

Fig. 13. Thermal fading of Iraqi salt at 25 °C (a) TL-HTP (150–350 °C), (b) TL-Total TP (50–350 °C), (c) TL-LTP (50–150 °C).

Table 1
Effect of dose rate on the thermoluminescence of common salt irradiated to 1.596 Gy.

Dose rate	TL/mg
0.012 mGy/min	16581
0.56 Gy/min	16608

Table 2
Effect of relative humidity on TL-response.

Date	TL/mg salt sample inside lab	TL/mg salt sample outside lab	Relative percentage between them	Relative humidity(%)
1/4/2010	54282	51939	4.3	32
3/4/2010	54278	51953	4.2	31
5/4/2010	54280	51980	4.2	30
6/4/2010	54208	51982	4.1	30
8/4/2010	54228	51992	4.1	30
10/4/2010	54248	51997	4.1	27
12/4/2010	54280	51985	4.1	30
13/4/2010	54281	51877	4.4	48
15/4/2010	54272	51995	4.1	27
17/4/2010	54280	51870	4.4	73
23/4//2010	54278	51978	4.2	41
26/4/2010	54280	51976	4.2	47

After giving the table salt sample, which weighs 300 mg with a dose of 5.6 Gy, the thermoluminescence of an amount of the sample weighing 1 mg is measured for 3 min after irradiation. The remains are stored in plastic containers at a constant temperature *T*. Then the sample is brought out of another amount of the same sample as a reading average of 5–10 times. Then, we draw the rate of relative thermoluminescence, which remains as a result of the thermal storage period against the storage time at constant temperature (25 °C). Fig.13 represents the thermal fading of peaks at high and low temperatures in addition to the total fading of both peaks.

It can clearly be noticed that the low temperature peak (LTP) fades quickly in relation to storage period than the high temperature peak (HTP) .

In reference to what is mentioned above, when salt is used as a radiation dosimeter, the peak that must be used should be the high temperature peak (HTP) or within a temperature range between 150 and 350 °C for measurements. At such temperatures, the rate of thermal fading is less as measured along two weeks.

3.4. Dose rate effect

In order to investigate the effect of dose rate on the thermoluminescence of common salt (TL/mg), a set of samples has been irradiated to 1.596 Gy at two different dose rates: 0.012 mGy/min and 0.56 Gy/min; we see that the effect of dose rate is very small, see Table 1.

3.5. The effect of relative humidity

To study the effect of relative humidity, two weeks of the salt samples under study are taken. They weigh 300 mg. Each one is placed in a plastic container. One of them is put in a dry place inside the lab. The other is placed outside the lab. The thermoluminescence is measured daily after giving them a fixed dose of 0.56 Gy. The measurement continues for one month. The results are listed in Table 2.

It can be observed that the difference in thermoluminescence between the lab sample and those outside the lab is very little; still this difference can be taken into consideration when measurements are conducted.

4. The effect of pre-irradiation annealing on the glow curve

For studying the effects of annealing on the form of glow curve of the samples in question, an amount of sample of Iraqi food salt was processed at 100, 200, 300, and 400 °C in a high temperature oven for 1 h and then it was transferred to a low temperature oven at 100 °C for 2 h.It was then allowed to cool at room temperature. Later on, amounts of the same weights 1 mg were exposed at ambient temperature to 0.37 Gy of gamma rays, and then put in the TL-reader one after the other. Such annealing led to changes in the form of glow curve that are shown in Fig.14 in which we observe the following:

1. One of the characteristics of this figure is that it changes in glow curve while increasing the temperature of annealing.
2. A noticeable change was found in response to the low temperature peak while the temperature of annealing was increased.
3. Shifting of peak temperature T^* of high temperature toward low temperatures.
4. The maximum response to annealing of the samples under study is 400 °C for 1 h and 100 °C for 2 h, a result that agrees with what the researchers have found [4].

After knowing the temperature suitable for annealing, we started to deal with the samples under study at 400 °C/1 h and 100 °C/2 h, and then they were left to cool at room temperature. Those samples were given the same dose of 0.37 Gy and their thermoluminscence intensity was read under the same conditions. Figs. 15 and 16 show glow curves of English food salt samples and Iranian food salt samples that were pre-irradiation annealed and not post-irradiation annealed, in which all samples have almost the same behavior except for Iranian salt. It seems that their response appears in the high temperature peak, contrary to that of other samples. Such a response at high temperature peak is important when the sample uses as a dosimeter.

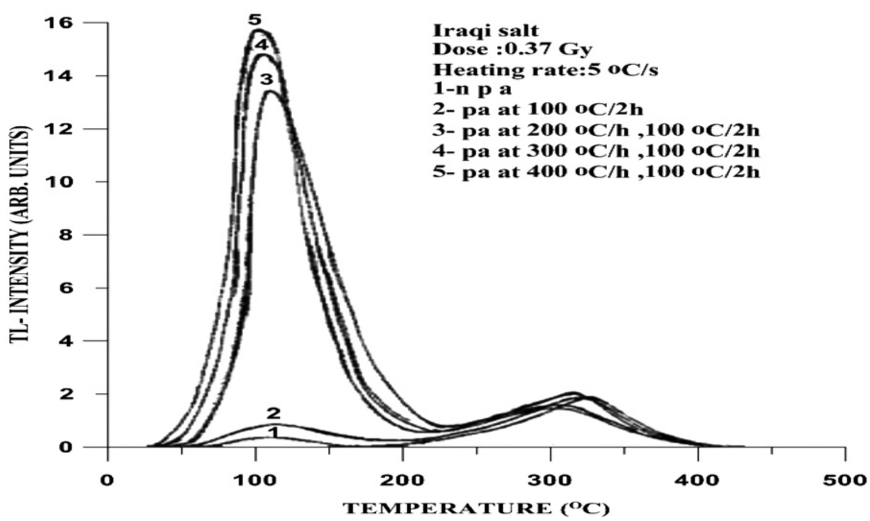

Fig. 14. TL glow curves for Iraqi salt npa and pa treatment with different temperatures.

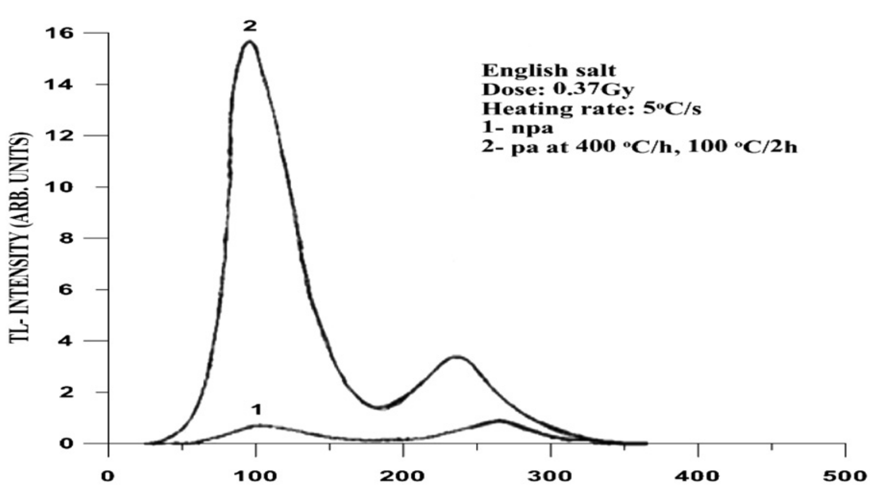

Fig. 15. TL glow curves for English salt npa and pa treatment.

5. The relative TL-characteristics of LiF (TLD-700) and Iranian salt

After pre-irradiation annealing at 400 °C/1 h,100 °C/2 h and post-irradiation annealing at 100 °C/20 min for all samples of common salt and lithium fluoride, the TL of samples were measured with the same dose (0.37 Gy). The glow curves were measured at a heating rate of 5 °C/s. For the form of glow curves that are shown in Fig.17 we see the main glow peaks lying in the range 150–400 °C for Iranian salt and in the range 150–350 °C for LiF (TLD-700).

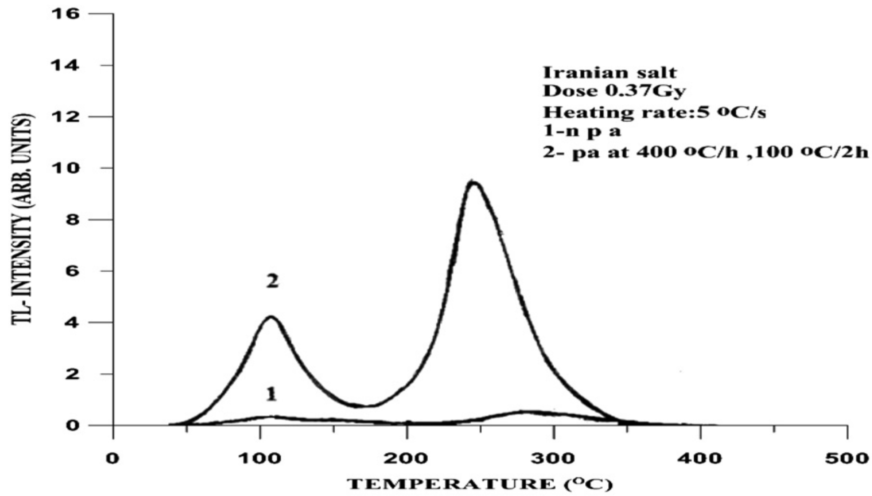

Fig. 16. TL glow curves for English salt npa and pa treatment.

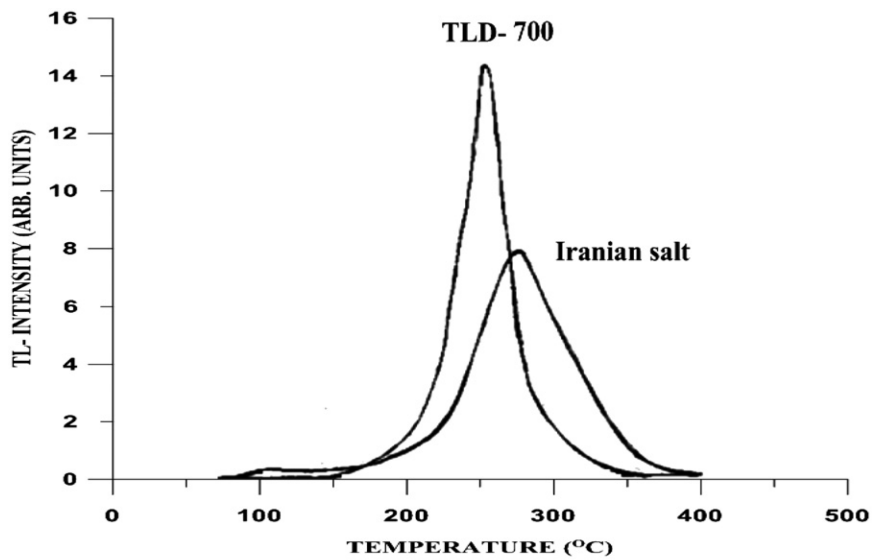

Fig. 17. Glow curve of Iranian salt and LiF (TLD-700).

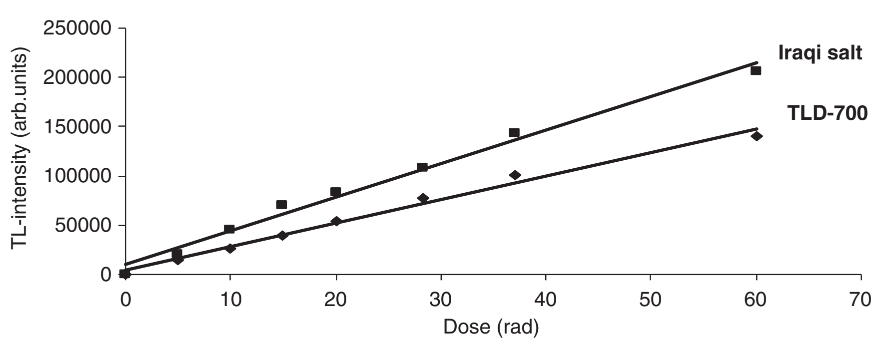

Fig. 18. Dose–response relationship of Iranian salt and TL-D700 after pre- and post-irradiation annealing.

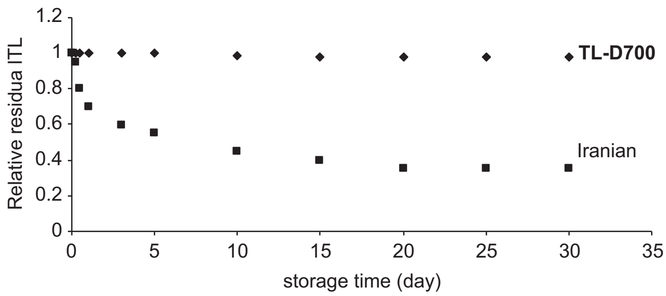

Fig. 19. Thermal fading of Iranian salt and lithium fluoride after storage at 25 °C pre- and post-irradiation annealing.

Also, the dose–response relationship and thermal fading for the area under glow curve have been investigated, see Figs.18 and 19. The TL glow curve for both is linear with dose, but the thermal fading of LiF is less than that of Iranian salt.

6. Conclusion

From the study of the ability to use food salt as a dosimeter, we have come out with the following conclusions:

1. The appearance of two clear peaks in the TL glow curve at low and high temperatures and for all the table salt samples studied.
2. The dose–response is linear for the glow curve of the high temperature peak for all samples.
3. The pre-irradiation annealing at 400 °C/h, 100 °C/2 h increases the salt sensitivity and the post-irradiation annealing with 100 °C/20 min reduces the thermal fading.
4. TL-characteristics of table salt (Iranian salt) are generally similar to TL-characteristics of the TLD-700.
5. The advantage of common salt as a gamma ray TL dosimeter includes: good tissue equivalence, excellent sensitivity and linearity of response as compared to lithium fluoride in the dose range of interest in personnel and environmental monitoring.

Acknowledgement

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