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Pasting and Nutritional Characteristics of Black Rices Harvested in Korea

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Abstract

Three black rices (Suwon 415, Iksan 427 and Sanghaehyanghyeolla) harvested in Korea were examined in their pasting characteristics, and minor nutrients (vitamins and minerals) in comparison to those of a brown rice (Dongjinbyo). Based on the amylose content, brown rice and Suwon 415 were normal rices (22.7 and 19.6%, respectively), whereas Iksan 427 and Sanghaehyanghyeolla were waxy rices (0.4 and 0.6%, respectively). Iksan 427 and Sanghaehyanghyeolla showed similar viscosity patterns with significantly low pasting temperatures and viscosity. Brown rice showed higher pasting viscosity and pasting temperature than black rices, and its viscosity pattern was similar to Suwon 415. Brown rice and Suwon 415 displayed higher hardness but lower adhesiveness of their gels. Black rices contained more non-carbohydrate components and dietary fiber than brown rice. From the amino acid analysis, black rices contained more acidic amino acids (aspartic and glutamic acids) than brown rice. Among the black rices, Suwon 415 had the highest content of total essential amino acids (4.3%). Black rices also contained higher amounts of vitamin B complexes (thiamin, riboflavin and niacin) and minerals (K, Mg and Ca) than brown rice. Sanghaehyanghyeolla showed an exceptionally high amount of Ca (12 mg%).

Key words: black rice, pasting characteristics, minor nutrients

INTRODUCTION

The consumption pattern of rice in Korea has been significantly changed in recent years. Consumers are more interested in minor nutrients which have a variety of biofunctions. From this trend, special varieties such as naturally colored or flavored rices have been introduced in the market. Among the colored varieties, black rices became popular during the last few years in Korea, and the interest in cooked rice added to black rice has been consistently increasing (1). Korean black rices originated from China, but some of varieties are currently harvested in specific locations such as Jindo in Korea (1). The major varieties of black rices for Korean consumption include Suwon 415, Iksan 427 and Sanghaehyanghyeolla (Sanghae).

The Korean black rices have been studied in terms of their texture changes after cooking (2), characteristics of black rice Sikhe (3) and pigments in black rice (4-9). But the studies have mainly focused on the coloring agents including the stability and antioxidant activity. Nam and Kang (10,11) reported that the bran extract from the colored rice exhibited high activity for the antimutagenic and anticancer activities. But pasting and gelation characteristics related to the cooking properties of the black rices harvested in Korea have rarely been studied.

In this study, in order to evaluate pasting and nutritional characteristic, gelatinization characteristics such as pasting viscosity and crystal melting, and gel textures were examined with three major Korean black rices (Suwon 415, Iksan 427 and Sanghae) and a brown rice for comparison. B-type vitamins (thiamin, riboflavin and niacin), minerals (Ca, Fe, Mg, K and Zn), dietary fiber and amino acid compositions were quantitatively analyzed.

MATERIALS AND METHODS

Materials

Sanghae and a brown rice (Dongjinbyo), which had been harvested in Jindo, Korea were provided by a local farm. Suwon 415 and Iksan 427 were provided by Bekjae Nongsan Co. (Boryung, Korea). All the rice samples were harvested in 1997. The hull-less rice kernels were ground into flours for the experiments (Cyclotec 1093, Tecator, Hoganas, Sweden).

Proximate compositions

Moisture content was measured by using an infrared moisture analyser (Ohaus MB200, Florham Park, NJ). Crude protein was analyzed by using an auto-kjeldahl system (Kjeltec 1026, Tecator, Hoganas, Sweden), and crude lipids and ash were analyzed following the procedures of the AOAC official methods (12). Total carbohydrate content was calculated by subtracting the protein, lipids and ash contents from the total.

Total dietary fiber content

The total dietary fiber contents in the rice flours were determined following the procedure of Prosky et al. (13).

Amylose content

As a means of determining the amylose content of a rice flour, the enthalpy for melting of amylose-lipid complex was measured using a differential scanning calorimeter (DSC 6100, Seiko Instruments Inc., Chiba, Japan). Samples, which usually contained about 1.0 mg of rice flour with lysolecithin (L-

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α-lysophosphatidyl choline) from egg yolk (Sigma Chemical Company, St. Louis, MO) of 0.5 mg and 5 μl of water were weighed directly into an aluminum pan and sealed. Thermograms were obtained at a heating rate of 10°C/min. Both first and second scanning were carried out from 20°C to 130°C. The enthalpy of melting of the amylose-lysolecithin complex obtained on rescanning was higher than that on first scanning. Therefore, the enthalpy of rescanning was used to estimate the amylose content of the rice flour to the following formula: (14,15)

$$\text{Amylose content (\%)} = \frac{\text{Enthalpy (J/g) for rice flour}}{\text{Enthalpy for amylose (15.6 J/g)}} \times 100$$

Blue value

Blue value of the rice flours was determined by the procedure of Gilbert and Spragg (16).

Melting temperature and enthalpy

Melting temperature and enthalpy of the rice flours were measured by using a differential scanning calorimeter (DSC 6100, Seiko Instruments Inc., Chiba, Japan). The instrument was calibrated with indium and mercury. The rice flour (2.0±0.1 mg) was weighed into an aluminum pan and excess distilled water was added to the flour at a weight ratio of 4 : 1 (water : rice flour). The pan was hermetically sealed and held 25°C for at least 1 hr before scanning in the DSC. The sample was heated from 20°C to 100°C at a heating rate of 10°C/min.

Pasting viscosity

Pasting viscosity of aqueous rice flour dispersion (7% solid) was measured by using a Rapid Viscoanalyzer (Newport Science and Instruments, Warriewater, Australia). The dispersion was pasted by heating from 25°C to 95°C at a heating rate of 4.5°C/min, held for 10 min, and then cooled to 50°C at 4.5°C/min.

Gel texture analysis

Rice flour dispersion in water (30%, w/w) was heated for 20 min with a cover in a boiling water-bath while mechanically stirring, and then the paste was transferred into petri-dishes (55 mm diameter, 15 mm depth). After cooling for 1 hr at room temperature, the paste was covered and then stored at 4°C for 24 hrs for gel formation. Texture of the rice gel was measured using a Texture Analyser (TA-XT2, Stable Microsystem, Surrey, UK). After the top portion above the edge was removed with a wire cheese-cutter to make the gel surface smooth, the rice flour gel was compressed with a cylindrical plunger (40 mm diameter) to 20% strain at a speed of 1.0 mm/sec. The compression test was repeated three times and significant difference ($p<0.05$) was identified using Duncan's multiple range test (SAS Institute, Cary, NC, USA).

Amino acid analysis

Amino acid compositions were measured by following the procedure of White et al. (17) by using a HPLC system (Waters, Milford, MA) equipped with a Pico-Tag column (46°C) and a UV detector (254 nm).

Vitamin B content

Three water-soluble vitamins (thiamin, riboflavin and niacin) were analyzed. For vitamin B_1 (thiamin) and B_2 (riboflavin), rice flour (1 g) was autoclaved in 0.1 N HCl (10 ml) at 120°C for 30 min. The solution was then adjusted to pH 4.5 with 2 N sodium acetate solution. Taka diastase solution (5%, 2 ml, Sigma Chemical Company, St. Louis, MO) was added into the solution and the mixture was incubated at 48°C for 3 hrs. With a potassium ferricyanide/ KOH solution (1% in 15% KOH, 3 ml), thiamin in the sample solution was oxidized to thiochrome. The solution was neutralized with 3.75 N HCl, and passed through Sep-Pak C_{18} cartridge (Waters, Miliford, MA). The solution was analyzed with a HPLC equipped with a Nova-Pak C_{18} column (3.9×150 mm, Waters) (18).

Niacin was analyzed by the Konig reactions described in the AOAC procedure (12).

Mineral content

Rice flour (2~10 g) was decomposed in a furnace (550~600°C), and the ash was mixed with 3 N HCl (10 ml). The mixture was heated on a hot plate for 10 min, and then diluted into 100 ml, with deionized water. Analysis of the mineral compounds was performed by using an atomic absorption flame emission spectrophotometer (AA-670F, Shimadzu, Tokyo, Japan).

RESULTS AND DISCUSSION

Proximate compositions

The black rices tested contained higher contents of protein, lipids, ash and total dietary fiber than the brown rice (Table 1). Among the black rices, Sanghae showed the highest content of protein (12.06%). Suwon 415 contained more lipids and ash compared to Sanghe or Iksan 427. The compositional differences between brown and black rices agreed with the report by Kim et al. (2) and Kim (19). But the differences among the three varieties of the black rices were relatively small.

The total dietary fiber was higher in black rices than in the brown rice. Especially Suwon 415 showed the highest content (5.1% based on dry weight), which was 1.7% greater than the brown rice. Ha et al. (20) also reported that the black rices had more dietary fiber than brown rice. But those of Suwon 415 and Sanghae were different from their report. This was caused by the differences of measurement and the cultivation area. The fiber exists mainly in the outlayers of the kernel such as pericarp and bran (21,22). The data may imply the different weight portions of the fiber-rich brans between the black and brown rices. The higher dietary fiber content in the black rice is nutritionally beneficial.

Amylose content

Amylose content was determined by meaning the melting enthalpy of amylose-lysolecithin complex under DSC (Table

Table 1. Proximate compositions of brown and black rices (%w/w, dry basis)

Rice samples	Protein	Lipids	Ash	Carbohydrates[1)]	TDF[2)]
Brown	9.56±0.07	2.62±0.04	1.39±0.02	86.43	3.40±0.06
Suwon 415	11.52±0.06	3.40±0.39	1.87±0.03	83.21	5.10±0.03
Iksan 427	10.30±0.06	3.30±0.15	1.78±0.02	84.62	4.64±0.09
Sanghae	12 06±0.03	2.92±0 20	1.65±0.01	83.37	4.52±0.09

[1)]Calculated by subtracting protein, lipids and ash contents from the total
[2)]Total dietary fiber

2). The result revealed that the brown rice and Suwon 415 were normal rices and Iksan 427 and Sanghae were waxy rices. The result agreed with that reported by Kim and coworkers (23). Blue value exhibited good correlation with the amylose contents measured by DSC.

Melting temperature and enthalpy

Thermograms of the rice flours by DSC showed the differences in the temperature range and enthalpy for starch melting among the tested rice samples (Fig. 1). The onset temperature for starch melting was in a range from 55.2°C for Iksan 427, to 62.5°C for Sanghe. But the melting enthalpy was lowest with Sanghae (6.3 J/g) and highest with Iksan 427 (9.8 J/g). Therefore, Iksan 427 started melting earlier, but the melting occurred in a wider temperature range and this required higher enthalpy than others (Fig. 1). The melting temperatures of the rice flour samples were slightly higher than those reported from rice starches (19,24). This was caused by the inhibitory effects of the contaminant protein on starch melting (25).

Pasting viscosity

Viscosity profile during the pasting of rice flour was significantly different among the tested samples (Fig. 2). Brown rice and Suwon 415 which were normal rices showed similar viscograms in which the peak viscosity was relatively higher but the shear thinning and set-back occurred more significantly than the waxy rices (Iksan 427 and Sanghae). The final viscosity at 50°C was significantly higher with Suwon 415 and brown rice flours, and the black rice flours were all less viscous than the brown rice flours. Pasting temperature where the viscosity started increasing on the viscogram was about 20°C higher with the normal rices (Suwon 415 and brown rice) compared to waxy rice (Sanghae and Iksan 427). These paste viscosity results agreed with Juliano who reported amylose contributed in raising the final viscosity and setback (26).

Table 2. Amylose content and blue value of brown and black rice flours

Rice samples	DSC		Blue value
	Enthalpy (J/g)	Amylose content (%)	
Brown	3.54	22.7	0.153
Suwon 415	3.06	19.6	0.103
Iksan 427	0.07	0.4	0.030
Sanghae	0.10	0.6	0 034

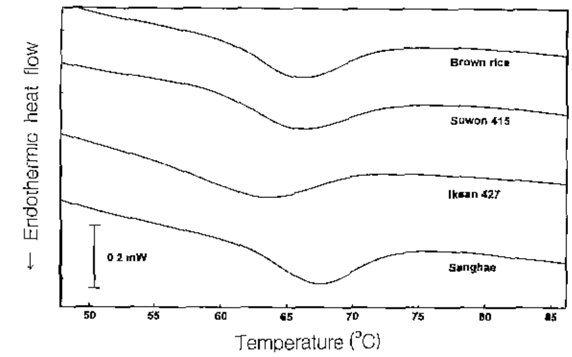

Fig. 1. DSC thermograms of brown and black rice flours.

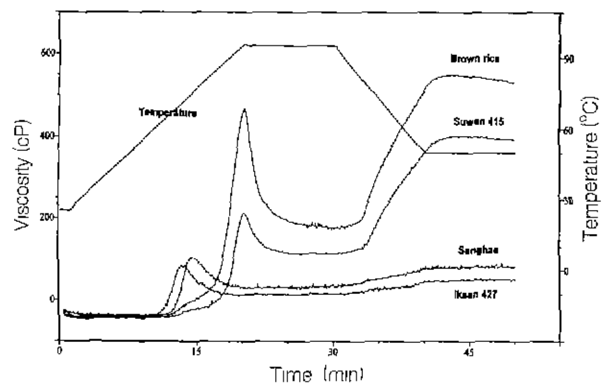

Fig. 2. Paste viscograms of brown and black rice flours.

Gel texture

Texture of rice flour gels was significantly different between normal and waxy rices (Table 3). Waxy rice gels didn't have gel-forming properties even at high solid concentration (30% rices, w/w). Hardness of brown rice gel showed higher than black rice gels. Among the black rices, Suwon 415 which had normal amylose content showed the highest hardness value. Waxy rice formed a very soft gel matrix. The result of gel texture had correlation with setback of pasting

Table 3. Characteristic of gel texture of brown and black rice flours

Rice samples	Hardness (g_f)	Adhesiveness ($g_f \cdot mm$)
Brown	579[a1)]	61[a]
Suwon 415	437[b]	94[b]
Iksan 427	53[c]	132[c]
Sanghae	66[c]	206[d]

[1)]Data with different alphabets are statistically different ($p<0.05$).

Table 4. Amino acid compositions of brown and black rices (mg%, dry basis)

Rice samples	Asp	Glu	Ser	Gly	His	Arg	Thr	Ala	Pro	Tyr	Val	Met	Iso	Leu	Phe	Lys	TAA[2]	TEAA[3]
Brown	842	1860	244	535	211	847	208	609	624	437	688	220	477	970	538	383	9693	3484
	(8.7)[1]	(19.2)	(2.5)	(5.5)	(2.2)	(8.7)	(2.1)	(6.3)	(6.4)	(4.5)	(7.1)	(2.3)	(4.9)	(10.0)	(5.6)	(4.0)	(100.0)	(35.9)
Suwon 415	641	1949	342	684	254	1088	298	745	724	647	837	285	577	1129	683	495	11378	4304
	(5.6)	(17.1)	(3.0)	(6.0)	(2.2)	(9.6)	(2.6)	(6.5)	(6.4)	(5.7)	(7.4)	(2.5)	(5.1)	(9.9)	(6.0)	(4.4)	(100.0)	(37.8)
Iksan 427	410	1533	169	578	189	876	209	684	675	462	784	163	537	1052	609	443	9373	3797
	(4.4)	(16.4)	(1.8)	(6.2)	(2.0)	(9.4)	(2.2)	(7.3)	(7.2)	(4.9)	(8.4)	(1.7)	(5.7)	(11.2)	(6.5)	(4.7)	(100.0)	(40.5)
Sanghae	596	1651	224	524	193	860	226	579	617	531	668	208	478	886	535	377	9153	3378
	(6.5)	(18.0)	(2.5)	(5.7)	(2.1)	(9.4)	(2.5)	(6.3)	(6.7)	(5.8)	(7.3)	(2.3)	(5.2)	(9.7)	(5.9)	(4.1)	(100.0)	(36.9)

[1]( ) : % based on total amino acid content
[2]Total amino acid content
[3]Total essential amino acid content

viscosity. Normal rice had higher amylose content than waxy rice, which caused fast retrogradation. Therefore, normal rice had harder gel than waxy rice. Adhesiveness of rice gel exhibited opposition to hardness. Waxy rice gels showed higher value of adhesiveness than normal rice gels of gel texture, and Sanghae had the highest value.

Amino acid compositions

As shown in Table 4, the amino acid compositions of the three black rices did not show significant differences among the varieties. However, the total amino acid content appeared highest with Suwon 415 (11.38%), whereas Sanghae contained the lowest amount (9.15%). But the previous result showed that Sanghae had the highest amount of protein (12.06%) among the samples. The difference (about 3%) between protein and total amino acid contents for Sanghae might have originated from the non-protein nitrogen.

Comparing the total essential amino acid contents, Suwon 415 also showed the highest content (4.30%), which equaled 37.8% of the total amino acids. But this ratio for essential amino acids was highest with Iksan 427 (40.5%). Major amino acids in the black and brown rice samples were glutamic acid, leucine, arginine and valine. This result was similar to the result reported by Koh et al. (27), but the contents of other amino acids were different. Although black and brown rices showed similar compositions (Table 4), the acidic amino acids such as aspartic acid and glutamic acids were higher (up to 4%) in the brown rice. Lysine which is one of the limiting amino acids in rice did not show any significant difference between the black and brown rices.

Vitamin B content

As indicated in Table 5, the three B type vitamins were found to exist more at higher levels in the black rices than the brown rice. Sanghae showed the highest thiamin content (0.359 mg%), and this was 0.1 mg% greater than that of the brown rice. Suwon 415 showed the thiamin content similar to the brown rice. Riboflavin content in black rices ranged from 0.074 to 0.090 mg% which were 0.03~0.04 mg% greater than that of the brown rice. Suwon 415 contained the highest amount of riboflavin. But niacin content was highest in Iksan 427 (5.14 mg%). The overall compositions of the three vitamins in the black rices were similar

Table 5. Thiamin, riboflavin and niacin contents of brown and black rices (mg%, dry basis)

Rice samples	Thiamin	Riboflavin	Niacin
Brown	0.250^{c}[1]	0.044^{c}	3.373^{c}
Suwon 415	0.231^{c}	0.090^{a}	4.661^{b}
Iksan 427	0.335^{b}	0.074^{b}	5.140^{a}
Sanghae	0.359^{a}	0.076^{b}	3.493^{c}

[1]Data with different alphabets are statistically different ($p<0.05$).

to the values reported in a literature (28). But the result showed that thiamin was less and riboflavin was higher compared to the values reported by Ha et al. (20). As Juliano reported (29), vitamin content, particularly thiamin, decreased during grain storage. Also bran is the major source of vitamins in rice (30). The result may indicate the inherent differences of rice bran among the samples.

Mineral content

Black rices showed higher contents in some minerals than brown rice as shown in Table 6. Especially the calcium content was most significantly different among the varieties. Among the samples, Sanghae contained an exceptionally large amount of Ca (11.95 mg%), whereas brown rice had only 1.36 mg%. Sanghae also contained the greater amount of Mg (102 mg%) than other samples. For Fe and Zn, there was no significant difference among the samples. But Suwon 415 showed a slightly higher content for Fe than others. Fe and Zn didn't show a difference between brown and black rices, whereas K and Mg displayed a difference between the two rices. This result was corresponding to that of Ha et al. (20) and Kim (19). But especially, the Ca contents did not agree with the reported data. The mineral contents might be affected significantly by the soil and other growing conditions.

Table 6. Mineral contents of brown and black rices (mg%, dry basis)

Rice samples	Ca	Fe	Mg	K	Zn
Brown	1.36^{d}[1]	6.63^{b}	92.64^{c}	222.25^{b}	1.55^{c}
Suwon 415	3.82^{c}	6.96^{a}	97.10^{b}	292.67^{a}	1.50^{b}
Iksan 427	5.93^{b}	5.64^{c}	93.44^{c}	308.15^{a}	0.88^{d}
Sanghae	11.95^{a}	6.57^{b}	101.95^{a}	285.54^{a}	1.69^{a}

[1]Data with different alphabets are statistically different ($p<0.05$).

But the experimental data shows that the black rices are superior in providing nutritive minerals in comparison to the brown rice.

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