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Comparsion of Maximum Viscosity and Viscometric Method for Identification of Irradiated Sweet Potato Starch

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Abstract

A study was carried out to compare viscosity and maximum viscosity methods for the detection of irradiated sweet potato starch. The viscosity of all samples decreased by increasing stirring speeds and irradiation doses. This trend was similar for maximum viscosity. Regression coefficients and expressions of viscosity and maximum viscosity with increasing irradiation dose were 0.9823 ($y=335.02e^{-0.3366x}$) at 120 rpm and 0.9939 ($y=-42.544x+730.26$). This trend in viscosity was similar for all stirring speeds. Parameter A, B and C values showed a dose dependent relation and were a better parameter for detecting irradiation treatment than maximum viscosity and the viscosity value itself. These results suggest that the detection of irradiated sweet potato starch is possible by both the viscometric and maximum visosity method. Therefore, the authors think that the maximum viscosity method can be proposed as one of the new methods to detect the irradiation treatment for sweet potato starch.

Key Words : gamma irradiation, viscosity, maximum viscosity, sweet potato starch

1. Introduction

Gamma irradiation, a technique with the potential to protect food from contamination during storage, is permitted in Korea for sweet potato starch up to 5 kGy [1] . Sweet potato starch composed of amylose, which is essentially a linear molecule containing glucose units linked by alpha-1,4 linkages with few branches and amylopectin, an alpha-l,4 linked glucose units attached glycosidically by alpha-1,6 linked glucose, is a food reservoir providing a good energy source at a very low price in human diets and widely used in chemical and food industries [2] . In recent years, detection techniques of irradiated foods have been required to control international trade, supervise correct labelling, avoid multiple irradiation, and control the absorbed dose and homogeneity of the dose distribution of irradiated foods [3] . In previous studies, viscometric detection of irradiated foods have been mainly carried out for peppers and spices using a viscometer [4-14] and viscosity measurement has been proposed as a method to detect the irradiation treatment of foods containing high amounts of starch. Starch is degraded by gamma irradiation, resulting in a decrease in viscosity [15-17] , hence viscosity measurement and maximum viscosity measurement, using the gelatinization process that occurs when starch granules are heated in water at 90℃ or above, could be proposed as a detection method for irradiated sweet potato starch.

On the basis of this background, the aim of this study is to examine sweet potato starch which has not yet been tried in the viscometric detection field, compare the maximum viscosity method at first adapted as a new method for the detection of sweet potato starch in this paper and the viscometric method, establish parameters for detecting irradiated sweet potato starch which are independent of viscosity measuring conditions, and add new data in this field.

2. Materials and Methods

2.1. Materials and Gamma irradiation

Sweet potato starch was purchased from Dusan Co. (Ich'on, Kyonggi, Korea). The moisture contents of sweet potato starch was 13.20±0.20%, and the starch content of dried sweet potato starch was 0.948±0.06g/g. Samples were packed in polyethylene bags and irradiated at 1, 2, 3, 5, 7, 10, and 15 kGy using a Co-60 irradiator (AECL, Canada) at the Korea Atomic Energy Research Institute. A ceric-cerous dosimeter was used to measure the exact total absorbed dose of gamma irradiation.

2.2. Determination of Starch and Moisture Content

The moisture content was measured using the AOAC method [18] . Starch content was determined according to the Hayashi and Kawashima's method [19] with a slight modification.

2.3. Viscosity Measurement

Viscosity was measured according to Hayashi *et al.*'s [6-10] method with a slight modification. Sweet potato starch was placed in glass bottles and 5% solutions were prepared. After adding 2.14 mL of 33% NaOH, the samples were mixed thoroughly for 30 s. The glass bottles were heated for about 30 min in an autoclave (100℃) and were left in an incubator (30℃) for 3 h to maintain uniform temperature. The viscosity of sweet potato starch was determined using the spindle RV 3 of the Brookfield DV-Ⅲ rotation viscometer at 30℃ and measured at 30, 60, 90, 120, 150, 180, and 210 rpm.

2.4. Measurements of Brabender Visco-Amylograph

Maximum viscosity was measured according to Medcalf and Gilles' method [20] with a slight modification. The concentrations of the suspensions were 50g/450㎖ of sweet potato starch. The suspension was homogenized with a homogenizer (Nihonseiki Kaisha Co Ltd., Japan) for 2 min at 10,000 rpm, and was uniformly heated from 45℃ to 93℃ with a constant temperature rise of 3℃/min, held at 93℃ for 15 min. Pasting curves were obtained by means of a Brabender visco-amylograph (Brabender Co Ltd., Germany) with a 700-cmg cartridge. Initial pasting temperature was the temperature of the paste when the viscosity began to rise from the base line on the recording paper. Maximum viscosity temperature is the temperature of the paste when the maximum viscosity defined as the viscosity of maximum peak height, was reached.

2.5. Parameter Values

Identification parameters A, B, and C were calculated as follows: parameter A = viscosity per irradiation dose/moisture content, parameter B = parameter A per irradiation dose/amount of starch in a 1 g sample, and parameter C = parameter B per irradiation dose/parameter B of control.

2.6. Statistical Analysis

All experiments were triplicated. Significant differences were determined using Duncan's multiple range test. Regression expressions and coefficients were determined through regression analysis with SPSS (Statistical Package for Social Science) version 7.5.

3. Results and Discussion

3.1. Amylograph Characteristics of Irradiated Sweet Potato Starch

Amylograph characteristics of irradiated sweet potato starch are shown in Table 1. Initial pasting temperatures varied between 73.5±0.0°C and 75.0±0.0°C. Maximum viscosity temperatures varied between 78.0±0.0°C and 81.0±2.1°C, which showed no change statistically according to increasing irradiation dose. The maximum viscosities of unirradiated and irradiated sweet potato starch at 1, 3, 5, 7, 10, and 15 kGy exhibited a reduction from 750.0±14.1 B.U. of unirradiated control to 700.0±0.0, 595.0±21.2, 490.0±28.3, 415.0±35.4, 312.5±31.8, and 105.0±7.1 B.U., respectively and showed significant changes ($P<0.05$). Fig. 1 shows the amylograms of sweet potato starches irradiated at various doses. As shown in Fig. 1, the maximum viscosity of irradiated sweet potato starch reduced with increasing of irradiation doses.

3.2. Changes of Viscosity at Various Rpm and Doses

Table 2 shows the viscosities of irradiated sweet potato starch with increasing dose levels and rpms. Viscosity showed a marked reduction with increasing dose levels and almost disappeared at 15 kGy. In the control and all irradiation doses, viscosity according to increasing rpms reduced from the control to 3 kGy but showed a contrary trend from 5 kGy to 15 kGy. Significant differences in viscosities among irradiation doses were clearly observed at all stirring speeds ($p<0.05$).

Similar results for starch have been reported. MacArthur and D'Appolonia [21] 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 the molecule. Roushdi *et al.* [22] also reported that a decrease in viscosity values for gamma irradiated corn starch was due to the decreased starch chain length. Nene *et al.* [23] found that irradiated (10 kGy) red gram flour exhibited a very low maximal gelatinization viscosity (350 B.U.) compared to the control (860 B.U.), and, in isolated red gram starch, the viscosity dropped from 860 B.U. in the control to 100 B.U. in the irradiated (10 kGy) samples. Others have found that peak viscosity, setback values, final viscosity and the consistency of irradiated brown rice decreased with increasing levels of irradiation. The decrease in peak viscosity in rice by irradiation may be attributed to starch depolymerization [24] .

In principle, Sokhey and Hanna [25] explained that the reduction of viscosity in irradiated starch was caused by the free radicals created by gamma irradiation. Increasing doses of gamma irradiation creates increasing intensities of free radicals in carbohydrates, which are responsible for molecular changes such as the uncoiling of starch chains and fragmentation by the breaking of the hydrogen bonds of the starch molecules. These changes may affect the physical and rheological properties of starch and decrease viscosity. Based on the above papers, the reason for the reduction in viscosity in sweet potato starch was guessed similar to that explained by Sokhey and Hanna [25] .

3.3. Parameter Values of Irradiated Sweet Potato Starch

To remove the affected variation for viscosity, the parameter values derived from the maximum viscosity and viscosity of sweet potato starch are listed in Table 3 and 4. Hayashi *et al.* [6] reported that the viscosity divided by the starch content to calculate a normalized parameter provides a more consistent response to irradiation treatment than any viscosity value. The parameter values of irradiated sweet potato starch showed a dose dependent relation between unirradiated and irradiated samples and indicated that all of the values for the unirradiated samples were higher than the irradiated ones. A normalized parameter of the samples is a better parameter for detecting irradiation treatment than the viscosity value itself because the moisture and starch contents of sweet potato starch have an influence on viscosity. Therefore, we expect that the apparent viscosity divided by moisture (parameter A), starch content (parameter B), and irradiated samples divided by the control of parameter B (parameter C) provide detection values that reduce the fluctuation of viscosity values among the sweet potato starch samples.

3.4. Regression Expressions and Coefficients Between Viscosity and Irradiation Dose

Regression expressions and coefficients of viscosities among irradiation doses of sweet potato starch are listed in Table 5, which shows that the regression coefficients are very high between irradiation dose and viscosity.

4. Conclusions

All samples indicated a decrease of viscosity and maximum viscosity by increasing the irradiation dose. This tendency for viscosity was similar for all stirring speeds. These results suggest that the detection of irradiated sweet potato starch is possible by both the viscometric and maximum viscosity method.

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Table 3. Parameter values derived from the viscosities of irradiated sweet potato starch

Rpm	Parameter	Irradiation Dose (kGy)							
		Control[1]	1	2	3	5	7	10	15
30	PA[2]	39.59	23.99	15.11	9.76	4.92	3.20	2.36	1.53
	PB[3]	41.76	25.31	15.94	10.29	5.18	3.37	2.48	1.61
	PC[4]	1.0000	0.6060	0.3816	0.2465	0.1244	0.0809	0.0595	0.0388
60	PA	37.19	18.18	12.05	9.39	5.03	3.39	2.52	1.68
	PB	39.23	19.17	12.71	9.90	5.30	3.57	2.65	1.77
	PC	1.0000	0.4889	0.3239	0.2524	0.1355	0.0911	0.0678	0.0452
90	PA	33.02	16.58	12.20	9.21	4.92	3.83	2.96	1.97
	PB	34.83	17.49	12.87	9.72	5.19	4.04	3.12	2.07
	PC	1.0000	0.5022	0.3696	0.2790	0.1491	0.1159	0.0897	0.0596
120	PA	28.58	16.68	12.12	8.95	5.02	4.03	3.27	2.17
	PB	30.14	17.59	12.78	9.44	5.30	4.25	3.45	2.20
	PC	1.0000	0.5836	0.4241	0.3132	0.1755	0.1413	0.1142	0.0758
150	PA	25.89	15.98	11.58	8.71	5.30	4.42	3.58	2.37
	PB	27.31	16.86	12.22	9.19	5.59	4.66	3.78	2.50
	PC	1.0000	0.6170	0.4473	0.3365	0.2045	0.1709	0.1384	0.0916
180	PA	23.71	15.28	11.20	8.77	5.63	4.72	3.84	2.56
	PB	25.01	16.12	11.81	9.25	5.94	4.97	4.04	2.69
	PC	1.0000	0.6444	0.4722	0.3700	0.2377	0.1990	0.1620	0.1080
210	PA	22.47	14.70	11.13	8.83	5.98	4.98	4.11	2.75
	PB	23.70	15.50	11.74	9.31	6.31	5.25	4.34	2.90
	PC	1.0000	0.6541	0.4953	0.3928	0.2660	0.2215	0.1831	0.1224

[1] Control = unirradiated sample.

[2] PA : Parameter A

[3] PB : Parameter B

[4] PC : Parameter C

Table 1. Brabender visco/amylograph characteristics of unirradiated and irradiated sweet potato starch with different doses

Characteristics	Irradiation Dose(kGy)						
	Control[1)]	1	3	5	7	10	15
Initial pasting temp.(℃)	75.0±0.0[a2)]	75.0±0.0[a]	74.3±1.1[ab]	73.5±0.0[b]	73.5±0.0[b]	74.3±1.1[ab]	75.0±0.0[b]
Maximum viscosity temp.(℃)	78.0±0.0[a]	81.0±2.1[a]	81.0±0.0[a]	79.5±2.1[a]	79.5±0.0[a]	79.5±0.0[a]	80.3±1.1[a]
Maximum viscosity (B.U.[3)])	750.0±14.1[a]	700.0±0.0[a]	595.0±21.2[b]	490.0±28.3[c]	415.0±35.4[d]	312.5±31.8[e]	105.0±7.1[f]

[1)] unirradiated sample

[2)] [a-g] Means with the same superscripts in each row are not significantly different ($p<0.05$).

[3)] B.U. = Brabender Unit

Mean value ± Standard Deviation for 3 measurements

Table 2. Viscosity of sweet potato starch at various doses and stirring speeds

(Unit : centipoise (cP))

rpm	Irradiation Dose(kGy)							
	Control[1)]	1	2	3	5	7	10	15
30	522.6 ± 32.8^{aA}	316.7 ± 8.8^{bA}	199.4 ± 20.8^{cA}	128.8 ± 5.1^{dA}	65.0 ± 5.0^{eA}	42.3 ± 0.8^{efA}	31.1 ± 3.8^{FA}	20.3 ± 2.81^{fA}
60	490.9 ± 23.6^{aA}	240.0 ± 8.3^{bB}	159.0 ± 6.6^{cB}	123.9 ± 1.9^{dAB}	66.5 ± 5.2^{eA}	44.7 ± 0.5^{fB}	33.3 ± 0.0^{fgA}	22.2 ± 0.9^{gA}
90	435.9 ± 25.0^{aB}	218.9 ± 3.3^{bC}	161.1 ± 10.6^{cB}	121.6 ± 2.0^{dABC}	65.0±0.5eA	50.5 ± 0.9^{efC}	39.1 ± 0.2^{fgB}	26.0 ± 0.7^{hB}
120	377.3 ± 19.7^{aC}	220.2 ± 3.1^{bC}	160.0 ± 5.0^{cB}	118.2 ± 2.6^{dBC}	66.2 ± 0.8^{eA}	53.3 ± 1.4^{fD}	43.1 ± 0.3^{fC}	28.6 ± 0.5^{gC}
150	341.8 ± 11.9^{aCD}	210.9 ± 4.8^{bCD}	152.9 ± 5.0^{cB}	115.0 ± 5.5^{dC}	69.9 ± 0.9^{eAB}	58.4 ± 0.9^{fE}	47.3 ± 0.6^{gD}	31.3 ± 1.1^{hD}
180	313.0 ± 15.3^{aDE}	201.7 ± 3.9^{bDE}	147.8 ± 7.7^{cB}	115.8 ± 5.0^{dC}	74.4 ± 0.9^{eBC}	62.3 ± 0.8^{fF}	50.7 ± 1.0^{gE}	33.8 ± 0.6^{hE}
210	296.6 ± 18.8^{aE}	194.0 ± 3.1^{bE}	146.9 ± 7.2^{cB}	116.5 ± 4.7^{dBC}	78.9 ± 0.54^{eC}	65.7 ± 0.5^{fG}	54.3 ± 0.3^{fF}	36.3 ± 0.5^{gF}

[1)] Control = unirradiated sample.

[a-h] Means with the same superscripts in each row are not significantly different ($p < 0.05$).

[A-G] Means with the same superscripts in each column are not significantly different ($p < 0.05$).

Mean value ± Standard Deviation for 3 measurements

Table 4. Parameter values derived from the maximum viscosity of unirradiated and irradiated starch with different doses

Parameter values	Irradiation Dose(kGy)						
	Control[1)]	1	3	5	7	10	15
PA[2)]	56.82	53.03	45.08	37.12	31.44	23.67	7.95
PB[3)]	59.93	55.93	47.55	39.16	33.16	24.97	8.39
PC[4)]	1.0000	0.9333	0.7934	0.6532	0.5533	0.4166	0.1399

[1)] - [4)] Refer to the legend in Table 3.

Table 5. Regression expressions and coefficients of irradiated sweet potato starch

	Rpm	Regression expressions and coefficients	
Viscosity	30	$y = 485.55e^{-0.4164x}$	$R^2 = 0.9923$
	60	$y = 398.19e^{-0.3792x}$	$R^2 = 0.9561$
	90	$y = 363.63e^{-0.3597x}$	$R^2 = 0.9648$
	120	$y = 335.02e^{-0.3366x}$	$R^2 = 0.9823$
	150	$y = 335.02e^{-0.3366x}$	$R^2 = 0.9823$
	180	$y = 280.78e^{-0.2797x}$	$R^2 = 0.9761$
	210	$y = 265.35e^{-0.2572x}$	$R^2 = 0.9709$
Maximum viscosity		$y = -42.544x + 730.26$	$R^2 = 0.9939$

y : viscosity

x : irradiation dose

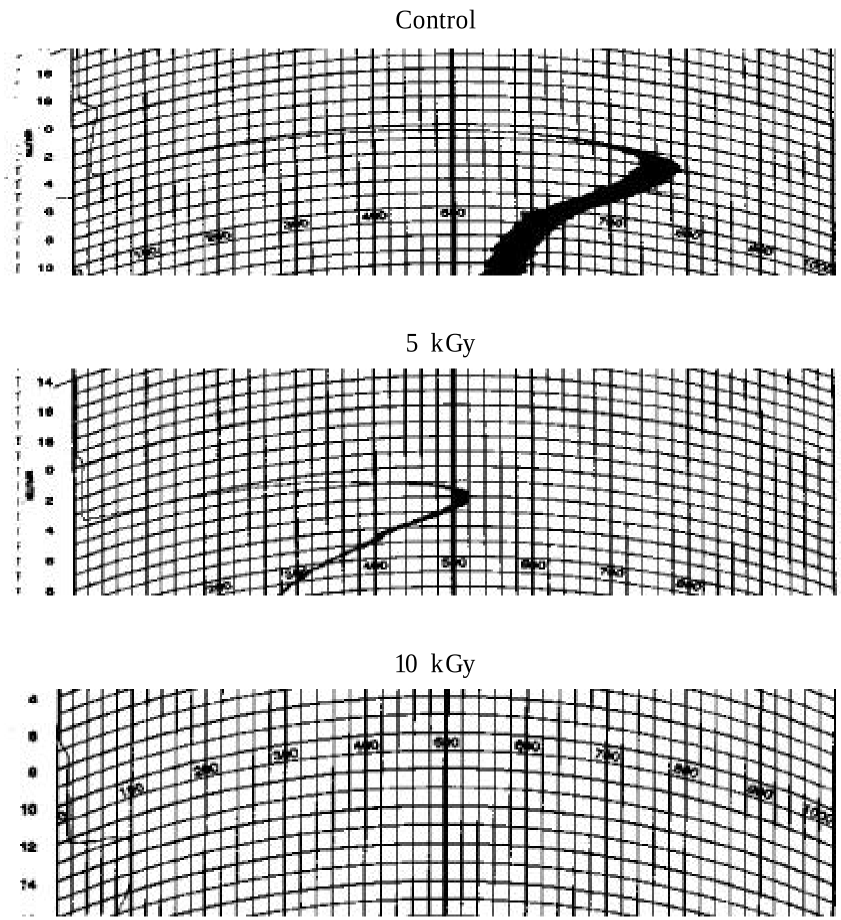

Fig. 1. Amylograms of sweet potato starch unirradiated and irradiated with different doses.