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Utilization of Brabender Visco-Amylograph to Detect Irradiated Starches

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Abstract

A study was carried out to establish the detection method of irradiated corn, potato, and sweet potato starches. The samples were packed in polyethylene bags and irradiated with 1, 3, 5, 7, 10, and 15 kGy using a Co-60 irradiator. The maximum viscosity of irradiated and unirradiated corn, potato, and sweet potato starches reduced by increase of irradiation dose levels and showed significant differences which clearly showed the effect of irradiation dose levels ($p<0.05$). Regression expressions and coefficients ($p<0.000$) of corn, potato, and sweet potato starches were $y=-38.538x+718.23$ ($r^2=0.9761$), $y=669.97e^{-0.1372x}$ ($r^2=0.9820$) and $y=-42.544x+730.26$ ($r^2=0.9939$), respectively. Normalized parameter A, B and C values showed a dose dependent relationship and were a better parameter for detecting the irradiated starches than that of the maximum viscosity itself.

Key words: starch, gamma irradiation, maximum viscosity, Brabender visco-amylograph

INTRODUCTION

In Korea, gamma irradiation is permitted for starches up to 5 kGy and is a physical technique for food preservation that seems to have the potential to protect foods from contamination during storage (1). Recently, consumers have recognized the need for detection methods of irradiated foods and their absorbed doses. Therefore, reliable methods to detect irradiated foods are necessary to check compliance with labeling regulations and to supplement the labeling process (2). Starch is the most abundant substance among plant products and is a major food reservoir providing a good energy source with a very low price in human diets. Starch is also widely used in the chemical and food industry (3). Starch composed of amylose and amylopectin is degraded by gamma irradiation, resulting in a decrease in viscosity (4-6). Therefore, measurement of viscosity was suggested as a detection method for irradiated starches. The maximum viscosity measurement, using the gelatinization process that occurs when starch granules are heated in water at 90°C or above, can be proposed as a new method to detect the irradiation treatment of starch. In the previous studies, viscometric detection was proposed as a method to detect irradiated foods containing high amounts of starch such as spices (7-17). The purpose of this study was to study a detection method for irradiation treatment by maximum viscosity measurement as the basic data for the viscometric detection of irradiated foods containing starch (like cereals and peppers).

MATERIALS AND METHODS

Samples

Corn, potato and sweet potato starches were purchased from Dusan Co Ltd., Korea. The moisture contents of corn, potato and sweet potato starches were 12.09±0.30%, 13.92±0.50% and 13.20±0.20%, respectively. Also, starch contents were 0.95±0.08 g/g, 0.95±0.07 g/g, and 0.95±0.06 g/g, respectively.

Gamma irradiation

Samples were packed in polyethylene bags and irradiated with 1, 3, 5, 7, 10, and 15 kGy (±5 Gy) 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.

Measurements of Brabender visco-amylograph

Maximum viscosity was measured according to the Medcalf and Gilles method (18) with a slight modification. The concentrations of suspensions were 55 g/450 ml for corn starch, 45 g/450 ml for potato starch and 50 g/450 ml for 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°C to 93°C with a constant temperature rise of 3°C/min, and was held at 93°C 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 was that of the paste when maximum viscosity was reached. Maximum viscosity was defined as the viscosity of maximum peak height.

Determination of moisture and starch contents

The moisture content was measured by the AOAC method

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(19). Starch content was determined according to Hayashi and Kawashima's method (20) with a slight modification. Ten mg of cereal grains was hydrolysed in 2 ml of 1 N HCl for 5 hr at 100°C. Water was added to the hydrolysed sample suspension to make up to 8 ml. Ten µl of the diluted suspension was incubated with 2.5 ml of reaction solution for 3 hr at 37°C. The reaction solution is composed of 0.1 M phosphate buffer (pH 6.0), 4 µlml^{-1}glucose oxidase (G-6891 1000/ml, Sigma), 0.25 µlml^{-1} peroxidase (P-3912, 16,000 U/g, Sigma) and 1 mg ml^{-1} 2,2′-Azinodi (3-ethylbenzthiazoline-6-sulfonate) (A-1888, Sigma). Absorbance of the incubated solution was measured at 420 nm (OD sample). Absorbance of blank (OD blank) was determined except diluted suspension and absorbance of the standard (ODstandard) was determined with 10 µl of 0.1% glucose instead of the diluted suspension. The starch content was calculated by multiplying glucose content by 0.9, as follows: Starch content (g of starch/g of sample)=(0.9×(OD sample-OD blank)/OD standard).

Calculation of identification parameter

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

Statistical analysis

All measurements were made in 3 replicates for each sample. A significant difference in the mean values was determined by using Duncan's multiple range test after one-way ANOVA, and regression expressions and coefficients were determined by regressive analysis using SPSS (Statistical Package for Social Science) version 7.5. The significant level was $p<0.05$.

RESULTS AND DISCUSSION

Amylograph characteristics of irradiated starches

The amylograph characteristics of unirradiated and irradiated corn starch at 1, 3, 5, 7, 10 and 15 kGy are summarized in Table 1. As shown in Table 1, the initial pasting temperature was 64.5±0.0°C in all of the samples and the maximum viscosity temperatures varied between 76.5±0.0°C and 81.3±0.0°C. The maximum viscosity showed significant differences depending on the irradiation dose levels and reduced with increase of irradiation dose levels. Variations of initial pasting, maximum viscosity temperature, and maximum viscosity were observed at the various doses ($p<0.05$). The initial pasting temperature showed no significant difference. However, the maximum viscosity temperature showed a slight decrease with increase of irradiation dose.

The initial pasting temperature, the maximum viscosity temperature, and the maximum viscosity of irradiated potato starch are presented in Table 2. Potato starch irradiated at 15 kGy exhibited a very low maximum viscosity (95.0±6.7 B.U.) compared to the control (760.0±14.1 B.U.). Initial pasting temperature was not changed but maximum viscosity temperature showed a slight decrease with increase of the irradiation dose. The maximum viscosity decreased significantly by increasing irradiation dose levels ($p<0.05$).

The amylograph characteristics of irradiated sweet potato starches are shown in Table 3. The initial pasting temperatures varied between 73.5±0.0°C and 75.0±0.0°C. The 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 starch irradiated at 1, 3, 5, 7, 10, and 15 kGy exhibited a reduction from 750.0±14.1 B.U. of the unirradiated control to 700.0±0.0 B.U., 595.0±21.2 B.U., 490.0±28.3 B.U. 415.0±

Table 1. Brabender visco/amylograph characteristics of unirradiated and irradiated corn starches with different doses

Characteristics	Irradiation dose (kGy)						
	0[1)]	1	3	5	7	10	15
Initial pasting temp. (°C)	60.0±0.0[a2)]	60.0±2.1[a]	58.5±0.0[a]	57.0±0.0[a]	57.0±0.0[a]	57.0±0.0[a]	56.3±1.1[a]
Maximum viscosity temp. (°C)	81.3±0.3[a]	80.3±1.1[a]	79.5±0.0[b]	76.5±0.0[b]	78.0±2.1[b]	76.5±0.0[b]	76.5±0.0[b]
Maximum viscosity (B.U.[3)])	765.0±21.2[a]	675.0±48.5[b]	575.0±49.5[c]	490.0±0.0[d]	430.0±14.1[e]	372.5±3.5[f]	140.0±14.1[g]

[1)]Unirradiated sample
[2)]Means with the same superscripts in each row are not significantly different ($p<0.05$).
[3)]B.U.=Brabender Unit

Table 2. Brabender visco/amylograph characteristics of unirradiated and irradiated potato starches with different doses

Characteristics	Irradiation dose (kGy)						
	0[1)]	1	3	5	7	10	15
Initial pasting temp. (°C)	64.5±0.0[a2)]	64.5±0.0[a]	64.5±0.0[a]	64.5±0.0[a]	64.5±0.0[a]	64.5±0.0[a]	64.5±0.0[a]
Maximum viscosity temp. (°C)	70.5±0.0[a]	70.5±0.0[a]	69.0±0.0[ab]	69.0±0.0[b]	69.0±0.0[bc]	69.0±0.0[c]	69.0±0.0[c]
Maximum viscosity (B.U.[3)])	760.0±14.1[a]	565.0±7.1[b]	465.0±7.0[c]	317.5±10.6[d]	220.0±0.0[de]	165.0±7.1[e]	95.0±6.7[f]

[1,3)]Refer to the legend in Table 1.
[2)]Means with the same superscripts in each row are not significantly different ($p<0.05$).

Table 3. Brabender visco/amylograph characteristics of unirradiated and irradiated sweet potato starches with different doses

Characteristics	Irradiation dose (kGy)						
	0[1)]	1	3	5	7	10	15
Initial pasting temp. (°C)	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. (°C)	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	415.0±35.4[d]	312.5±31.8[e]	105.0±7.1[f]

[1,3)]Refer to the legend in Table 1.
[2)]Means with the same superscripts in each row are not significantly different ($p<0.05$).

35.4 B.U., 312.5±31.8 B.U., and 105.0±7.1 B.U., respectively and showed significant changes ($p<0.05$).

Fig. 1 shows the amylograms of corn starches, potato starches and sweet potato starches irradiated at various doses. As shown in Fig. 1, maximum viscosity of the irradiated starches reduced with increase of irradiation doses.

Similar results for starch have been reported by many other researchers. Sabularse et al. (21) reported that the decrease in peak viscosity (maximum viscosity) by irradiation may be attributed to starch depolymerization in irradiated brown rice grain. Nene et al. (22) reported that irradiated (10 kGy) red gram (*Cajanus cajan*) flour exhibited a very low maximal gelatinization viscosity (maximum viscosity) (350 B.U.) compared to the control (860 B.U.). MacArthur and D'Appolonia (23) and Roushdi et al. (24) also reported that the viscosity decrease in gamma irradiated corn starch was related to the chain length reduction of the starch. Komiya et al. (4) reported that the maximum viscosity of both potato and corn starches, with and without oil treatment before irradiation, decreased gradually with increased irradiation doses.

Sokhey and Hanna (25) explained that the changes in starch were caused by the free radicals created by gamma irradiation which bring about molecular changes and fragmentation of starch molecules, which might affect the physical and rheological properties, i.e. the decreasing viscosity of foods containing high amounts of starch (such as cereals).

Regression expressions and coefficients ($p<0.001$) of corn, potato and sweet potato starches were $y=-38.538x+718.23$ ($r^2=0.9761$), $y=669.97e^{-0.1372x}$ ($r^2=0.9820$) and $y=-42.544x+730.26$ ($r^2=0.9939$), respectively, where x is irradiation dose (kGy) and y is maximum viscosity (B.U.) (Fig. 2).

Parameter values derived from maximum viscosity

The parameter values derived from the maximum viscosity of corn, potato and sweet potato starches are presented in Table 4. The normalized parameters for the samples (Parameters A, B, and C) were a better parameter for detecting irradiation treatment than that of the maximum viscosity itself. The parameter values showed a dose dependent relationship between unirradiated and irradiated samples and indicated that all values of unirradiated samples were higher than those of irradiated ones. Hayashi et al. (10) reported that much more consistent viscosity values could be obtained if the viscos-

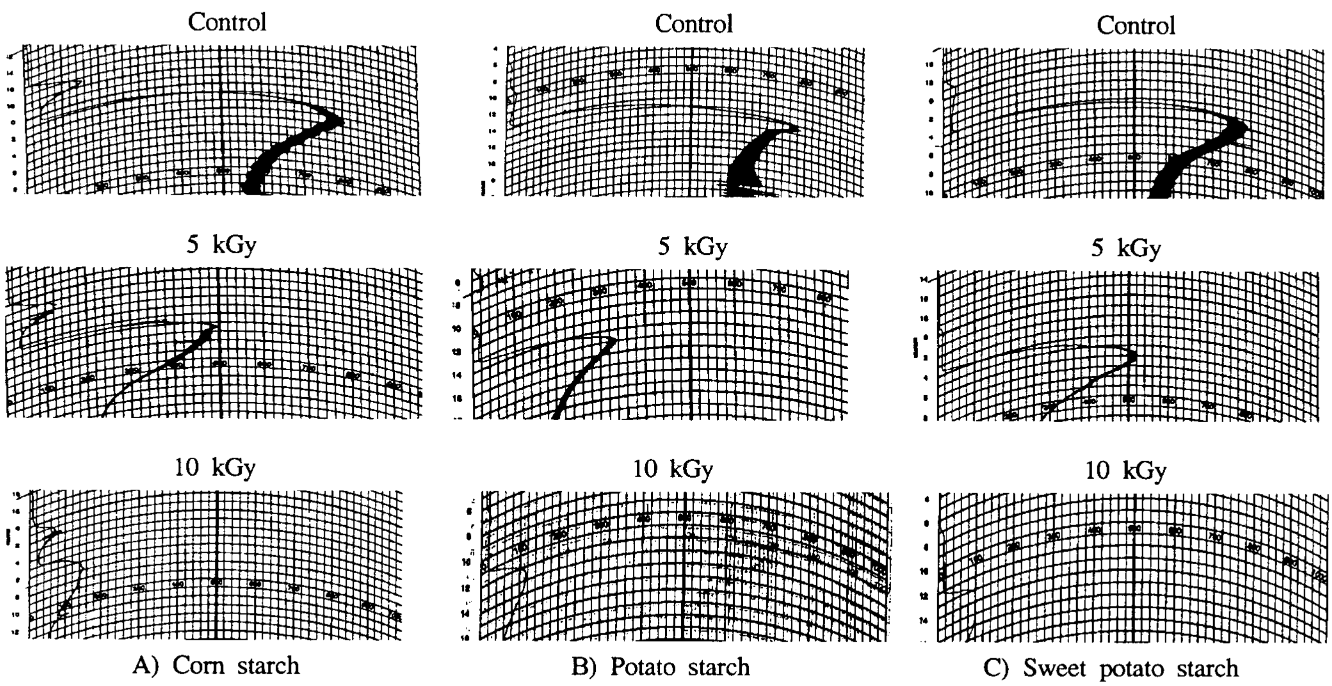
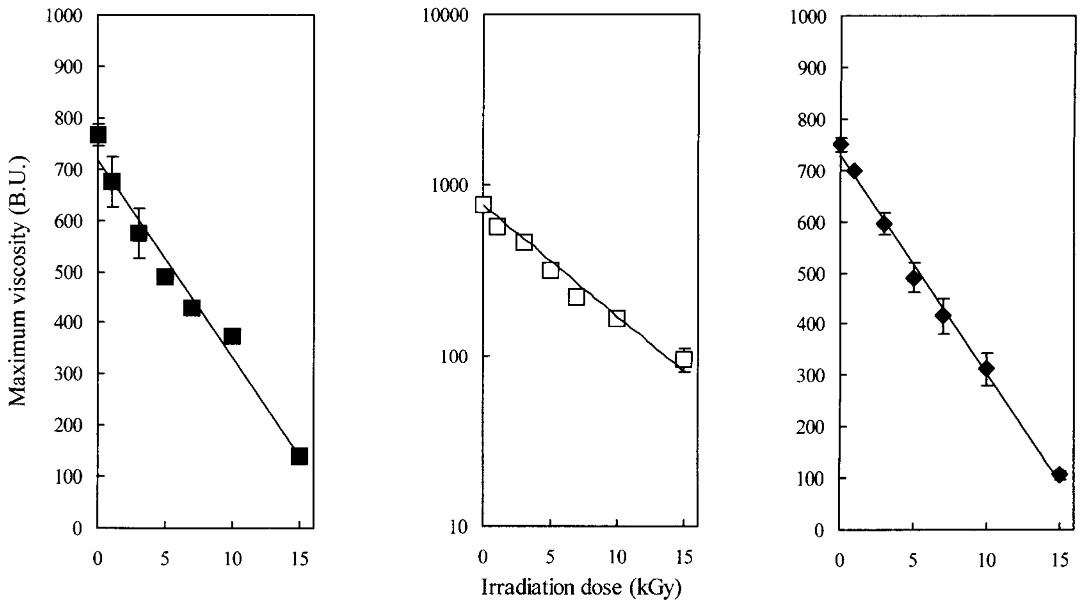


Fig. 1. Amylograms of corn, potato and sweet potato starches unirradiated and irradiated with different doses.



A) Corn starch B) Potato starch C) Sweet potato starch

Fig. 2. Regression curves between irradiation dose and maximum viscosity of different starches.

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

Parameter values		Irradiation dose (kGy)						
		0[1]	1	3	5	7	10	15
C.S.[2]	Parameter A[5]	63.27	55.83	47.56	40.53	35.57	30.81	11.58
	Parameter B[6]	66.81	58.95	50.22	42.80	37.56	32.53	12.23
	Parameter C[7]	1.0000	0.8824	0.7517	0.6406	0.5622	0.4870	0.1830
P.S.[3]	Parameter A	54.59	40.59	33.41	22.81	15.80	11.85	6.82
	Parameter B	57.46	42.73	35.17	24.01	16.63	12.47	7.18
	Parameter C	1.0000	0.7435	0.6120	0.4178	0.2829	0.2171	0.1249
S.S.[4]	Parameter A	56.82	53.03	45.08	37.12	31.44	23.67	7.95
	Parameter B	59.93	55.93	47.55	39.16	33.16	24.97	8.39
	Parameter C	1.0000	0.9333	0.7934	0.6532	0.5533	0.4166	0.1399

[1]Unirradiated sample
[2]Corn starch
[3]Potato starch
[4]Sweet Potato starch
[5]Maximum viscosity on irradiation dose/moisture content.
[6]Parameter A on irradiation dose/starch amount in 1 g of sample (g).
[7]Parameter B on irradiation dose/control of parameter B.

ity of a sample was normalized for starch content, since macromolecules greatly influence jellification properties. Therefore, it is expected that defined parameters A, B, and C will provide detection values not affected by materials or measuring conditions.

CONCLUSION

The maximum viscosity of irradiated and unirradiated corn, potato, and sweet potato starches reduced with the increase of irradiation dose levels and showed significant differences depending on irradiation dose levels ($p<0.05$). Regression expressions and coefficients ($p<0.000$) of corn, potato and sweet potato starches were $y=-38.538x+718.23$ ($r^2=0.9761$), $y=669.97e^{-0.1372x}$ ($r^2=0.9820$) and $y=-42.544x+730.26$ ($r^2=0.9939$), respectively. High regression coefficients were observed between irradiation dose and maximum viscosity. These results suggest that the detection of irradiation for corn, potato, and sweet potato starches was possible by the defined parameter obtained from the maximum viscosity with a Brabender visco-amylograph.

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