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Viscometric and Pulsed Photostimulated Luminescence Properties of Irradiated Glutinous Rice

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Abstract

This study was carried out to establish a method for the detection of irradiated glutinous rice by measuring pulsed photostimulated luminescence (PPSL) and viscometric properties. Viscosity was determined using a Brookfield DV-III rotation viscometer at 30°C and measured at 30, 60, 90, 120, 150, 180, and 210 rpm. All irradiated samples indicated a decrease in viscosity with increasing stirring speeds (rpm) and irradiation doses. Treatments with 2~5 kGy significantly decreased the viscosity. The photon counts of the irradiated glutinous rice were measured by PPSL and the photon counts of the non-irradiated and irradiated glutinous rice measured immediately after irradiation exhibited an increase with increasing irradiation dose. The photon counts of irradiated glutinous rice almost disappeared with the lapse of time when stored under normal room conditions, but was still possible to detect after 12 months of darkroom storage. Consequently, these results indicate that the detection of irradiated glutinous rice is possible by both viscometric and PPSL methods.

Key words: detection methods, viscosity, PPSL, gamma irradiation, glutinous rice

INTRODUCTION

Glutinous rice, also called waxy and sweet rice, is characterized mainly by the ratios of amylose and amylopectin in the starch (1). Glutinous rice is a more expensive rice with a higher amylopectin content than non-glutinous rice, which is higher in amylose; and has been traditionally used to prepare Korean foods requiring a more sticky texture such as rice cakes (2). Since an irradiation dose of 5 kGy totally controls the growth of many fungi and bacteria, gamma irradiation is used as a cereal preservation method (3).

Recently, consumer demand for non-irradiated foods has necessitated the development detection methods for irradiated foods (4). Therefore, the methods to detect irradiated foods are a useful means to check compliance with labeling regulations (5,6). Generally, starch composed of amylose and amylopectin is major determinant of viscosity in starch foods, but is degraded by gamma irradiation, resulting in a decrease in viscosity (7-16). Pulsed photostimulated luminescence (PPSL), which uses light to stimulate the release of trapped charge carriers following irradiation, has been applied to detection studies of irradiated foodstuffs and designed to allow direct measurements for rapid screening purposes (17-25).

Therefore, viscosity and PPSL measurements are possible detection methods for irradiated glutinous rice. This paper is the first to describe the changes in viscosity and PPSL of irradiated glutinous rice.

MATERIALS AND METHODS

Materials and irradiation

The glutinous rice used for this study was purchased from a local market. The samples were packed in polyethylene bags and irradiated with 1, 3, 5, 7, 10, and 15 kGy using a Co-60 irradiator (AECL, IR-79, Ontario, Canada) with an absorbed dose 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. The samples were stored under normal laboratory conditions at ambient room temperature, or were stored in a dry oven (KMC-1203P3, Vision Scientific Co., LTD, Seoul, Korea) for darkroom conditions. The stored samples were prepared for the experiment by crushing and sieving below 50 mesh.

Viscosity

Viscosity was measured according to the method of Hayashi et al. (7,8) with a slight modification. The glu-

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tinous rice powdered below 50 mesh was placed in a glass bottle and mixed with water to prepare an 8% aqueous solution. After adding 2.14 mL of 33% NaOH in 100 mL of glutinous rice solution, 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 obtain an uniform temperature. Viscosity was determined using spindle RV 3 of the Brookfield DV-III rotation viscometer (Brookfield Engeineering Laboratories Inc., USA) at 30°C, and measured at 30, 60, 90, 120, 150, 180, and 210 rpm.

Pulsed photostimulated luminescence (PPSL)

PPSL measurement was carried out using a PPSL system (serial; 0021, SURRC; Scottish Universities Research and Reactor Center, Glasgow, UK) composed of a control unit, sample chamber, and detector head assembly. The control unit contains a stimulation source 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 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.

The radiation-induced photon counts (PPSL signals) emitting per sec from the irradiated samples were automatically accumulated in a personal computer and presented the photon counts accumulated up to 60 s and 120 s (22). The photon counts of the samples were recorded (18-22,26). The samples were measured in triplicate under the same laboratory and instrumental conditions.

RESULTS AND DISCUSSION

Changes of viscosity

The changes in viscosity were measured according to irradiation doses and various stirring speeds for irradiated glutinous rice. The viscosities of irradiated glutinous rice are shown in Fig. 1. The viscosities of non-irradiated glutinous rice (control) at 30, 60, 90, 120, 150, 180, and 210 rpm were measured at 7977.7±543.0, 5398.7±405.5, 4476.7±351.5, 3921.0±121.8, 3394.3 ±36.7, 2803.7±400.0 and 2702.0±362.4 cP, respectively. The viscosities of the samples irradiated at 10 kGy were measured at 122.2±19.2, 100.0±0.0, 96.3± 6.4, 94.4±9.6, 88.9±7.7, 87.0±3.2 and 84.1±2.71 cP, respectively. The viscosities decreased according to in-

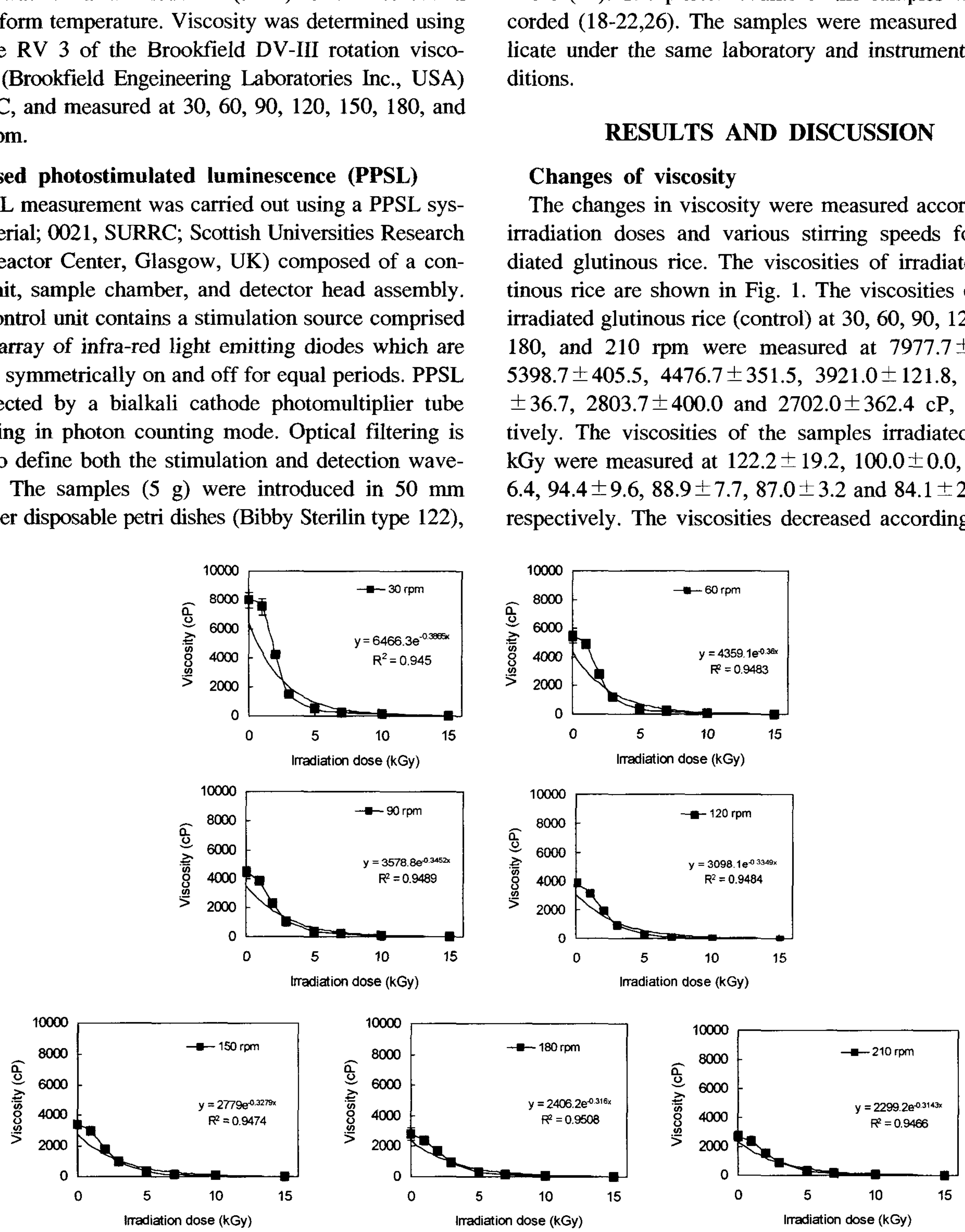

Fig. 1. Change of viscosity and regression curves between irradiation dose and viscosity of irradiated glutinous rice.

creasing irradiation dose and stirring speeds in all groups.

Other investigators have reported similar results. Yi et al. (12,16) reported that irradiated cereal showed a marked reduction in viscosity and higher irradiation doses gave rise to higher reductions in apparent viscosity. Most of the above results agreed with those reported by many other researchers (13,14), as well as Yi et al. (12,16) for other cereals.

Decay rate of viscosity and, regression expressions and coefficients

Table 1 showed that viscosities of irradiated glutinous rice were strongly influenced by the irradiation doses. The viscosity of glutinous rice irradiated at 1, 2, 3, 5, 7, 10 and 15 kGy decreased 5.7, 47.1, 81,2 93.9, 96.9, 98.5 and 99.6%, respectively, indicating that viscosity decreased greatly with increasing irradiation doses compared to the control values (0 kGy). This tendency according to storage conditions also was similarly observed at other rpms. The regression expressions and coefficients of viscosity for glutinous rice are shown in Fig. 1. High regression coefficients were obtained. Based on the above results, a viscosity measurement method can be proposed as a detection method for irradiated glutinous rice.

The changes of photon counts with irradiation doses and measurement times

The changes in photon counts of the irradiated glutinous rice measured by PPSL are shown in Table 2. The photon counts of the glutinous rice measured for 60 and 120 s exhibited an increase with increasing ir-

Table 1. Decay rate of viscosity in irradiated glutinous rice at 8% concentration with varied irradiation doses and rpms

rpm	Irradiation dose (kGy)							
	0	1	2	3	5	7	10	15
30	NC[1)]	5.7	47.1	81.2	93.9	96.9	98.5	99.6
60	NC	9.4	49.0	77.7	92.5	96.1	98.2	99.3
90	NC	13.9	48.2	76.3	91.9	95.6	97.8	99.2
120	NC	18.0	48.1	74.6	91.4	95.2	97.6	99.1
150	NC	12.7	46.9	71.8	90.7	95.1	97.3	99.0
180	NC	2.5	41.0	66.9	89.3	94.4	96.9	98.8
210	NC	12.6	42.3	67.0	89.4	94.5	96.8	98.7

[1)]Not calculated.

Table 2. The changes in accumulated photon counts of non-irradiated and irradiated glutinous rice according to storage conditions and time (unit: Photon counts)

Storage period & condition		Measurement time (s)	Irradiation dose (kGy)			
			0	1	5	10
0 day		60	648±155[1)]	23,991±3,685	24,343±5,835	23,496±3,071
		120	804±305	37,797±9,825	40,024±7,977	38,524±4,040
1 month	Room[2)]	60	244±49	361±150	351±155	296±29
		120	275±27	345±67	520±241	496±107
	Darkroom[3)]	60	272±21	8,415±2,448	12,731±6,014	11,232±1,445
		120	302±58	14,577±3,940	21,254±9,395	19,258±2,458
3 months	Room	60	260±141	334±213	308±81	290±34
		120	339±52	479±481	291±45	223±54
	Darkroom	60	342±82	10,181±3,633	9,195±436	9,726±3,998
		120	330±173	14,313±1,259	15,216±507	14,497±3,201
6 months	Room	60	252±109	300±58	386±163	319±49
		120	384±246	310±47	387±173	202±76
	Darkroom	60	214±56	11,345±4,058	11,173±5,816	10,003±2,582
		120	135±12	13,663±3,587	13,470±5,304	13,530±4,332
12 months	Room	60	253±127	00±80	352±48	305±67
		120	318±96	297±62	340±116	730±101
	Darkroom	60	302±68	9,827±2,485	8,955±2,170	8,795±1,013
		120	256±43	12,564±2,506	13,075±4,653	14,257±1,477

[1)]Mean value±standard deviation for 3 measurements.
[2)]Room condition: Laboratory conditions.
[3)]Darkroom condition: Dry oven condition on room temperature.

radiation dose. Also, the photon counts of the glutinous rice measured for 120 s were higher than those measured for 60 s. In all samples, the photon counts of the glutinous rice samples were higher than those of the non-irradiated samples when measured immediately after irradiation (control). Therefore, we conclude that the detection of irradiated glutinous rice is possible by measuring PPSL properties for 60 s and 120 s.

Influence of storage conditions

The differences in the photon counts according to the storage conditions (room and darkroom) were clearly observed. In rice stored under darkroom storage conditions, the photon counts of glutinous rice were easily observed, but the photon counts after 12 months of storage under normal room condition were almost undetectable (Table 2). Irradiated samples showed much higher photon counts than the non-irradiated samples after 12 months of storage under darkroom conditions, and were easily detected after the 12 months of storage. Therefore, we conclude that PPSL is useful as a method for detection of irradiation treatment of glutinous rice, if the rice has been stored in the dark. After 12 months storage, rice irradiated at 1, 5, and 10 kGy had 120 s PPSL signals that were reduced by 99.2, 99.2 and 98.1%, respectively, if stored under normal room conditions; but 66.7, 67.3 and 63.0%, respectively, under darkroom conditions, compared to the initial values (0 day) (Table 3). The decay rate was higher under normal room storage conditions than in darkroom conditions, and this trend was consistent according to storage conditions in all samples regardless of other treatments. Yi et al. (22) reported that when marjoram was irradiated at 5 kGy and stored for 24 weeks under normal room and darkroom conditions, the accumulated PPSL signals at 5 kGy resulted in the signal intensity falling to approximately 74% in room condition and 38.2% in darkroom conditions. Yi and Yang (25) also reported that the accumulated PPSL signals of sesame seeds irradiated at 1, 5, and 10 kGy after 12 months resulted in the signal intensity falling to approximately 32.5, 60.2, and 52.8%, respectively, in darkroom condition and 99.9, 99.2, and 99.2%, respectively, in normal room conditions. Their results are consistent with the results of this paper. They also explained that the reason for the greater decrease in accumulated PPSL signals under normal room storage conditions was differences in the exposure to light (20-22). Storage under normal room conditions result in stimulation by ambient light (sunlight etc.) instead of infrared used in PPSL, resulting in a reduction in radiation-induced PPSL photon counts. Hence, normal storage led to higher decrease in accumulated PPSL signals in the glutinous rice. Although the accumulated PPSL signals of the all glutinous rice decreased with increasing storage times, the

Table 3. Changes in decay rate calculated from accumulated PPSL signals of irradiated glutinous rice measured in the 60 and 120 s measurement times during storage periods of 12 months under room and darkroom conditions (unit: %)

Storage period & condition		Measurement time (s)	Irradiation dose (kGy)			
			0	1	5	10
0 day		60	NC[1)]	0	0	0
		120	NC	0	0	0
1 month	Room[2)]	60	NC	98.5	98.6	98.7
		120	NC	99.1	98.7	98.6
	Darkroom[3)]	60	NC	64.9	47.7	52.2
		120	NC	61.4	46.9	50.0
3 months	Room	60	NC	98.6	98.7	98.0
		120	NC	98.7	99.3	99.4
	Darkroom	60	NC	57.6	62.2	58.6
		120	NC	62.1	61.9	62.3
6 months	Room	60	NC	98.7	98.4	98.6
		120	NC	99.2	99.0	99.5
	Darkroom	60	NC	52.7	54.1	57.4
		120	NC	63.9	66.3	64.9
12 months	Room	60	NC	98.7	98.6	98.7
		120	NC	99.2	99.2	98.1
	Darkroom	60	NC	59.0	63.2	62.6
		120	NC	66.7	67.3	63.0

1)Not calculated.
2)Room condition: Laboratory conditions.
3)Darkroom condition: Dry oven condition on room temperature.

irradiated samples showed higher photon counts than those of non-irradiated samples, when stored under darkroom conditions. Therefore, on the basis of the above results, we conclude that detection of irradiated glutinous rice stored under darkroom condition is still possible after 12 months by measuring viscometric and PPSL properties.

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