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Influence of Amylose Content and Particle Size on Physicochemical Properties of Rice Flours

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Abstract

Seven rice varieties (Suweonjo, Suweon232, BG276-5, IR44, IR41999-139, Suweon230 and Yongjubyeo) were used to study the influence of amylose content and particle size on the physicochemical properties of rice flours. Suweonjo had the highest amylose content (27.1%) and particle size distribution of rice flour prepared in a pin mill revealed that Yongjubyeo (17.2% amylose content) had the finest flour particle as supported by scanning electron microscopy (SEM). Suweonjo had the highest value in hardness of rice grain but the lowest length/width ratio. There were no significant differences in color values among the rice flours. Data of Brabender visco/amylograph was not associated with amylose content. Yongjubyeo had the highest maximum viscosity and breakdown value while Suweonjo had the lowest maximum viscosity, setback value and breakdown value. Yongjubyeo had the lowest water solubility index (WSI). The Suweon232 rice variety absorbed more water than any other varieties but rice varieties and amylose contents affected water absorption a little.

Key words: rice flour, amylose content, particle size

INTRODUCTION

Rice has been shown to vary widely in its cooking and eating characteristics. This depends on rice variety, amylose content and gelatinization behavior as reported by many workers (1-5). Rice flour, produced by grinding whole grain, should reflect the same characteristic as shown by rice from which it was ground. Milling methods used for grinding reveal an effect on physicochemical properties of that rice flour (6-8). Among the properties of rice flour, the amylose content in rice is considered the most important factor used in describing and predicting cooking and processing qualities of rice, and numerous reports has been pointed out this relationship as described by Juliano (9). Also, pasting behavior is an important functional property that reflects the combined effect of amylose content, particle size and physical state of starch granules after milling to rice flour. Varietal differences in amylose content alter the quality of rice products such as fermented rice cake "puto" in the Philippines and bread made from 100% rice flour. Particle size of rice flour also affects the textural quality of rice products (10-13). Juliano (14) also cited that the particle size range of 100~150 um was the smallest fraction for making rice noodle which withstood heating without disintegration. Bean et al. (15) reported that particle size has an effect on the texture, volume and appearance of layer cake made from 100% rice flour. Rice varieties have specific combinations of several factors within each grain types to influence the properties of rice flour (9,14). A few variations are typical, having combinations of properties that do not follow grain-length designation. Thus grain length alone will not predict the final properties of the rice flour. In this report, selected rice varieties were used to study their properties of amylose content and particle size of rice flour in order to provide the information for specific rice product uses.

MATERIALS AND METHODS

Materials

Seven rice varieties (Suweonjo, Suweon232, BG276-5, IR44, IR41999-139, Suweon230 and Yongjubyeo) were obtained from Suweon Crop Experiment Station R.B.D. (Rice Breeding Div.) and rice was dried to a moisture content of 12% for milling and dehulled in a Satake grain testing mill at 3 min intervals to produce 10% of milling. All grains were held at -4°C until needed.

Determination of morphological property

Length and width of 30 grains were measured with a callipers (Mitutoyo, Japan). Hardness was measured by Instron (Model 1140, Instron Universal Testing Machine, USA) with 100 mm/min drive speed and 100 mm/min chart speed.

Properties of rice flour

Rice flours were obtained by using a pin mill (Kyoung-Chang, Korea). Amylose content was determined by method of Juliano (16). The content of moisture, fat and protein of the flour were determined by the method of AOAC (17). Particle size distribution of the rice flour was obtained using the Elzone particle size analyzer (Model Elzon 280pc, England). Color values of the rice flour were measured by using the color and color difference meter (Yasuda Seiki Seiakusho Ltd., Osaka, Japan).

Visco/amylograph

Pasting characteristics of rice flour dispersion (8% w/v, dry

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Table 1. Morphological characteristics of milled rice grain

Varieties	Average length (mm)	Average width (mm)	Average thickness (mm)	L/W ratio	Brown rice hardness	Grain hardness
Suweonjo	5.0^{d}	2.8^{a}	2.2^{a}	1.8	19.0^{c}	13.6^{a}
Suweon 232	5.5^{cd}	2.8^{a}	2.1^{ab}	2.0	23.1^{a}	10.1^{d}
BG276-5	6.3^{b}	2.7^{ab}	2.0^{b}	2.3	23.3^{a}	11.5^{c}
IR44	7.1^{a}	2.3^{c}	1.8^{c}	3.0	20.9^{bc}	11.4^{c}
IR41999-139	6.7^{b}	2.2^{c}	1.9^{c}	3.0	19.7^{c}	12.7^{b}
Suweon 230	5.9^{c}	2.6^{b}	2.0^{b}	2.3	21.9^{b}	10.8^{d}
Yongjubyeo	5.6^{c}	2.6^{b}	1.9^{c}	2.2	20.1^{bc}	12.2^{b}

[a~d]Means in columns with different superscript letters are significantly different ($p<0.05$).

weight basis with 450 ml distilled water) were determined using a Brabender Visco/Amylograph with 700 cmg sensitivity cartridge. The temperature was raised from 30 to 95°C at 1.5°C/min and held at 95°C for 15 min, then the temperature was cooled down to 50°C at 1.5°C/min.

Determination of water absorption index (WAI) and water solubility index (WSI)

The flour fractions were analysed for their WAI and WSI by the modified procedure of Anderson (18). A 2.5 g sample of flour was suspended in 30 ml of water at 25°C in a 50 ml tared centrifuge tube, stirred intermittently for 30 min, and centrifuged at 3,000 g for 10 min. Twenty milliliters of supernatant liquid were poured carefully into a tared evaporating dish. The remaining gel was weighed and the WAI calculated from its weight. The results were expressed as gram of absorbed water per gram of dry flour. As an index of water solubility, the amount of dried solids recovered by evaporating the supernatant from the water absorption test was expressed as percentage of dry solids in 2.5 g sample.

Scanning electron microscope (SEM)

The rice flours were mounted on aluminum stubs which were coated with gold-palladium and examined with a SEM (Hitachi HHS-2R, Japan) at 15 kV.

RESULTS AND DISCUSSION

Morphology of rice grain

Morphological characteristics of milled rice grain are presented in Table 1. Morphological properties of rice grain showed significant differences ($p<0.05$) depending on the varieties; length ranged from 5.0 to 7.1 mm, width 2.2 to 2.8 mm, thickness 1.8 to 2.2 mm, length/width ratio 1.8 to 3.0, hardness of brown rice 19.0 to 23.3 and grain hardness 10.1 to 13.6.

Chemical properties of rice flour and color values

The proximate analysis of rice flours showed that amylose was 17.2 to 27.1%, lipid 0.4 to 0.7%, protein 6.8 to 11.4% and ash 0.3 to 0.6%. Suweonjo had the highest amylose and protein content and Yongjubyeo had the lowest amylose content. Significant variations in content of amylose, protein, lipid and ash were observed for various rice varieties (Table 2). There were no significant differences in the whiteness of rice flours between rice varieties except IR44 (Table 3). Colors of raw milled rice range from white to dark gray. Dark gray can occur when rice is milled with stains of the endosperm of rice.

Table 2. Proximate analysis of various rice flours (%)

Varieties	Amylose	Lipid	Protein	Ash
Suweonjo	27.1^{a}	0.5^{b}	11.4^{a}	0.5^{b}
Suweon 232	26.6^{b}	0.4^{c}	10.1^{b}	0.4^{c}
BG276-5	24.6^{c}	0.4^{c}	9.3^{c}	0.4^{c}
IR44	24.1^{d}	0.5^{b}	6.8^{c}	0.3^{d}
IR41999-139	22.0^{e}	0.5^{b}	9.1^{c}	0.5^{b}
Suweon 230	20.0^{f}	0.7^{a}	7.5^{d}	0.5^{b}
Yongjubyeo	17.2^{g}	0.7^{a}	8.7^{cd}	0.6^{a}

[a~g]Means in columns with different superscript letters are significantly different ($p<0.05$).

Particle size distribution

As shown in Table 4, Suweonjo showed the largest average particle size and standard deviation (SD), while Yongjubyeo the smallest ones. The rice flours prepared in the pin mill showed a difference in their particle size distribution (Fig. 1). Particle size distribution and average particle size of rice flours varied significantly by rice varieties. This was related to amylose content, hardness, length and other mechanical properties (14), but

Table 3. Color values of rice flours

Varieties	L	a	b	⊿E
Suweonjo	89.1^{a}	0.3^{b}	7.0^{a}	6.3^{ab}
Suweon 232	90.2^{a}	0.4^{b}	6.1^{ab}	5.4^{b}
BG276-5	89.8^{a}	0.4^{b}	6.6^{ab}	5.9^{b}
IR44	86.7^{b}	0.3^{b}	8.0^{a}	7.7^{a}
IR41999-139	88.1^{a}	0.5^{a}	7.1^{a}	6.4^{ab}
Suweon 230	89.0^{a}	0.1^{c}	7.3^{a}	6.6^{a}
Yongjubyeo	88.3^{a}	0.1^{c}	7.6^{a}	6.9^{a}

[a,b]Means in columns with different superscript letters are significantly different ($p<0.05$).

Table 4. Size distributions of various rice flours (μm)

Varieties	Geometric mean	Arithmetic mean	Mode	Median	S.D.
Suweonjo	67.41	84.66	83.90	62.89	60.94
Suweon232	47.47	56.20	75.41	52.63	31.51
BG276-5	47.59	55.93	55.01	51.32	31.26
IR44	45.72	55.87	65.42	48.67	35.70
IR41999-139	47.99	58.83	53.12	52.55	37.11
Suweon230	47.82	56.91	66.70	52.53	33.91
Yongjubyeo	45.50	50.85	51.29	47.66	23.80

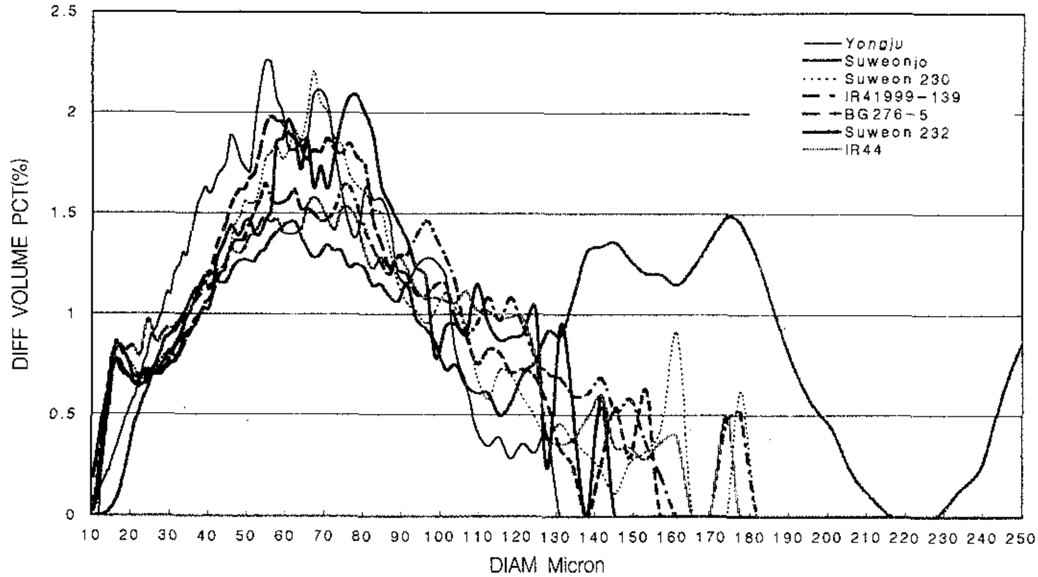

Fig. 1. Particle size distribution of rice flours prepared in a pin mill on rice varieties.

Bhattacharya et al. (19) reported that particle size was not affected by length and width or hardness of grain. Amylose content did not significantly influence the average particle size of flours but significantly changed the shapes of the particle size distribution curves. High-amylose rice yielded slightly coarser flour than intermediate or low-amylose rice, suggesting differences in grain hardness. Wet-milled rice flour had the lowest ash content and the smallest geometric mean particle size (6). Particle size of flour strongly influenced the viscosity: probably the finer flour, due to their greater surface area per unit weight, underwent easier and greater swelling in water compared to coarser flours and hence showed greater viscosity (20).

Properties of visco/amylograph

The data of initial pasting temp., maximum viscosity, hot paste viscosity, cooled paste viscosity, breakdown and setback value recorded on visco/amylograph are presented in Table 5. Initial pasting temperature was affected by rice flours from different varieties. Suweon232 had the lowest initial pasting temperature. Yongjubyeo with the finest flour and low amylose content showed maximum viscosity while IR44 had a lower maximum viscosity with a fine flour.

Table 5. Visco/amylograph properties for various rice flours

Varieties	A	B	C	D	E	F
Suweonjo	78	120	120	200	0	80
Suweon 232	66	340	340	510	0	170
BG276-5	75	690	590	900	100	300
IR44	72	140	140	280	0	140
I.R.41999-139	79.5	670	390	640	280	250
Suweon230	66	340	340	510	0	170
Yongjubyeo	69	710	380	580	330	200

A: Initial pasting temp. (°C)
B: Maximum viscosity (B.U.)
C: Hot paste viscosity (B.U.)
D: *Cooled paste viscosity (B.U.)*
E: Breakdown (B.U.)
F: Setback (B.U.)

Suzuki (21) reported that peak viscosity and breakdown of starch paste are positively correlated and breakdown is negatively correlated with setback and consistency. Yongjubyeo had the highest breakdown which represents consistency during processing. The data did not agree with Hemavathy and Bhat (22) and they also reported that peak viscosity increased significantly from high amylose to little or no amylose rice. Nishita and Bean (23) reported the absence of pasting viscosity due to delayed swelling of starch granules embedded in the relatively large endosperm chunks of coarse flours as compared with the earlier onset of swelling for smaller chunks in the fine flours. The lack of protein structure increased the fragility of the granules and proteins with intact disulfide bonds making the swollen granules less susceptible to breakdown, either by conferring strength to the swollen granules or by reducing the degree of swelling. Degree of gelatinization and gel strength increased when protein disulfide bonds were cleaved. Therefore, *specific starch granule-associated protein may possibly influ*ence the gelatinization behavior of rice starch granules (24). Data of higher viscosity might be partly caused by their finer particles. The viscosity of the Suweonjo variety increased slightly, presumably because of the slight increase in fineness of the rice flour. 12% paste viscosity in rice is directly proportional to amylose content and slurry viscosity results are contrary to the amylose content (20).

Suweonjo had the lowest setback value which represents retrogradation while BG276-5 had the highest setback value. Setback values of rice flours showed similar behavior as indicated by the peak viscosity. Rice flour with lower setback value has a soft gel and high correlation with amylose content (25). Differences in moisture contents in dry-milled flours did not affect their gelatinization and retrogradation properties (26).

Properties of WAI and WSI

WAI is determined by the amount of water which starch and protein can absorb before the chains become separated completely (27). Water absorption of Suweon232 and Suweon230 rice flours were larger than those of BG276-5 and IR41999-139 (Fig. 2). The Suweon232 rice variety absorbed more water than any other varieties but rice varieties and amylose contents affected water absorption very little. Nishita and Bean (23) reported that water absorption capacity was greater for fine flours.

Microstructure of rice flours

Scanning electron photomicrographs (Fig. 3) revealed the visual differences of rice flours in structure between rice varieties, and similar results with data of particle size distribution. The rice flour of Suweonjo are very big and rigidly shaped while Yongjubyeo had very small particle size and uniform size. All photomicrographs showed fragments of rice flours prepared in a pin mill (dry-milling) while Kum et al. (6) reported that the wet-milled flour particles were observed as a cluster of rice flours.

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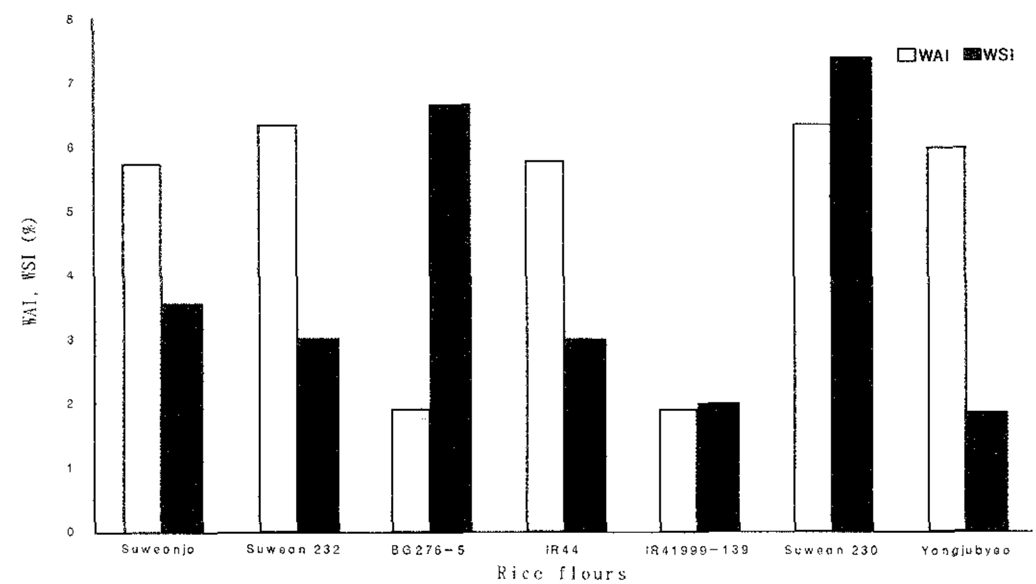

Fig. 2. Water absorption index (WAI) and water solubility index (WSI) of rice flours at 25°C.

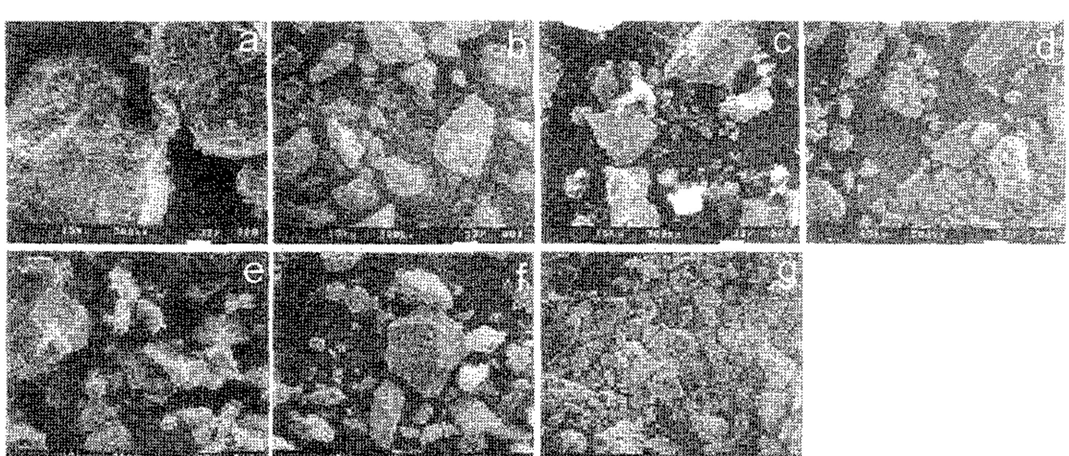

Fig. 3. Scanning electron micrographs of rice flours prepared in a pin mill (Bar indicates 33 μm).
a: Suweonjo b: Suweon 232 c: BG276-2 d: IR44 e: IR41999-139 f: Suweon 230 g: Yongjubyeo

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