DETECTION OF IRRADIATED POTATOES AND ONIONS USING PHOTO-STIMULATED LUMINESCENCE (PSL) MEASUREMENTS

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ABSTRACT

Photo-stimulated luminescence (PSL) measurement was conducted to detect irradiated potatoes and onions after dark storage for 1 week, 3 and 6 months. Using screening and calibrated PSL, all the samples were correctly distinguished between non-irradiated and irradiated samples at doses 50, 150 and 500 Gy based on photon count values. The PSL signal stability of irradiated samples (150 and 500 Gy) appeared to fade upon 6 months storage but remained well above upper threshold values of 5000 photon counts/60 s (PCs) for irradiated potatoes and onions. The PCs of irradiated tubers and bulbs showed a general trend of increase with the increase in doses up to 500 Gy. Samples showed highest intensity after irradiation. The differences in intensity to irradiation are possibly attributed to the varying quantity and quality of silicate minerals present in each tuber sample. Tubers irradiated at doses higher than 150 Gy, showed sensitivity index ratio of less than 10. Sensitivity Index was suggested for irradiated samples at doses slightly above 150 Gy. Irradiated samples at doses less than 150 Gy should be subjected for further investigation using thermoluminescence (TL) analysis. The results of this study provide a useful database on the applicability of PSL technique for the detection of Malaysian irradiated tubers and bulbs.

ABSTRAK

Teknik PSL digunakan untuk mengesan kentang dan bawang yang disinar selepas penyimpanan selama 1 minggu, 3 dan 6 bulan dalam keadaan gelap. Hasil pengukuran secara saringan dan kalibrasi PSL berjaya membezakan antara kentang dan bawang yang tidak disinar dan disinar pada dos 50, 150 dan 500 Gy. berdasarkan nilai kiraan photon/60s. Kestabilan signal PSL umbisi disinar (150 dan 500 Gy) menunjukkan sedikit penurunan selepas 6 bulan penyimpanan tetapi masih melebihi nilai nilai ambang 5000 photon counts/s (PCs) untuk kentang dan bawang yang disinar. Nilai PCs mempamerkan kecenderungan peningkatan dengan dos sinaran sehingga dos 500 Gy. Sampel menunjukkan intensiti yang tinggi apabila disinar. Perbezaan intensiti mungkin disebabkan oleh perberbeza kandungan dan kualiti mineral silikat yang hadir pada sampel. Kedua-dua umbisi yang disinar melebihi dos 150 Gy menunjukkan nisbah indeks sensitiviti kurang dari 10. Indek sensitiviti dicadangkan untuk sampel tersinar melebihi dos 150 Gy. Sampel kurang dari dos 150 Gy dicadangkan untuk penganalisaan lanjut menggunakan *analisis termoluminesens (TL). Hasil kajian ini menyediakan pangkalan data ke atas kesesuaian teknik PSL untuk mengesan umbisi disinar di pasaran Malaysia.*

Keywords: Tubers, bulbs, photo-stimulated luminescence (PSL), index sensitivity, calibrated PSL, irradiated food

INTRODUCTION

Irradiation treatment is used by many countries all over the world to inhibit sprouting in potatoes (Thomas, 1984). Sprouting is the most obvious manifestation of deterioration of potatoes. It increases susceptibility to bruise and decreases the marketability and the processing characteristics of potatoes (Hassan A. *et al.*, 2000). This technique has the potential to prevent the sprouting of stored vegetables that can lead to improved product quality (Arvanitoyannis *et al.*, 2009). In case of various root crops, many studies have described useful effect of low dose irradiation (50-150 Gy) for sprout inhibition (Cho et al., 2006) and relatively high dose (1 kGy or more) for other technical purposes (Kwon, *et al.*, 1984; Kwon, *et al.*, 2002; Nayak *et al.*, 2007).

With the increase in γ-irradiation treatments for tubers, having reliable methods to distinguish between irradiated and non-irradiated materials will be useful to regulatory authorities. Studies on detection methods for irradiated food have been carried out on the basis of the physical, biological, chemical and microbiological changes in foods exposed to ionizing radiation during the last few decades (Delincée, 2002). Among the physical techniques, pulsed photo-stimulated and thermo-luminescence measurements are the leading techniques used for irradiated food. When exposed to ionizing radiation, mineral debris which are found on the sample store energy in charge carriers at structural, interstitial or impurity sites. In photo-stimulated luminescence (PSL) analysis, the irradiated minerals release charge carriers upon optical stimulation by electromagnetic radiation of the appropriate wavelength, and the emission of stored energy (photo-stimulated luminescence) is measured by a sensitive detector (Schreiber, 1996). The PSL detection method has been used for rapid screening of many irradiated foods including brown shrimps, spices, seasonings, and shellfish (Sanderson *et al.*, 1996).

In view of the increasing use of irradiation technology for tubers, this study aimed to investigate the potential of PSL measurement technique for detecting irradiated potatoes and onions. The objective was to establish baseline data on PSL measurement of available potatoes and onions for identification of γ-ray irradiation treatment. Principal characteristics of sensitivity, dose response and signal stability during storage were also studied.

MATERIALS AND METHODS

Preparation and Irradiation of Samples

Potato and onion samples were purchased from the local market. Sample (100 g each) was packed in black polyethylene bags, sealed and irradiated at doses 0, 50, 150 and 500 Gy using cobalt-60 gamma source (Gamma cell -220, dose rate 37.4 gray/min) at National University of Malaysia (UKM). The average absorbed dose was determined by using fricke and optic chromic dosimeter (ASTM Standard: E 1026, 2003). All samples (non-irradiated and irradiated) were stored under dark condition at chilled storage 1^{0}C for up to 3 and 6 months to confirm the stability of detection parameters.

Photo-stimulated Luminescence (PSL) Measurement

The PSL signals of all tubers and bulbs samples were measured using a SUERC pulsed Photo-stimulated Luminescence Irradiated Food Screening System (SUERC: Scottish Universities Environmental Research Centre). The system comprised of control unit, sample chamber, detector head assembly and personal computer. The PSL measurements were performed according to EN 13751 (2009). Skins of potatoes and onions were placed in 50 mm diameter disposable petri dish (Bibby Sterilin type 122, Glasgow, UK). All measurements were made under subdued lighting to minimise bleaching. A stimulation source, located in the control unit and composed of an array of infra-red light emitting diodes, was pulsed symmetrically on and off for equal periods. A bialkali cathode photomultiplier tube operating in photon counting mode was used as the PSL signal detector. The PSL signals (photon counts, PCs) of the samples were recorded in the measuring mode at the rate of counts/60s and were presented at PCs/ 60 s. All measurements were done in triplicates.

The irradiation status of the samples was determined using screening PSL whereby PSL signals are analysed with respect to two thresholds. Samples with signals below the lower threshold value of 700 counts/60 s (T_1) are categorised as non-irradiated (negative) while those more than the upper threshold of 5000 counts/60 s (T_2) suggests irradiated samples (positive). Samples with signal levels between the two thresholds (700-5000 counts/60 s) were classified as intermediate (M) and was further investigated using calibrated PSL to determine the PSL sensitivity of the sample. Calibrated PSL was performed to determine the PSL sensitivity of samples by subjecting all the tubers in the petri dish to 1 kGy radiation dose after the initial PSL measurement, and then re-measured. Sensitivity index (ratio of calibrated to initial PSL signal) was determined for all the tubers samples.

RESULTS AND DISCUSSION

The PSL photon counts (PCs) for the tubers and bulbs samples, measured as a function of irradiation dose and storage periods are presented in Figure 1. The PCs of all non-irradiated samples were less than the lower threshold value (700 counts/60s), clearly indicating them as negative (T_1, non-irradiated) while the PCs of all irradiated tubers (1 week) were higher than the upper threshold value (T_2 =5000 counts/60 s) indicating irradiation treatment. Intermediate response was observed for onions samples irradiated at at 50 Gy, indicating PSL was able to discriminate between irradiated and non-irradiated samples studied. Thus in this study, all the samples were correctly identified based on the PSL signal intensity.

The effect of radiation dose on signal intensity (Figure 1A) shows a general trend of increasing PCs with increasing dose up to 500 Gy. Irradiated potatoes (150 and 500 Gy) after 3 months of storage showed lower signal intensity compared to those stored for 1 week but increased again after 6 months of storage. For irradiated onions (150 Gy), (Figure 1B) the signal intensity was lower for samples stored at 3 months as compared to those stored for 6 months. However, generally the PCs decreased after 6 months of storage in all the samples compared to the first week storage. For 1 week of storage, both potato and onion samples showed a significant increase in signal intensity with increasing doses up to 500 Gy. This result suggests that dose dependency for the PSL signals is not always apparent especially at lower doses less than 150 Gy. According to Bayram & Delincée (2004), this observation could be attributed to the variation of mineral grains being on the surface of the dispensed sample layer and also to the saturation of the energy traps in all common minerals upon irradiation. It was also observed that response to PSL signals at a specific dose showed variation between the irradiated tubers. At dose 500 Gy, irradiated potato recorded highest PCs value of (5194321 ± 2277) followed by onion (76180 ± 227). As PSL sensitivity depends on the quantities and types of minerals within the sample, this variation could be attributed to the varying amount of mineral debris present in each tuber sample.

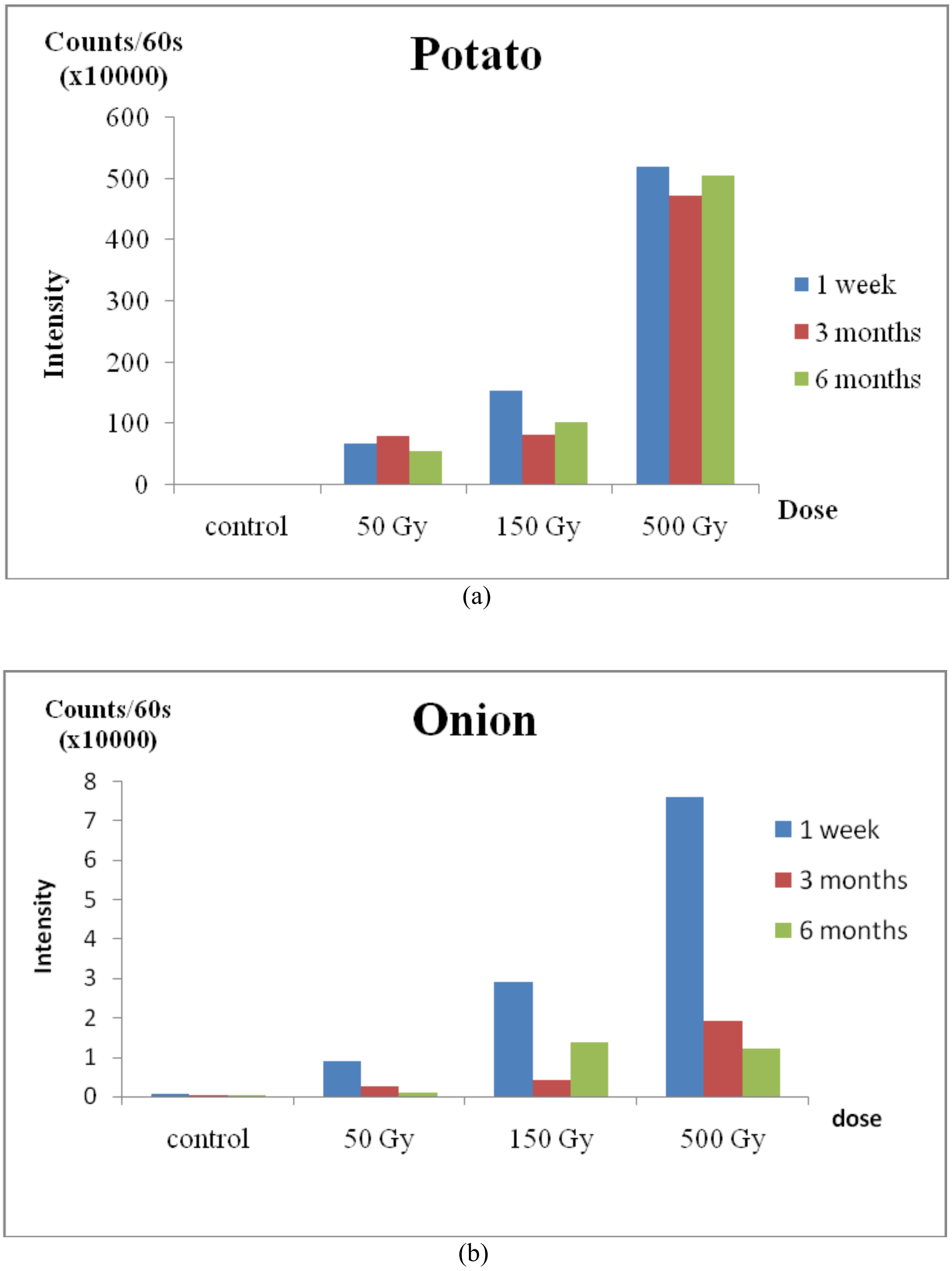

Figure 1. The signal intensity of non-irradiated and irradiated tubers: (a) Potato and (b) Onion after 1 week, 3 and 6 months storage in the dark.

From Figure 1, it was noted that the PCs of all irradiated tubers and bulbs decreased after storage for 6 months. However, the PCs intensity for onions at higher dose 500 Gy decreased at 3 months storage. The result suggests fading of the PSL signal with storage time. Nevertheless, the signal intensity of all stored samples (150 and 500 Gy) remained significantly higher than upper threshold values making it still possible to distinguish them from non-irradiated tubers and bulbs. Similar finding was reported by Pal et al. (2010) for 19 different herbs. The result of this study suggests that PSL measurement is suitable for the detection of irradiated potatoes since the PSL responses from irradiated samples are consistently greater than those of non-irradiated ones. Furthermore, long term storage for potatoes showed fading of the PSL response to below lower threshold value for irradiated food. However, PSL responses from irradiated onions are suggested that PSL measurement with dose more than 150 Gy.

Long term storage for onions showed fading the PSL at 50 Gy responses to below threshold value (intermediate).

Although PSL signals below the lower threshold (T1) are generally associated with non-irradiated materials, it can also derive from low sensitivity of irradiated materials as ratio less than 10. Calibrated PSL can distinguish these few cases since irradiated samples usually show only a small increase in PSL after re-irradiation whereas non-irradiated samples show a substantial increase in PSL signal after irradiation (EN 13751, 2009). In this study, the sensitivity index (ratio of calibrated to initial PSL) of the tubers and bulbs is shown in Table 1. According to Liwen *et al.* (2013), sensitivity index value below 10 indicates samples have been irradiated whilst values above 10 indicates non-irradiated samples. From Table 1, all non-irradiated and irradiated tubers and bulbs at 50 Gy produced sensitivity index above 10, with values ranging from 12.7 to 7441.4 for tubers and bulbs. In contrast, all tuber and bulb samples irradiated below 150 Gy have sensitivity index values of less than 10. Differences in the sensitivity index values obtained for low irradiated tubers and bulbs were likely due to the variation in the types and quantity of silicate materials such as feldspar and quartz contaminating the tubers, as suggested by Ijaz *et al.* (2008). The photon counts during the storage in the dark after irradiation more than 100 Gy treatment were consistent with those reported earlier by other researchers (Alberti A., *et al.*, 2007; Bayram, G. *et al.*, 2004; Goulas, A. E. *et al.*, 2008). From the table shown, sensitivity index was not suitable to be used for detecting irradiated food of less than 50 Gy, and further investigation are recommended using other analysis (EN 13571, 2009). The irradiated samples of less than 150 Gy also required further study by thermoluminescence (TL) analysis or other validated methods.

Table 1. Sensitivity index of tubers and bulbs

Dose levels (Gray)	Sensitivity Index					
	Potato			Onion		
	1 week	3 months	6 months	1 week	3 months	6 months
0	3815.0	580.6	7441.4	344.0	121.6	162.4
50	12.7	6.9	16.5	15.7	22.6	75.0
150	4.1	4.7	5.9	5.1	6.1	4.3
500	1.8	0.2	1.8	1.9	2.1	2.5

*Calibrated PSL/initial PSL

CONCLUSION

Photo-stimulated luminescence (PSL) was successfully applied in detecting irradiation treatment of the analysed tubers and bulbs with doses more than 150 Gy. The PSL signal intensity remained high even after 6 months of storage for potatoes and onions (150 and 500 Gy), indicating its suitability for detecting tubers and dry food ingredients which have long shelf-life. However, assessment of the irradiation dose from the PSL can be erroneous and hence misleading since the signal intensities are affected by the irradiation dose as well as by the nature and amount of contaminating inorganic material. The samples with dose less than 150 Gy were recommended for further investigation by thermoluminescence (TL) analysis (EN 1788, 2009). The results of this study provide a useful database on the applicability of PSL technique in the detection of irradiated tubers and bulbs. The availability of a method to detect irradiated food will be useful to the regulatory authority for enforcing labeling control in Malaysia. Further investigation is recommended for all cases where calibration does not resolve the issue.

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