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Properties of Corn Starches Isolated from Irradiated Glutinous and Non-Glutinous Corn Grains

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Abstract

Physicochemical properties of corn starches isolated from non-glutinous and glutinous corn grains following γ-irradiation up to 10kGy were investigated. Blue value, water binding capacity and swelling power decreased, while alkali number and solubility increased by γ-irradiation, which was more pronounced in glutinous corn starch than in non-glutinous corn starch. The optical transmittance increased with an increment of heating temperature and applied irradiation doses. No significant difference was observed in Hunter's color value between both starches isolated from non-irradiated and irradiated corn grains. Amylograph viscosities decreased remarkably as dose levels increased. The overall effects of γ-irradiation was more distinguished in glutinous starch than in non-glutinous starch.

Key words: gamma irradiation, corn starch, physicochemical properties

INTRODUCTION

Gamma irradiation produces free radicals on starch molecules that can alter their size and structure(1-4). The effects of ionizing radiation on starch in wheat(5,6) and barley(7) have been reported. Gamma irradiation is capable of hydrolyzing chemical bonds, thereby cleaving molecules into small fragments that may be either electrically charged ions or uncharged free radicals. These changes may affect the physical and rheological properties of irradiated foods, resulting in increased solubility of starch(8) and decrease in swelling power(9) and in relative viscosity(10) of starch paste.

However, much less is known about the physicochemical properties of corn starches isolated from the irradiated glutinous and non-glutinous corn grains. In a previous paper(11), we have demonstrated the efficacy of γ-irradiation for improving the corn starch isolation process and hygienic quality. The moisture-uptake rate constant and starch yield gradually increased as irradiation dose levels increased. Irradiation at 1 and 5kGy was effective for sterilizing all contaminated microorganisms of non-glutinous and glutinous corns, respectively.

In this study, in order to demonstrate how the γ-irradiated corn grains contributes to the quality of isolated corn starch, we investigated the physicochemical properties of the starches isolated from the glutinous and non-glutinous corn grains irradiated at different dose levels(0~10kGy).

MATERIALS AND METHODS

Materials

A local variety of non-glutinous and glutinous corns was harvested in September 1993 at the Korea Crop Experiment Station of Rural Development Administration. The corns were field-dried in the traditional manner to a final moisture content of about 12%.

γ-Irradiation

Lots(200g) of the corns were packed in polyethylene bags and exposed to a Co^{60} source of γ-radiation having a flux of 1kGy/hr(3.7 pBq, Co^{60} γ-irradiator) at ambient temperature(15±0.5°C). The dose levels applied to the samples were 0~10kGy.

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Isolation of starch

Non-irradiated and irradiated corns(2kg) were used for starch isolation. Starch samples from the corns were isolated in the laboratory as described by Boyer and Liu(12), except that the slurry was successively screened through 70 to 325-mesh sieves. The starch sample was air-dried and passed through a 100-mesh sieve. These starches were assumed to contain about 11% moisture and 85% starch.

Physicochemical properties

The blue value was determined by the method of Gilbert and Spragg(13), alkali number by Schoch(14) and water binding capacity by Medcalf and Gilles(15). Solubility and swelling power of corn starch was determined by the method of Schoch(16). Isolated corn starch(0.5g) was dispersed in 25ml of distilled water and heated at 80°C for 1hr in a water bath with gentle stirring. The suspension was centrifuged and the supernatant dried at 110°C in a dry oven. Solubility was determined by weighing the residual dissolved starch. Swelling power was measured by determining the water retention capacity of undissolved starch.

The swelling power of starch was calculated according to the following equation(16).

$$\text{Swelling power} = \frac{\text{wt. of sedimented paste} \times 100}{\text{wt. of sample} \times (100 - \%\text{solubles})}$$

Viscoamylograms of the isolated starch were determined with a Brabender Viscoamylograph, using a 700 cm · g sensitivity cartridge. Isolated starch(40g of non-glutinous and 25g of glutinous starches) was mixed with distilled water(final slurry, 500ml) to form a homogeneous lump free suspension. This was heated and then cooled in the Brabender Amylograph with a constant rate of 1.5°C/min.

Transmittance of the starch solution was analyzed using a spectrophotometer(Bausch & Lomb, spectronic 710) at 625nm. Isolated corn starch(0.4g) was dispersed in 200ml of distilled water and heated to 100°C on a hot plate with gentle stirring. Transmittance of the solution was measured at temperatures ranging from 50 to 100°C.

The color of isolated starches expressed in Hunter's L(lightness), a(redness), b(yellowness) and ΔE(overall color difference) was measured by a color/color difference meter(model N-1001, Nippon denshoku Kogyo Co., Japan).

RESULTS AND DISCUSSION

Blue value

Changes in blue value for non-irradiated and irradiated non-glutinous and glutinous starches are given in Fig. 1. The blue value of non-glutinous corn starch isolated from the corns irradiated at 0.5~4kGy was found to be similar to that of the non-irradiated control. At 5 and 10kGy, however, a decrease in blue value was observed. In the case of glutinous corn starch, blue value decreased from 0.5kGy irradiation dose level. At 10kGy, considerable decrease in the blue value was observed for glutinous corn starch. The results are consistent with those obtained by Ciesla et al.(2), who reported that irradiation destroys the order in which crystalline and amorphous regions of the molecule within a starch granule are arranged.

Blue value reflects the amount of linear chains in starch; longer linear chain or a higher number of linear chains show higher blue value. Thus, the results suggest that γ-irradiation may cause a decrease in linear chain length of non-glutinous and glutinous corn star-

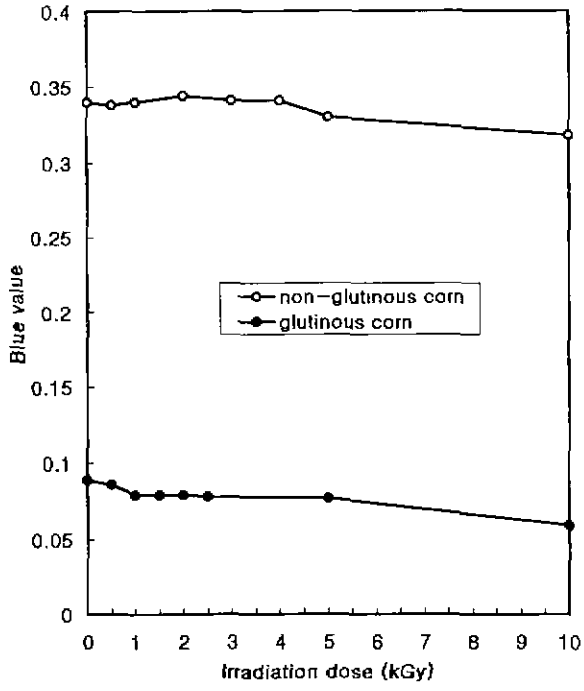

Fig. 1. Changes in the blue value of non-glutinous and glutinous corn starches isolated from non-irradiated and irradiated corn grains.

ches, and this effect is more pronounced in glutinous corn starches, high amylopectin contents, than in non-glutinous corn starch.

Alkali number

The effects of γ-irradiation on the alkali number of isolated glutinous and non-glutinous starches are shown in Fig. 2. The alkali number increased depending on the increment of irradiation dose levels. Non-glutinous and glutinous corn starches resulted in an increment of 13.3 to 18.3 and 5.8 to 13.4 as the irradiation dose increased from 0 to 10kGy, respectively. Especially, the alkali number of isolated glutinous corn starch irradiated at 10kGy was more than two times higher than that of the non-irradiated control starch. The effect of γ-irradiation on the alkali number was more pronounced in glutinous corn starches than in non-glutinous corn starch. The results were shown to be well correlated with those of blue value.

Alkali number provides a relative measure of the number of terminal aldehyde groups in the starch. Therefore, the results suggested that γ-irradiation caused a breakdown of starch structure, resulting in an increase of the number of terminal aldehyde groups.

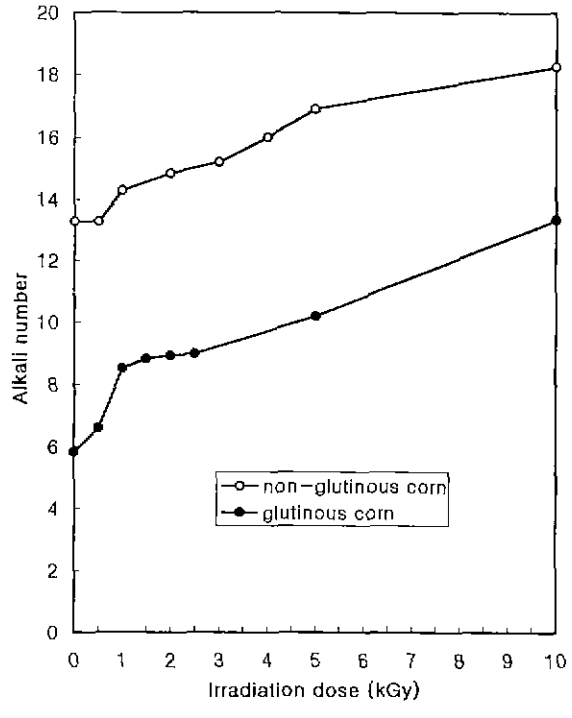

Fig. 2. Changes in the alkali number of non-glutinous and glutinous corn starches isolated from non-irradiated and irradiated corn grains.

Transmittance pattern and Hunter's color value

Fig. 3 shows the transmittance patterns of isolated corn starches as a function of irradiation dosage and heating temperature. Optical transmittance of nonglutinous and glutinous starch suspensions(0.2%) increased with elevation of heating temperature and irradiation dose level, while increasing pattern of the optical transmittance was different; a significant increase was observed over the temperature range of 90~100 and 70~90°C in non-glutinous and glutinous corn starches, respectively. In addition, non-irradiated and irradiated glutinous corn starch suspensions were more transparent than those of non-glutinous starch suspensions over the temperature range of 75~100°C.

The color of corn starch was little affected by irradiation treatment of corn grain(Table 1). A small increase in "b" value(yellowness) was observed in starches isolated from non-glutinous and glutinous corn grains irradiated at 5 and 10kGy. No noticeable changes in overall color difference(ΔE) was observed between the non-irradiated control and 10kGy-irradiated samples.

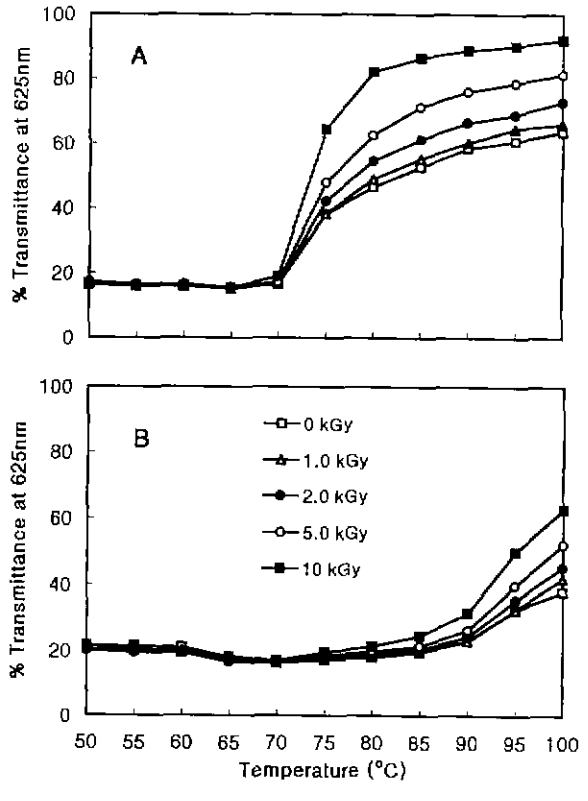

Fig. 3. Transmittance of 0.2% non-glutinous and glutinous starch suspensions at various temperatures.
A: Glutinous corn starch
B: Non-glutinous corn starch

Table 1. Hunter's color values of non-glutinous and glutinous corn starches isolated from non-irradiated and irradiated corn grains[1)]

Color parameter[2)]	Irradiation dose(kGy)									
	0	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	10.0
Non-glutinous starch										
L	95.3	94.7	95.2	nm[3)]	95.5	nm	95.4	94.8	95.8	95.3
a	-0.6	-0.9	-0.8	nm	-0.8	nm	-0.9	-1.0	-0.9	-0.8
b	-0.5	-1.0	-0.8	nm	-1.0	nm	-0.5	-0.7	-0.4	-0.1
ΔE	0.0	0.8	0.3	nm	0.6	nm	0.3	0.7	0.6	0.4
Glutinous starch										
L	96.2	96.2	96.2	96.4	96.4	96.3	nm	nm	96.2	95.6
a	-1.1	-1.1	-1.0	-0.9	-1.1	-1.0	nm	nm	-1.1	-1.1
b	-0.8	-0.8	-0.8	-0.7	-0.5	-0.6	nm	nm	-0.4	-0.1
ΔE	0.0	0.0	0.1	0.3	0.4	0.2	nm	nm	0.4	0.9

[1)]Each value is the average of triplicate determinations
[2)]L: Degree of lightness(white 100 ↔ 0 black)
a: Degree of redness(red +100 ↔ -80 green)
b: Degree of yellowness(yellow +70 ↔ -80 blue)
[3)]ΔE: Overall color difference=($\sqrt{(\Delta L)^2+(\Delta a)^2+(\Delta b)^2}$)
nm: not measured

Water-binding capacity, solubility and swelling power

Changes in water binding capacity of corn starches by γ-irradiation are shown in Fig. 4. Water binding capacity of non-glutinous and glutinous corn starches was affected by γ-irradiation. Irradiated non-glutinous and glutinous corn starches showed lower water binding capacity than those of non-irradiated starches, though water binding capacity increased gradually at more than 0.5kGy.

Changes in solubility of corn starches isolated from non-irradiated and irradiated corn grains are shown

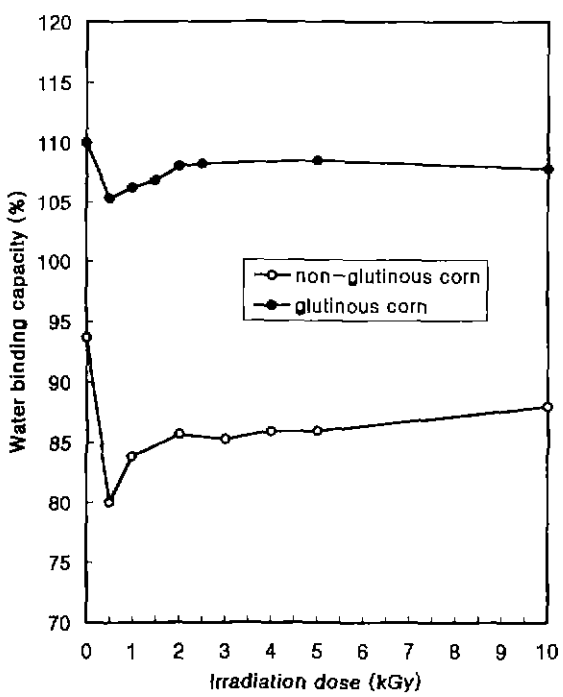

Fig. 4. Changes in water binding capacity of non-glutinous and glutinous corn starches isolated from non-irradiated and irradiated corn grains.

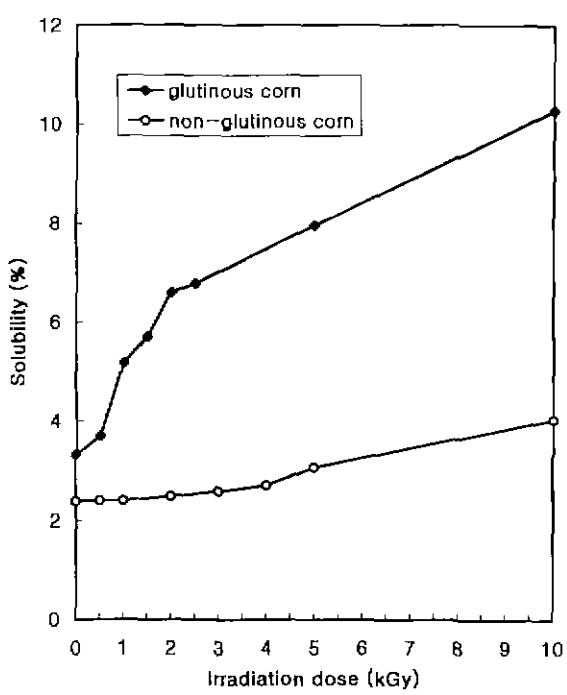

Fig. 5. Solubility of non-glutinous and glutinous corn starches isolated from non-irradiated and irradiated corn grains.

Table 2. Amylograph indices on non-glutinous and glutinous corn starches isolated from non-irradiated and irradiated corn grains

Irradiation dose (kGy)	Initial pasting temperature(°C)[1]	Peak temperature (°C)	Peak height (B.U.)	30 min height (B.U.)[2]	Viscosity at 50°C (B.U.)
Non-glutinous corn(8%, dry basis)					
0	71.5	88.5	890	490	1,085
0.5	71.5	88.5	880	480	1,000
1.0	71.0	87.5	870	405	950
2.0	70.5	87.0	840	380	880
3.0	70.5	86.5	775	305	720
4.0	70.5	86.0	730	245	585
5.0	70.0	85.5	600	175	440
10.0	69.0	84.0	390	65	170
Glutinous corn(5%, dry basis)					
0	69.0	73.5	1,020	300	420
0.5	68.5	73.5	910	240	325
1.0	69.0	74.5	830	225	310
2.0	69.0	75.5	710	195	265
3.0	69.0	75.5	640	180	235
4.0	69.5	75.5	535	165	205
5.0	69.5	75.5	290	85	115
10.0	69.0	75.5	110	15	25

[1]Temperature at which the initial rise in the curve reached 10 B.U.
[2]Peak height after 30 min holding at 95°C

in Fig. 5. The solubility of non-glutinous and glutinous corn starches increased depending on the increment of irradiation doses, which was more pronounced in glutinous corn starch. The solubility of 10kGy-irradiated glutinous corn starch was about 3 times higher than that of the non-irradiated control.

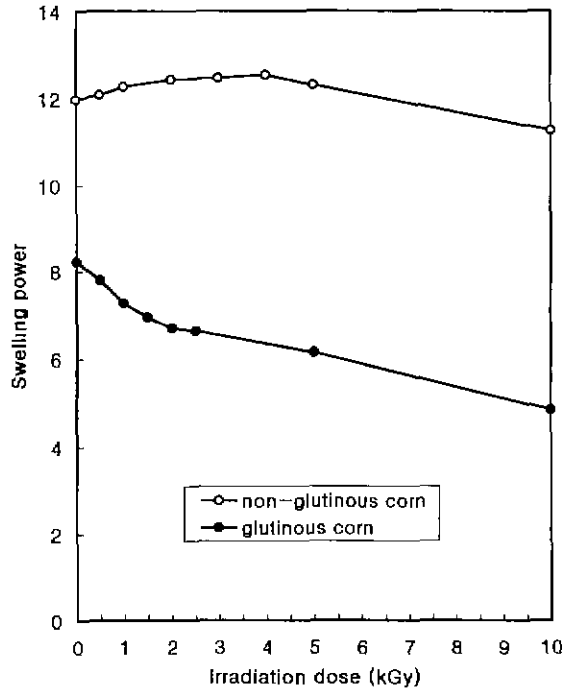

Fig. 6. Swelling power of non-glutinous and glutinous corn starches isolated from non-irradiated and irradiated corn grains.

Fig. 6 shows the changes in swelling power of non-irradiated and irradiated corn starches. Swelling power of non-glutinous corn starch increased slightly up to 4kGy and then decreased. A decrease in swelling power by γ-irradiation was also more pronounced in glutinous corn starch than in non-glutinous corn starch.

The observed changes in water binding capacity, solubility and swelling power resulting from γ-irradiation may be due to the degradation of corn starch.

Pasting properties

The results obtained from the amylograph curves of corn starches are shown in Table 2. Data in Table 2 indicated that the gelatinization properties of starches isolated from irradiated corn grains were considerably different from those isolated from non-irradiated corn grains. A progressive decrease in initial pasting temperature and peak temperature of non-glutinous corn starch was observed, while those of glutinous corn starch were little changed with an increment of irradiation dose level. The peak viscosity of starches isolated from irradiated corn grains decreased depending on the irradiation dose. The viscosity after 30min holding at 95°C and a viscosity at 50°C were also dramatically de-

creased by γ-irradiation, which was more pronounced in glutinous corn starch than in non-glutinous starch. Degradation of starch has been considered to be responsible for the viscosity changes caused by γ-irradiation(17-19). A similar decrease in amylogram units of irradiated wheat starch has been reported(20). Deschreider(21) has attributed these changes to shortening of polysaccharide chains, depending upon the irradiation dose level. The shift in the iodine complex towards shorter wave lengths with irradiated amylose also supports this view(22).

In conclusion, γ-irradiation to corn grains induced degradation of isolated starch and changes in physicochemical properties, which was more pronounced in glutinous corn starch than in non-glutinous corn starch. These changes could possibly impart different functional properties to help design new food and nonfood products. Also, gradual decreases in viscosity with an increment of irradiation dose may be useful for detection of irradiated starch-foods and their products.

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