J Food Sci Nutr
Vol 10, p 145~150 (2005)

J Food Science and Nutrition

Pulsed Photostimulated Luminescence (PPSL) of Gamma Irradiated Soybean Paste Powder

Sang-Duk Yi[1] and Man-Jin Oh[2†]

[1]*Nonghyup Korea Insam Research Institute, Nonghyup Koreainsam Co., LTD., Chungbuk 386-811, Korea*
[2]*Department of Food Science and Technology, Chungnam National University, Daejeon 305-764, Korea*

Abstract

This study was carried out to examine the properties of sample amount and storage conditions on the accumulated pulsed photostimulated luminescence (PPSL) signals of soybean paste powder. Difference amounts (0.1, 0.5 and 1 g) of soybean paste powder samples stored in normal room and darkroom conditions were measured. The PPSL signals of the soybean paste powders significantly increased with irradiation dose up to 10 kGy. The PPSL signals of irradiated soybean paste powder samples decreased with increasing storage periods. The decay rates were similar to regardless of storage conditions and sample amount. The PPSL signals of the irradiated soybean paste powder measured for 120 s were higher than those measured for 60 s. These results indicated that although the PPSL signal of all soybean paste powder samples decreased with increasing storage time, detection of irradiated samples was still possible after 12 months of storage regardless of sample amount and measurement times in both normal room and darkroom conditions.

Key words: soybean paste, irradiation, pulsed photostimulated luminescence (PPSL), storage condition

INTRODUCTION

Gamma irradiation is accepted for food hygiene in many countries. Detection techniques which are suitable to detect whether products are irradiated or not are needed to facilitate international trade and control irradiated food (1). Researcher on detection techniques have focused on reliable detection methods for specific irradiated foods (2-4).

Soybean paste powder, utilized as a component condiment to provide unique taste in instant soup powder, has a high potential for microbial contamination (5) and can provide a media for rapid growth microorganisms introduced by poor quality control. Therefore, irradiation of soybean paste powder permitted to assure a safe food supply.

The PPSL which uses light to stimulate the release of trapped charge in carriers is a radiation-specific phenomenon from energy storage by trapped charge from carriers of irradiation energy and is currently one of the physical detection methods for identification of irradiated foods (6-11). As the pulsed photostimulated luminescence (PPSL) is designed to allow direct measurements for rapid screening purposes without the need for sample preparation or re-irradiation such as the TL, PPSL is simple and quick requiring little training (12-16).

The objective of this study was to examine the effects of sample amount and storage conditions on differences in accumulated PPSL signals; thereby evaluating the possibility of using PPSL for the detection of irradiated soybean paste powder.

MATERIALS AND METHODS

Materials

Soybean paste powder used in this study was obtained from a local company (Gunpo, Korea). The moisture, crude protein, crude fat, carbohydrate, ash and salt contents of soybean paste powder sample were 11.9 ± 0.4, 19.7 ± 0.4, 3.2 ± 0.2, 28.6 ± 0.5, 36.5 ± 0.1 and 36.1 ± 0.2%, respectively.

Irradiation and sample storage

Soybean paste powder samples were packed in polyethylene bags (50 g) and irradiated using a Co-60 irradiator (AECL, IR-79, Ontario, Canada) with 1, 5, and 10 kGy at the Korea Atomic Energy Research Institute. To measure the exact amount of total absorbed dose of gamma irradiation, the dose rates for cobalt-60 sources were determined using a ceric-cerous dosimeter. The samples irradiated were directly used in PPSL without any other preparation. The normal room samples were stored for 12 months under laboratory conditions which

†Corresponding author. E-mail: ohmj@cnu.ac.kr
Phone: +82-42-821-6728, Fax: +82-42-821-6728

were under sunlight or a fluorescent light. The darkroom samples were stored for the same period in a oven chamber (K.M.C-1203P3, Vision Scientific Co., LTD, Seoul, Korea) to block out light and maintain the samples at room temperature.

PPSL system

Measurement of accumulated PPSL signals was carried out using a PPSL system purchased from Scottish Universities Research and Reactor Centre (SURRC, Glasgow, UK). The PPSL system is composed of a control unit, sample chamber, and detector head assembly. The control unit contains a stimulation source which is comprised of an array of infrared light (880~940 nm) emitting diodes which are pulsed symmetrically on and off for equal periods. PPSL signal is detected by a bialkali cathode photomultiplier tube operating in the photon counting mode and recorded automatically in a personal computer connected with the PPSL system. Optical filtering is used to define both the stimulation and detection wavebands (6-14,16).

PPSL measurement

The soybean paste powder samples (0.1, 0.5 and 1 g) were introduced in 50 mm diameter of disposable petri dishes (Bibby Sterilin types 122, Glasgow, UK) and were measured in the sample chamber for 60 and 120 s. The radiation-induced photon counts (PPSL signals) emitting per second from the samples were automatically accumulated in a personal computer and presented the photon counts accumulated for 60 s and 120 s (6-14,16).

Statistical analysis

Significant differences were determined using Duncan's multiple range test and a one-way ANOVA with SPSS (Statistical Package for Social Science) version 7.5. All experiments were repeated three times.

RESULTS AND DISCUSSION

PPSL signals of irradiated soybean paste powder

Table 1 and 2 show changes in accumulated PPSL signal according to storage conditions and sample amounts of soybean paste powders irradiated at 0, 1, 5, and 10 kGy. PPSL signals significantly increased with increasing irradiation dose and sample amount. Detection of irradiation by the PPSL system is based on higher radiation-induced PPSL signals than that of non-irradiated samples (17). Therefore, detection whether the sample has been irradiated or not was possible because of the higher signals of irradiated sample than that of non-irradiated sample. There were no significant differences in accumulated PPSL signals in non-irradiated soybean paste powders. Threshold levels which can distinguish non-irradiated samples from irradiated samples and measures of accumulated PPSL signals of non-irradiated samples were below 471±220 photon counts regardless of storage conditions and sample amount.

These results are consistent with the reported literatures, which has shown that the accumulated PPSL signals of irradiated Chinese sesame and perilla seeds, and Sudanese sesame seed (9), Korean sesame and perilla seeds (7), corn powder (6), shrimp-taste seasoning powder (10), starches, cereals and beans (8) were higher than that of non-irradiated ones in an irradiation dose-dependent manner.

Decay rate

If the PPSL response of irradiated materials is significantly greater than that of non-irradiated materials, and if the fading of the PPSL response is low over long-

Table 1. Changes in accumulated PPSL signals of irradiated soybean paste powder measured by PPSL with different sample amounts in the 60 s measurement times during storage for 12 months under normal room and darkroom conditions

(Unit: photon counts)

Samples (g)	Storage periods	Storage conditions	Irradiation dose (kGy) 0	1	5	10
0.1	0 month		312±99[1)d2)]	82,157±13,529[c]	417,078±35,425[b]	1,312,131±55,633[a]
	12 months	Normal room	287±30[d]	4,219±2,201[c]	35,810±2,623[a]	35,036±8,677[a]
		Dark room	271±57[d]	6,888±981[c]	45,908±1,005[b]	81,395±12,425[a]
0.5	0 month		266±103[d]	161,219±58,260[c]	1,249,871±163,355[b]	2,810,202±355,943[a]
	12 months	Normal room	246±42[d]	12,046±4,156[c]	71,955±21,953[b]	124,735±20,367[a]
		Dark room	255±54[d]	13,596±1,892[c]	76,951±6,380[b]	214,765±8,033[a]
1	0 month		250±64[d]	217,122±20,897[c]	2,432,879±293,322[b]	4,392,839±489,740[a]
	12 months	Normal room	217±26[d]	17,192±5,891[c]	73,982±17,995[a]	93,285±25,757[a]
		Dark room	206±21[d]	21,152±552[c]	93,640±1,012[b]	243,628±14,886[a]

[1)]Mean value±standard deviation for 3 measurements.
[2)]Means with the same superscripts in each row are not significantly different by Duncan's multiple range test and one way ANOVA ($p<0.05$).

Table 2. Changes in accumulated PPSL signals of irradiated soybean paste powder measured by PPSL with different sample amounts in the 120 s measurement times after storage for 12 months under normal room and darkroom conditions
(Unit: photon counts)

Samples (g)	Storage periods	Storage conditions	Irradiation dose (kGy) 0	1	5	10
0.1	0 month		471±220[1)d2)]	119,899±20,198[c]	622,708±71,193[b]	1,938,917±54,043[a]
	12 months	Normal room	338±53[d]	5,572±3,043[c]	48,759±4,163[a]	48,084±13,113[a]
		Dark room	339±58[d]	9,600±1,100[c]	62,935±970[b]	115,108±17,497[a]
0.5	0 month		320±96[d]	237,811±88,355[c]	1,931,587±250,232[b]	4,161,593±535,882[a]
	12 months	Normal room	281±47[d]	16,567±5,834[c]	102,969±30,918[b]	180,027±25,940[a]
		Dark room	295±61[d]	18,691±2,728[c]	112,147±2,212[b]	304,550±11,531[a]
1	0 month		338±48[d]	316,237±48,939[c]	3,621,399±455,858[b]	6,265,304±186,234[a]
	12 months	Normal room	301±29[d]	23,450±8,399[c]	103,746±25,864[b]	132,116±37,435[a]
		Dark room	274±37[d]	28,746±832[c]	136,171±4,729[b]	352,844±19,040[a]

[1)]Mean value±standard deviation for 3 measurements.
[2)]Means with the same superscripts in each row are not significantly different by Duncan's multiple range test and one way ANOVA ($p<0.05$).

term storage, PPSL measurement may be suitable to determine whether foodstuffs have been irradiated or not (17). Therefore, decay rates of PPSL signals of non-irradiated and irradiated soybean paste powder were observed during 12 months under normal room and darkroom conditions. Table 3 shows that PPSL signals of irradiated soybean paste powder were strongly influenced by the storage times. The PPSL signals of soybean paste powder after 12 months significantly decreased compared to the initial values (0 day) and there were not observed differences according to storage time and sample amounts.

In previous work on PPSL, when irradiated marjoram was stored during 24 weeks under normal room and darkroom conditions, the PPSL signals decreased (11) and the PPSL signals of irradiated sesame seeds after 12 months also significantly decreased (17). These results were in agreement with the results of this study. However, although the accumulated PPSL signals of the all soybean paste powders decreased with increasing storage times, the irradiated samples had higher photon counts than those of non-irradiated samples in normal room and darkroom conditions. In both conditions, detection of irradiation was still possible after 12 months.

Table 3. The decay rate of accumulated PPSL signals of irradiated soybean paste powder measured by PPSL with different sample amounts in the 60 and 120 s measurement times during storage of 12 months under normal room and darkroom conditions
(Unit: %)

Samples (g)	Storage periods	Storage conditions	Measurement times (sec)	Irradiation dose (kGy) 0	1	5	10
0.1	0 month		60	NC[1)]	0.0	0.0	0.0
			120	NC	0.0	0.0	0.0
	12 months	Normal room	60	NC	94.8	91.4	97.3
			120	NC	95.3	89.0	97.5
		Dark room	60	NC	91.6	92.2	93.8
			120	NC	91.9	89.9	94.1
0.5	0 month		60	NC	0.0	0.0	0.0
			120	NC	0.0	0.0	0.0
	12 months	Normal room	60	NC	92.5	94.2	95.6
			120	NC	93.0	94.7	95.7
		Dark room	60	NC	91.7	93.8	92.3
			120	NC	92.1	94.2	92.7
1	0 month		60	NC	0.0	0.0	0.0
			120	NC	0.0	0.0	0.0
	12 months	Normal room	60	NC	92.1	97.0	97.9
			120	NC	92.6	97.2	97.8
		Dark room	60	NC	90.3	96.2	94.5
			120	NC	91.0	96.3	94.3

[1)]Sample not calculated.

Greater decreases in the accumulated PPSL signals in samples stored under normal room conditions were thought to be due to differences in light exposure periods because storage under normal room condition after irradiation compared to darkroom condition can cause considerably higher instability follow emission of the radiation-induced PPSL photon counts trapped within the sample following stimulation by sunlight and other light present in normal room conditions, instead of just infrared.

Regression expressions and coefficients

Regression expressions and coefficients between irradiation doses and PPSL signals of irradiated soybean paste powder according to sample amount in 120 s measurement time are shown in Fig. 1, 2 and 3. Regression expressions and coefficients of soybean paste powder showed very high regression coefficients and this trend was similar for all samples.

Relationships between PPSL signals and general composition

Fig. 4 shows that PPSL signals of irradiated soybean paste powder was affected by ash and salt contents. As shown from Fig. 4, the PPSL signal was higher when the sample amount was higher. This result indicates that PPSL signal in the soybean paste powders was very closely related to ash and salt components. Generally, PPSL signals show more strongly in minerals because

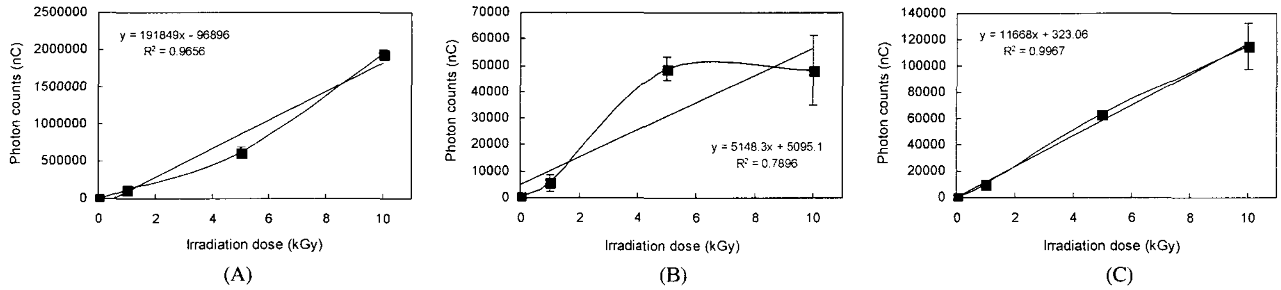

Fig. 1. Regression expressions and coefficients of variation between irradiation doses and accumulated PPSL signals measured with 0.1 g soybean paste powder sample in 120 s measurement times during storage of 12 months under normal room and darkroom conditions. (A) Sample measured immediately after irradiation. (B) Sample measured after 12 months in normal room condition. (C) Sample measured after 12 months in darkroom condition.

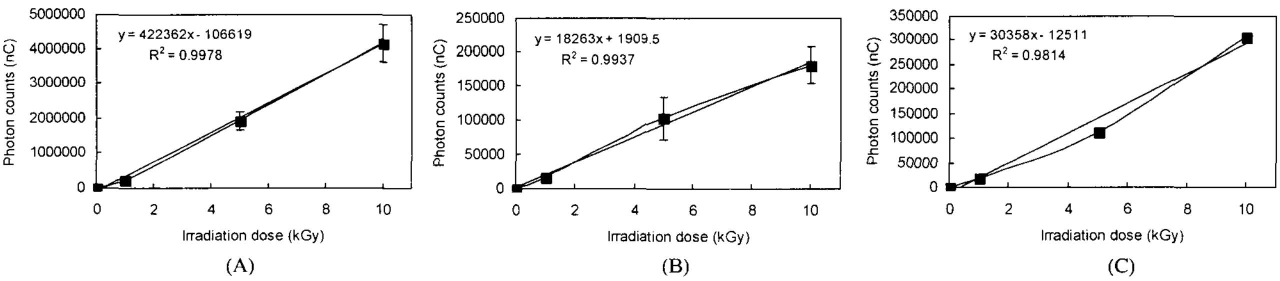

Fig. 2. Regression expressions and coefficients of variation between irradiation doses and accumulated PPSL signals measured with 0.5 g soybean paste powder sample in 120 s measurement times during storage of 12 months under room and darkroom conditions. (A) Sample measured immediately after irradiation. (B) Sample measured after 12 months in normal room condition. (C) Sample measured after 12 months in darkroom condition.

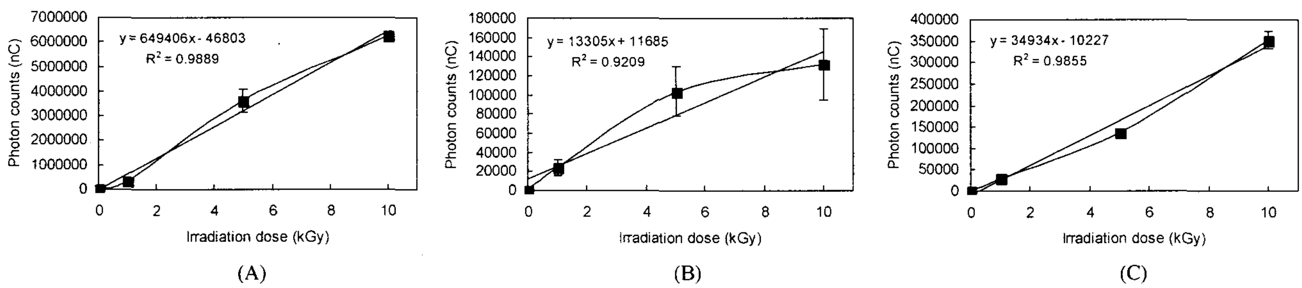

Fig. 3. Regression expressions and coefficients of variation between irradiation doses and accumulated PPSL signals measured with 1 g soybean paste powder sample in 120 s measurement times during storage of 12 months under normal room and darkroom conditions. (A) Sample measured immediately after irradiation. (B) Sample measured after 12 months in normal room condition. (C) Sample measured after 12 months in darkroom condition.

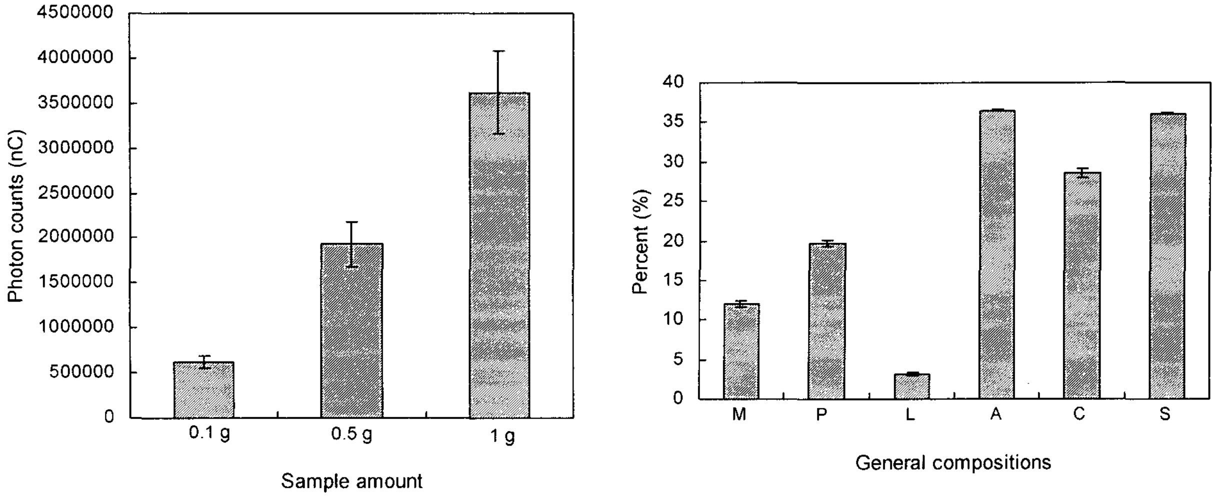

Fig. 4. Relationship between PPSL signals and general compositions in soybean paste powder irradiated at 5 kGy. M: Moisture, P: Protein, L: Lipid, A: Ash, C: Carbohydrate, S: Salt.

radiation energy is stored much more by trapping charge carriers at structural, interstitial or impurity site of minerals such as quartz and feldspar than any organic compounds (16). Therefore, in the soybean paste powder, the difference in PPSL signal according to increasing sample amount was guessed to be due to ash and salt contents having similar structure and specific property of mineral. This result is consistent with papers on shrimp flavor seasoning powder (10) that PPSL signal increased with increasing sample amount, PPSL signal of imported sesame and perilla seeds (9) that PPSL signal of minerals separated from sesame and perilla seeds was higher than that of the sesame and perilla seeds themselves and PPSL signal of *Ramen* soup powders (5). Consequently, although the PPSL signal of irradiated soybean paste powder decreased with increasing storage time, because higher photon counts were exhibited by irradiated samples than non-irradiated samples, detection was possible for up to 12 months in normal room and darkroom conditions. But since higher sample amounts (1 g) and darkroom conditions showed higher PPSL signals, the PPSL measurement condition was more reliable in 1 g samples stored under darkroom conditions. Therefore, we have demonstrated that the PPSL method is a suitable screening method for detecting irradiation treatment of irradiated soybean paste powder.

REFERENCES

1. Delience H. 1998. Detection of food treated with ionizing radiation. *Food Science & Technology* 9: 73-82.
2. Morehouse KM, Ku Y. 1992. Gas chromatographic and electron spin resonance investigations of irradiated shrimp. *J Agric Food Chem* 40: 1963-1972.
3. Stewart EM. 1996. The application of ESR spectroscopy for the identification of irradiated crustacea. *Appl Magn Reson* 10: 375-393.
4. Yi SD, Chang KS, Yang JS. 2000. Detection of irradiated cereals by viscosity measurement. *J Food Sci Nutr* 5: 93-99.
5. Yi SD, Yang JS, Oh MJ, Chang KS. 2002. Effect of storage conditions and the role of ash content in thermoluminescence (TL) characteristics and pulsed photostimulated luminescence (PPSL) of Ramen (instant noodle) soup powders irradiated on different particle size. *Food Sci Biotechnol* 11: 147-160.
6. Yi SD, Chang KS, Yang JS. 2001. Trial to identify irradiated corn powder by viscometric and pulsed photostimulated luminescence (PPSL) methods. *J Food Hyg Safety* 16: 82-87.
7. Yi SD, Woo SH, Yang JS. 2000. The use of pulsed photostimulated luminescence (PPSL) and thermoluminescence (TL) for the detection of irradiated perilla and sesame seeds. *J Food Sci Nutr* 5: 142-147.
8. Yi SD, Yang JS. 2000. The application of a pulsed photostimulated luminescence (PPSL) method for the detection of irradiated foodstuffs. *J Food Sci Nutr* 5: 136-141.
9. Yi SD, Woo SH, Yang JS. 2001. Pulsed photostimulated luminescence (PPSL) of irradiated importation sesame and perilla seeds. *Korean J Food Sci Technol* 33: 173-177.
10. Yi SD, Yang JS. 2001. Properties of pulsed photostimulated luminescence and thermoluminescence of gamma-irradiated shrimp-taste seasoning powder. *Food Sci Biotechnol* 10: 408-413.
11. Yi SD, Woo SH, Yang JS. 2001. Detection of pulsed photostimulated luminescence signals emitted by infrared stimulation of irradiated spices during storage under two conditions. *J Food Sci Nutr* 6: 152-157.
12. Sanderson DCW, Carmichael LA, Naylor JD. 1996. Recent advances in thermoluminescence and photostimulated luminescence detection methods for irradiated foods. In *Detection methods for irradiated foods*. McMurray CH, Stewart EM, Gray R, Pearce J, eds. The Royal Society of Chemistry, Cambridge, UK. p 124-138.
13. Chung HW, Delincée H, Kwon JH. 2000. Photostimulated luminescence-thermoluminescence application to detection of irradiated white ginseng powder. *Korean J Food Sci Technol* 32: 265-270.
14. Hwang KT, Uhm TB, Wagner U, Schreiber GA. 1998.

Application of photostimulated luminescence to detection of irradiated foods. *Korean J Food Sci Technol* 30: 498-501.

15. Schreiber GA. 1996. Thermoluminescence and photostimulated luminescence techniques to indentify irradiated foods. In *Detection methods for irradiated foods*. McMurray CH, Stewart EM, Gray R, Pearce J, eds. The Royal Society of Chemistry, Cambridge, UK. p 121-123.
16. European Committee for standard. 1997. Detection of irradiated food using photostimulated luminescence. English version of prEN 13751.
17. Yi SD, Yang JS. 2001. Influence of sample form, storage conditions and periods on accumulated pulsed photostimulated luminescence signals of irradiated Korean sesame and perilla seeds. *J Food Sci Nutr* 6: 216-223.

(Received January 21, 2005; Accepted March 2, 2005)