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Detection of Irradiated Korean Wheat Flour by Viscosity and Pulsed Photostimulated Luminescence (PPSL) Methods

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Abstract

This study was carried out to establish methods for irradiation detection of irradiation in Korean wheat flour by pulsed photostimulated luminescence (PPSL) and viscometric methods. The photon counts of the irradiated Korean wheat flour measured by PPSL immediately after irradiation increased with increasing irradiation dose. The photon counts in the irradiated Korean wheat flour almost disappeared with lapse of time after storage in normal room conditions, but irradiation detection was still possible after 6 months in darkroom conditions. All irradiated samples indicated a decrease in viscosity with increasing stirring speeds (rpm) and irradiation doses. Irradiation at 1 kGy significantly decreased the viscosity. Consequently, these results suggest that the detection of irradiated Korean wheat powder is possible by both viscometric and PPSL methods.

Key words: detection methods, viscosity, PPSL, gamma irradiation, Korean wheat

INTRODUCTION

Irradiation can be used for disinfecting as well as for the reduction of microbial contamination thereby reducing health hazards which might be caused by pathogenic microorganism and prevention of sprouting or delay ripening of fruit and vegetables (1-3). Detection techniques of irradiated foods have been required to control international trade, confirm correct labeling, avoid multiple irradiations and control the absorbed dose of irradiated foods (4-6). Recently, the detection of irradiated foods is required by many consumers. Therefore, the methods to detect irradiated foods are a useful means to check compliance with labeling regulations (7,8).

Pulsed photostimulated luminescence (PPSL), which uses light rather than heat to stimulate the release of trapped charge from carriers of irradiation energy, has been utilized for irradiated foodstuffs as a detection method which is designed to allow direct measurements for rapid screening purposes without the need for sample preparation (9,10).

Viscosity measurement has also been proposed as a method to detect irradiation treatment of foods containing high amounts of starch and have been carried out for some foods (11-15).

Generally, starch is composed of amylose and amylopectin. These two major component are degraded by gamma irradiation, resulting in a decrease in viscosity (16-26). Therefore, the objectives of this work were to establish viscometric and PPSL methods for detecting irradiated Korean wheat flour, which have not yet been examined in previous studies, and to describe the results for changes in viscosity and PPSL.

MATERIALS AND METHODS

Materials and irradiation

The Korean wheat flour used for this study was purchased from Dusan Co. (Icheon, Gyeonggi, Korea). The samples were packed in polyethylene bags and irradiated with 1, 2, 3, 5, 7 and 10 kGy using a Co-60 irradiator (AECL, IR-79, Ontario, Canada) at a dose rate of 10 kGy/h at the Korea Atomic Energy Research Institute. To measure the exact total absorbed dose of gamma irradiation, the dose rates for cobalt-60 sources were determined using a ceric-cerous dosimeter.

Measurement of pulsed photostimulated luminescence (PPSL)

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 infra-red light emitting diodes which are pulsed symmetrically on and off for equal periods. PPSL is detected by a bialkali cathode photomultiplier tube

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operating in photon counting mode. Optical filtering is used to define both the stimulation and detection wavebands. The samples (5 g) were introduced in 50 mm diameter disposable petri dishes (Bibby Sterilin type 122), with no other preparation, and measured in the sample chamber for 60 and 120 s. The photon counts of the samples were recorded (9). Samples stored at normal room conditions were stored in laboratory conditions with sunlight and an electric light. Samples stored in dark room conditions were stored in a dry oven (K.M.C-1203P3, Vision Scientific Co., LTD, Seoul, Korea) at room temperature.

Measurement of viscosity

Viscosity was measured according to Hayashi et al.'s (20-22) method with a slight modification. The Korean wheat flour was dissolved in distilled water to make an 8% aqueous solution to which 2.14 mL of 33% NaOH was added. The samples were mixed thoroughly for 30 sec. The glass bottle was heated for about 30 min in an autoclave (100°C). The glass bottle was left in an incubator (30°C) for 3 hr to maintain a uniform temperature. Viscosity was determined using a Brookfield DV-III rotation viscometer (Brookfield Engeineering Laboratories Inc., USA) equipped with an RV3 spindle at 30°C, and measured at 60, 120 and 180 rpm.

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

Changes in photon counts

The changes in photon count of the irradiated Korean wheat flour measured by PPSL are shown in Table 1. The photon counts from the irradiated Korean wheat flour measured for 60 and 120 s exhibited higher than from non-irradiated. Also, the photon counts from samples measured for 120 s were higher than those measured for 60 s. In all samples, the photon counts of the irradiated Korean wheat flour samples were higher than those of the non-irradiated samples when measured immediately after irradiation (control). Hence, the authors believe that irradiation detection of Korean wheat flour is possible by PPSL in both 60 s and 120 s measurement time. Differences in photon count according to storage conditions (normal room and darkroom) were clearly observed. In darkroom conditions, the photon counts of irradiated Korean wheat flour were observed after 6 months, but the photon count after one month in normal room conditions was almost undetectable (Table 2). As irradiated samples showed photon counts higher than those of non-irradiated samples in darkroom conditions, in this condition, irradiation detection was still possible after 6 months. Therefore, we think that PPSL has potential as a method for detecting the irradiation treatment of Korean wheat flour. Similar results for PPSL have been reported by other investigators. Sanderson et al. (26)

Table 1. Changes in accumulated photon counts of non-irradiated and irradiated Korean wheat flour according to storage conditions duration of storage (Unit: photon counts)

Storage time & condition		Measurement time (sec)	Irradiation dose (kGy) 0	1	5	10
0 month		60	260±85 [1)c2)]	15,253±4,449[b]	47,046±10,007[a]	45,597±6,045[a]
		120	232±121[c]	25,335±7,630[b]	67,953±9,518[a]	64,795±12,234[a]
1 month	Normal room	60	271±28[c]	2,996±2,373[a]	1,390±631[a]	1,781±712[a]
		120	417±82[c]	3,983±1,603[a]	2,139±1,259[a]	2,997±1,057[a]
	Dark room	60	336±36[c]	14,291±5,551[b]	31,934±1,543	39,471±4,676[a]
		120	515±234[c]	23,544±9,389[b]	49,828±5,664[a]	54,407±6,712[a]
3 months	Normal room	60	536±233[b]	960±134[a]	552±266[b]	627±47[b]
		120	468±245[b]	1,510±284[a]	720±490[b]	979±374[b]
	Dark room	60	306±33[c]	10,515±1,994	16,976±973[b]	26,173±3,719[a]
		120	294±164[c]	17,385±3,326[b]	29,299±13,203[a]	34,881±5,287[a]
6 months	Normal room	60	353±230[b]	478±104[b]	798±244[a]	996±527[a]
		120	311±55[c]	656±144[a]	1,188±544[a]	1,556±991[a]
	Dark room	60	323±139[c]	7,905±750[b]	17,913±8,761[a]	21,244±3,050[a]
		120	370±159[c]	13,239±1,240[b]	23,299±3,203[a]	30,881±5,287[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. Decay rate calculated from accumulated photon counts of irradiated Korean wheat flour with varied irradiation doses and storage conditions (Unit: %)

Storage time & condition		Measurement time (sec)	Irradiation dose (kGy)			
			0	1	5	10
0 month		60	NC[1)]	0	0	0
		120	NC	0	0	0
1 month	Normal room	60	NC	80.3	97.1	96.1
		120	NC	84.3	96.9	95.4
	Dark room	60	NC	6.3	32.1	13.4
		120	NC	7.1	26.7	16.0
3 months	Normal room	60	NC	93.7	98.8	98.6
		120	NC	94.0	98.5	97.7
	Dark room	60	NC	31.1	63.9	42.6
		120	NC	31.3	37.7	23.5
6 months	Normal room	60	NC	97.1	98.3	97.8
		120	NC	97.4	97.5	96.6
	Dark room	60	NC	48.2	61.9	53.4
		120	NC	47.7	50.5	32.2

[1)]Sample not calculated.

reported that the photon counts of intestinal grits and all irradiated shrimp were higher than non-irradiated ones. In principle, a PPSL emission occurs when the excited electrons return to the original level due to light (2,3). Consequently, these results suggest that detection of irradiated Korean wheat flour is possible by both PPSL methods.

Changes of viscosity

Fig. 1, 2 and 3 show the viscosity of irradiated Korean wheat powder at different dose levels and stirring speeds (rpms). Viscosity was reduced as dose levels and stirring speeds increased. Viscosity according to increasing irradiation doses was dramatically reduced from control with just 1 kGy of irradiation, and slowly reduced even further

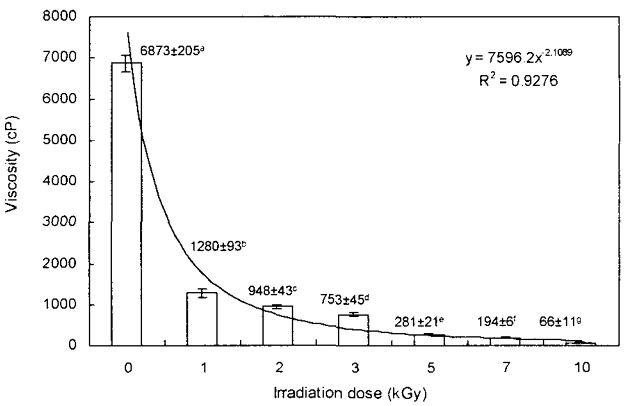

Fig. 1. Changes in viscosity and regression curves between irradiation dose and viscosity of irradiated Korean wheat flour measured at 60 rpm. Mean value±standard deviation for 3 measurements. [a-d]Means with the same superscripts in each row are not significantly different by Duncan's multiple range test and one way ANOVA ($p<0.05$).

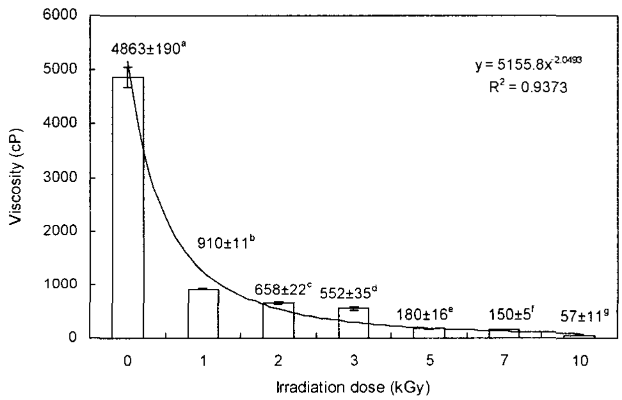

Fig. 2. Change in viscosity and regression curves between irradiation dose and viscosity of irradiated Korean wheat flour measured at 120 rpm. Mean value±standard deviation for 3 measurements. [a-d]Means with the same superscripts in each row are not significantly different by Duncan's multiple range test and one way ANOVA ($p<0.05$).

with doses of 2 kGy to 10 kGy (Table 3). The viscosities of non-irradiated Korean wheat flour were higher than in the irradiated flour in all samples. Therefore, it seems that if the viscosity of an unknown Korean wheat flour sample as measured by a viscometer is below or above that of an non-irradiated flour, we can distinguish whether it is irradiated or not. Based on these results, irradiation detection in Korean wheat flour is possible by a viscometric method, and this can be proposed as a detection method of irradiated Korean wheat flour.

Similar results for decreases in starch viscosity by irradiation have been reported. MacArthur and D'Appolonia (11) reported that reduced viscosity in irradiated starch was due to the degradation and uncoiling of starch chains, as well as the breaking of hydrogen bonds within

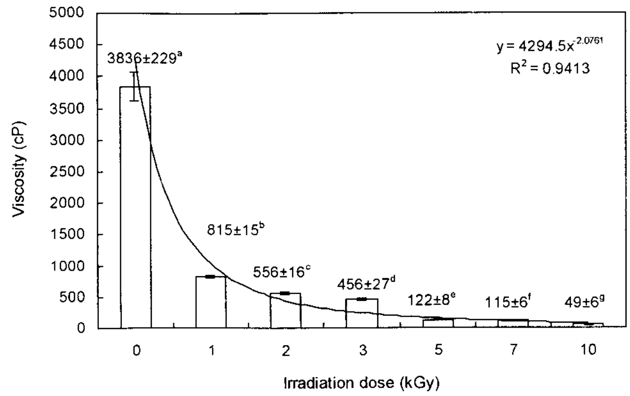

Fig. 3. Change of viscosity and regression curves between irradiation dose and viscosity of irradiated Korean wheat powder measured at 180 rpm. Mean value ± standard deviation for 3 measurements. [a-d]Means with the same superscripts in each row are not significantly different among group by Duncan's multiple range test and one way ANOVA ($p<0.05$).

Table 3. Viscosity decay rate of irradiated and non-irradiated Korean wheat powder (Unit: %)

rpm	Irradiation dose (kGy)						
	0	1	2	3	5	7	10
60	0	81.3	86.2	89.0	95.9	97.2	99.0
120	0	81.2	86.6	88.6	96.3	96.9	98.8
180	0	78.7	85.5	88.1	96.8	97.0	98.7

the molecule. Roushdi et al. (12) also reported that decreased viscosity for gamma irradiated corn starch was due to the decreased starch chain length.

The reduction of viscosity in irradiated starch was caused by the free radicals created by gamma irradiation. Free radicals are responsible for molecular changes such as the uncoiling of starch chains and fragmentation by the breaking of hydrogen bonds in the starch molecules. These changes may affect the physical and rheological properties of starch, thus decreasing the viscosity (13-15). The coefficients of variation (0.92 ~ 0.94) were very high between irradiation dose and viscosity (Fig. 1, 2 and 3). Hence, these results suggest that viscosity measurement a reliable and useful method to detect irradiation and that the PPSL method is necessary for rapid screening irradiated Korean wheat powder.

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