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PSL study of irradiated food: NaCl as possible reference material

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Abstract

Gamma-irradiated NaCl samples of different origin were studied with the aim to find a reliable, easy-to-use, low-cost standard for the PSL technique, an increasingly used screening method for irradiated food identification. Five different natural salt types (rock and sea salts) purchased in the local markets were studied along with a laboratory-grade NaCl. High sensitivity and reproducibility of the PSL response are good properties of salt, but the pronounced fading of the signal may be a severe limitation of its use as a reference material. The high sensitivity along with the linear dose dependence of the PSL response opens up the interesting possibility of salt as suitable material for retrospective and environmental dosimetry, especially in the case of accidental irradiation or malevolent use of ionizing radiation. Again, the extreme sensitivity of the PSL signal to light and the pronounced fading must be considered limiting factors, and further basic research is required before practical applications of salt be feasible.

Keywords: Photo-stimulated luminescence; Salt; NaCl; Dosimetry

1. Introduction

Food irradiation is a well-accepted, world-wide approach to reduce food-related health hazard and to extend food shelf-life. To meet consumer's rights, the international legislations require proper identification methods capable of classifying marketed foods as irradiated or non-irradiated. At the European level, member states are required to perform controls on an yearly basis. From the reports the European Commission released in the last years the photo-stimulated luminescence (PSL) method (CEN Standard EN 13751 (CEN, 2001)) is the most applied for screening analyses. Following the recommendations of the CEN Standard EN 13751, PSL measurements are worldwide performed using a pulsed PSL reader produced by the Scottish Universities Reactor Research Centre (SURRC, Glasgow, UK). As a basic quality assurance requirement, the use of proper reference material to check instrument performances is mandatory. It also assures consistency of measurements among different laboratories. A suitable reference material should have a PSL response stable in time, be highly reproducible and exhibit spectral characteristics similar to those typically found in food analysis. The solution adopted by SURRC makes use of irradiated ground paprika which is delivered along with the instrument. Within the framework of an on-going international intercomparison, scarce reproducibility of the paprika PSL signal has been recognized as the main limitation to the use of this material as reference for PSL measurements. Since salt is known to be a sensitive luminescent material (Nanto et al., 1991; Purohit and Joshi, 2000; Bailey et al., 2000; Ortiz et al., 2005; Zhang et al., 2005; Murthy et al., 2006; Cruz-Zaragoza et al., 2006), we were prompted to investigate into the PSL properties of irradiated salt to find a good alternative to paprika as reference material. The preliminary results reported here focus on time stability and reproducibility of the PSL response of different salt types. The experiments have been designed to yield preliminary information on the possible use of salt for retrospective accident dosimetry using PSL measurements.

2. Materials and methods

We studied five natural salt types purchased from the local markets and a laboratory-grade NaCl from Merck (Darmstadt, Germany), namely table sea salt, iodized table sea salt, table

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rock salt, iodized table rock salt, refined table rock salt and Suprapur NaCl. The refined table rock salt was re-crystallized during the industrial preparation process. Irradiation was performed with ^{60}Co gamma rays from a Nordion Gammacell 220 (Ottawa, Canada). The dose rate at the sample location was 0.6 Gy/min, with an uncertainty in dose delivery of about 2% at 1 SD. Samples were stored in sealed, light-protected containers under laboratory conditions. PSL measurements were made using a pulsed PSL "Irradiated food screening system" (SURRC, Glasgow, UK). Samples were prepared, handled and measured under subdued light. Aliquots of 2–5 g were introduced in the system in standard disposable 50-mm diameter Petri dishes. At the beginning of each set of measurements the sensitivity of the instrument was checked with a reference light source. The apparatus was further tested with irradiated and non-irradiated standard paprika supplied by SURRC, Glasgow, UK. During PSL measurements an empty chamber test was run periodically to ensure that the chamber was free from contamination. The number of photon counts recorded in 60 s was taken as PSL measurement result. All the results were classified according to the pre-set thresholds T_1 (700 counts/60 s, upper negative limit) and T_2 (5000 counts/60 s, lower positive limit) indicated in Standard EN 13 751 for herbs and spices. Properties under study were: reproducibility, sensitivity, dose–response and time stability of luminescence centres. Some TL measurements were also performed to understand the origin of the PSL signal of unirradiated rock salt samples using a Harshaw 3500 TL reader. TL measurements were made on about 30 mg aliquots in the 70–380 °C range with a heating rate of 6 °C/s.

3. Results

3.1. PSL results

Three aliquots of each salt type were initially measured as purchased. Results (the mean value of the three aliquots) are reported in Table 1 along with the PSL classification in negative, intermediate and positive results (CEN, 2001).

The results reported in Table 1 show that the examined samples have different PSL responses. Specifically, the high PSL positive results of the rock salt suggest that the material has stored the natural radiation background on a geological time scale. This information was lost during the industrial preparation process of the refined table rock salt which—like the Suprapur salt—led to a negative PSL classification. While optical bleaching might be responsible to some extent for the low level of the PSL response of sea salts, it should be borne in mind that this material has stored a negligible natural radiation background. The different radiation sensitivity of the various salts (see Table 2) might have also contributed to the observed differences.

Table 1
PSL total counts and classification of different salt types as purchased

Sample	PSL counts/60 s	PSL classification
Sea salt	1215	Intermediate
Iodized sea salt	2421	Intermediate
Rock salt	759 794	Positive
Iodized rock salt	688 929	Positive
Refined rock salt	570	Negative
Suprapur NaCl	560	Negative

Table 2
PSL sensitivity and reproducibility of different salt types

Sample	Dose (Gy)	Sensitivity (PSL counts/60 s Gy g)	Reproducibility (SD%)
Sea salt	0.5	1.84×10^6	9
Iodized sea salt	1.0	0.73×10^6	13
Rock salt	0.5	1.15×10^7	12
Iodized rock salt	0.5	6.52×10^6	12
Refined rock salt	1.0	1.7×10^7	12
Suprapur NaCl	1.0	3.08×10^6	18

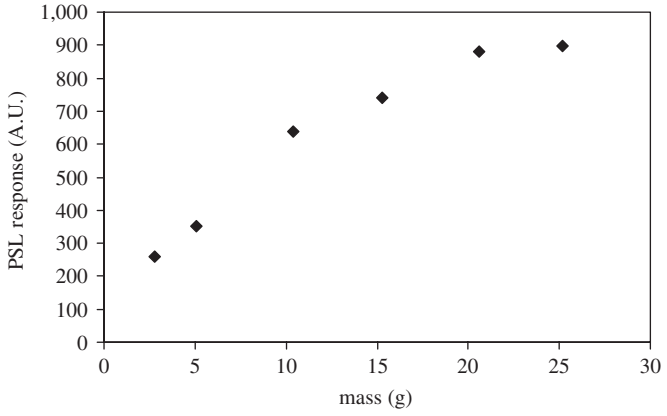

Fig. 1. Variation of PSL response with sample mass.

Before proceeding with the study of the laboratory irradiated salt, the non-iodized rock salt was used as purchased to determine the proper quantity of material to put in the Petri dishes for PSL measurements. The counts/60 s vs sample mass are reported in Fig. 1. PSL response increases linearly with sample mass up to about 10 g and saturates at about 20–25 g. As a compromise between sensitivity and the necessity to curb sample consumption, aliquots in the 2–5 g range were chosen for the experiments to follow. The use of small quantities of salt also limits the risk of contamination of the reading chamber. This choice requires sample mass normalization for quantitative analysis.

Table 2 reports the sensitivity of the different salts irradiated at various doses, as resulting from the mean PSL signal value over 10 aliquots. The irradiation doses were limited to 0.5 and 1 Gy, since the very high geological signal of rock salt suggested its high sensitivity. Moreover, preliminary tests on samples irradiated at doses of some kGy (same as those usually given to paprika) saturated the PSL instrument counter. To reset the geological PSL signal to zero, all salt samples were annealed at 150 °C for 1 h before irradiation. Table 2 also reports