Korean J. Crop Sci 44(3) : 288~295(1999)

Varietal Difference in Water Absorption Characteristics of Milled Rice, and Its Relation to the Other Grain Quality Components

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ABSTRACT

Nineteen japonica and Tongil-type rices were selected from seventy nine Korean and Japanese rice cultivars grown in 1989 based on the water uptake behavior of milled rice under the room temperature and boiling conditions. The selected rice cultivars were investigated for water absorbability and some physicochemical characteristics of milled rice, proper water amount for cooking and sensory evaluation of cooked rice. The relationships among the tested grain properties were also examined.

The highest varietal variation of water uptake rate was observed at twenty minutes after soaking in water. The maximum water uptake of milled rices at room temperature occurred mostly at about eighty minutes after soaking in water. Newly harvested rices showed a significantly lower water uptake rate of milled rice at 20 minutes after soaking, a relatively higher maximum water absorption ratio under the room temperature, and the less water uptake and volume expansion of boiled rice compared with the one-year old rice samples.

The water uptake rate and the maximum water absorption ratio showed significantly negative correlations with the K/Mg ratio and alkali digestion value(ADV) of milled rice. The rice materials showing the higher amount of hot water absorption exhibited the larger volume expansion of cooked rice. The harder rices with lower moisture content revealed the higher rate of water uptake at twenty minutes after soaking and the higher ratio of maximum water uptake under the room temperature condition. These water uptake characteristics were not associated with the protein and amylose contents of milled rice ansd the palatability of cooked rice.

The water/rice ratio(in w/w basis) for optimum cooking was averaged to 1.52 in dry milled rices (12% wet basis) with varietal range from 1.45 to 1.61 and the expansion ratio of milled rice after proper boiling was averaged to 2.63(in v/v basis). The water amount needed for optimum cooking was the lowest in Cheongcheongbyeo (Tongil-type rice) and the highest in Jinbubyeo, and the amount could be estimated with about 70% fittness by the multiple regression formula based on some water uptake characteristics, ADV and amylose content of milled rice as the independent variables.

Nineteen rice cultivars were classified into seven groups based on scatter diagram projected by principal component analysis using eight properties related to water uptake and gelatinization of milled rice.

Keywords : rice, water absorbability, proper rice cooking, varietal difference.

The palatability of cooked rice is known as largely affected by some physicochemical properties such as amylose and protein content, gelatinization temperature, and viscogram characteristics of milled rice (Choi et al. 1997, Del mundo 1979). The relative frequency of short glucose branches of amylopectin is also suggested to the other factor associated with the gel consistency of rice starch along with amylose content(Kang & Choi 1993). Choi et al.(1997) pointed out that the important physicochemical properties closely associated with the eating quality of cooked rice in low-amylose japonica rices were viscogram characteristics of rice flour and iodine blue value of extracted paste during twenty minutes of boiling.

The physical characteristics of cooked rice is largely affected by the soaking time and the added water amount for cooking. The relative crystallinity of rice starch is closely associated with the alkali digestibility and water uptake rate of milled rice grain(Kim et al. 1985b). Kim et al.(1985a) also reported that there were considerable varietal differences in the water uptake rate of milled rice not only within the japonica or Tongil-type rices but also between the two rice groups.

Therefore, this experiment was conducted to elucidate the varietal difference in water uptake behavior of milled rice under the room temperature and boiling conditions, and its association with the other grain quality components using the low-amylose japonica and Tonil-type rice cultivars.

MATERIALS AND METHODS

Seventy-nine Korean and Japanese rice cultivars including japonica and Tongil -type rices were used in the preliminary test to select rice cultivars by the

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water uptake behavior of milled rice under the room temperature and boiling conditions. Nineteen rice cultivars were selected from eleven varietal groups which was classified by scatter diagram on the plane of the 1st and the 2nd principal components based on six characteristics related to water uptake behavior in normal tap and boiling waters.

Water uptake rate of milled rice for selected rice materials was investigated at every ten minutes intervals from the start of soaking to forty minutes after soaking, and then 80 and 120 minutes after soaking in 20℃ tap water. About 10g of intact milled rice samples with two replications were prepared and weighed repeatedly at checking intervals.

Alkali digestion value(ADV) was determined in Little's(1958) visual scale(1-7) of spreading and clearing of milled rice kernel soaked in 1.4% KOH solution for 23 hours at 30℃ in chamber. Amylose content of milled rice was determined by relative absorbency of starch-iodine blue color in digested solution of 100-mesh rice flour using Rapid Flow Autoanalyzer(RFA-300) along with the simplified recipe(Choi et al. 1993). Protein content was obtained by total nitrogen multiplied by 5.95 after determining the nitrogen content of rice grain using Micro-Kjeldahl apparatus.

Water uptake ratio and volume expansion of boiled rice were measured by a modified cooking test of milled rice. Gel consistency was measured by the procedure of Cagampang et al.(1973).

Magnesium(Mg) and potassium(K) contents were determined by atomic absorption spectrophotometry.

The milled rices were cooked with an automatic rice cooker by the standard method of the rice quality laboratory in National Crop Experiment Station. The sensory evaluation test of cooked rice was carried out by well-trained twenty panelists with three replications of blind and randomized test using Chucheongbyeo (Akibare) as the standard variety.

RESULTS AND DISCUSSION

Nineteen rice cultivars were selected from seventy-nine Korean and Japanese rices including japonica and Tongil-type rices grown in 1989 by the water uptake behavior of milled rice under the room temperature and boiling conditions. The samples were evenly and randomly chosen from eleven varietal groups which was classified by the scatter diagram on the plane of the 1st and the 2nd principal components based on six characteristics including the water absorbability and volume expansion of milled rice in the normal tap and boiling waters(Fig. 1). Tongil-type rice varieties showed markedly narrower variation in the 2nd principal component score compared with japonica ones. The tested rice materials showed the largest varietal variation in water uptake

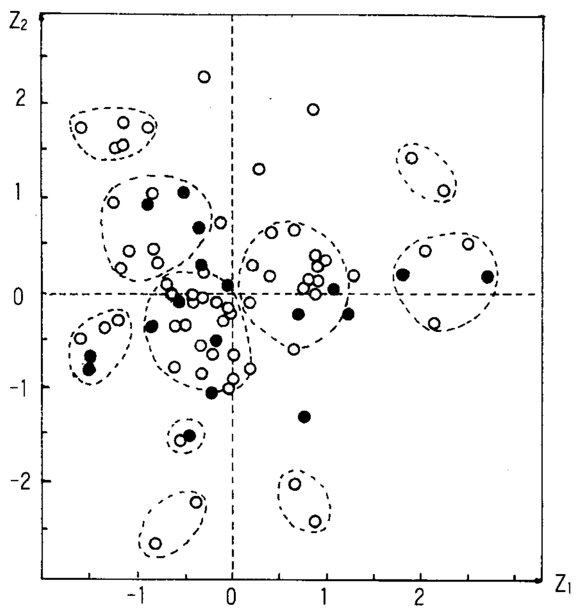


Fig 1. Scatter diagram of seventy nine rice cultivars on the plane of 1st(Z_1) and 2nd(Z_2) principal components indicating mainly the water absorbability of milled rice in normal tap water, and water uptake ratio and volume expansion of boiled rice, respectively. (○ : Japonica, ● : Tongil-type).

Table 1. Varietal variation of water absorption rate of milled rice in the tap or boiling water, and volume expansion of boiled rice in seventy-nine Korean and Japanese rice cultivars.

Water absorbability factors		Mean	Standard deviation	Coefficients of variation (%)	Range
Water absorption rate(%) in tap water(20℃) at	10MAS	18.9	1.96	10.4	14.3~25.6
	20MAS	25.1	2.78	11.1	20.5~31.7
	30MAS	28.8	2.12	7.4	25.1~34.8
	40MAS	30.0	1.87	6.2	26.7~35.5
Water uptake ratio of boiled rice (%)		168	16	9.5	120~206
Volume expansion of boiled rice (%)		158	2.1	13.3	100~200

MAS : Minutes after soaking.

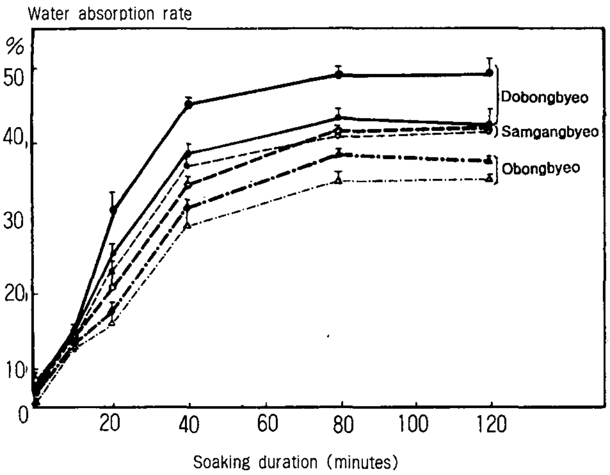


Fig 2. Comparison of water absorption rate of milled rice during 120 minutes after soaking in cool tap water(10℃) among three typical rice varieties, and between new and old rice harvested in 1990 and in 1989, respectively. Thick lines indicate the water absorbabilities of the newly-harvested rice and thin lines point out those of the old one.

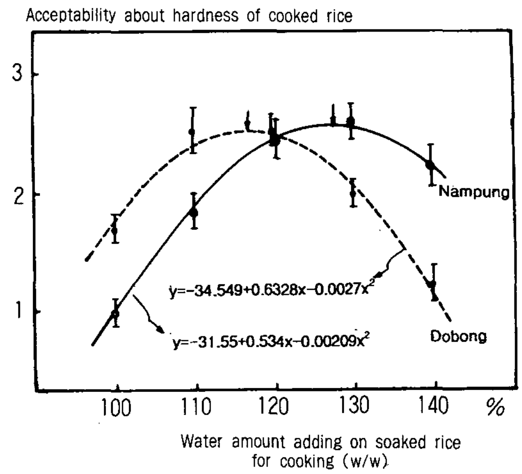


Fig 3. Changes in panels' mean acceptability on hardness of cooked rice as affected by the water amount added on soaked rice for cooking. The range of vertical bars indicate the standard error of panels' mean acceptability. The position of arrow marks indicate the proper water amounts for cooking the soaked rice of each variety.

rate at twenty minutes after soaking in normal tap water(20℃)(Table 1). It was averaged about 25.1% with the varietal range from 20.5 to 31.7%.

The maximum water uptake of milled rices at cool temperature occurred at about eighty minutes after soaking. Three typically different rice varieties in water uptake behavior for 120 minutes after soaking in cool tap water(10℃) were shown in Fig. 2. Cool-water uptake rate at 20 minutes after soaking in two japonica rices was significantly higher in nwely harvested milled rice than in one-year old one, while in Samgangbyeo, a Tongil-type rice, the water uptake rate at 20 to 40 minutes after soaking was slightly lower in newly harvested rice than in old one and became similar at 80 minutes after soaking.

In mean value of tested rice varieties, the newly harvested rice exhibited the significantly higher water uptake rate at 20 minutes after soaking in 20℃ tap water compared with the one-year old ones, but their water absorption ratio and volume expansion of boiled rice were remarkably lower than those of the old rice samples. The fresh rice samples showed the relatively larger varietal variation in water uptake components compared with the old ones(Table 2).

Kim et al.(1985a) reported that the milled rice of Tongil-type varieties showed relatively rapider hyd-

Table 2. Comparison of some properties related to the water absorbability of milled rice soaked in normal or boiling water and the alkali digestibility between the old rice harvested in 1989 and the new one harvested in 1990.

Character	Mean			Standard deviation		Coeffcients of variation	
	'89	'90	Sd	'89	'90	'89	'90
Water absorption rate (%)[a]	19.74	12.17	**	5.23	4.50	26.5	37.0
Maximum water absorption ratio (%)[b]	27.83	30.20	ns	2.49	4.61	8.9	15.3
Alkali digestion value (1-7)	6.06	5.53	ns	1.06	0.97	17.4	17.5
Water uptake ratio of boiled rice (w/w %)	127	118	**	9.1	10.7	7.1	9.1
Volume expansion of boiled rice (v/v %)	282	263	**	1.3	1.6	4.7	6.2

[a] Water absorption rate(%) of milled rice after 20 minutes of soaking in normal tap water (20℃)
[b] Maximum water absorption ratio(%) of milled rice was determined at 80~160 minutes after soaking in normal tap water (20℃)
Sd : Significancy of difference between two mean values.
** : Significant at 1% level. ns : Not significant at 5% level by t-test.

Table 3. Proper water amount of rice varieties for rice cooking.

Proper water amount for cooking on soaked milled rice basis(ml to 100g dry milled rice)			Proper water amount for cooking on dry milled rice basis(ml to 100g dry milled rice)		
Mean	Standard deviation	Range	Mean	Standard deviation	Range
122	3.76	114 ~ 128	152	4.90	145 ~ 161

Table 4. Classification of tested rice cultivars by proper water amount for rice cooking.

Proper water amount for cooking on soaked milled rice basis (ml)	Corresponding rice cultivars
110 ~ 115	Sasanishiki
116 ~ 120	Dobongbyeo, Cheongcheongbyeo, Yongjubyeo, Chucheongbyeo
121 ~ 125	Ilpumbyeo, Hwaseongbyeo, Nagdongbyeo, Samgangbyeo, Odaebyeo, Anjungbyeo, Chilseongbyeo, Kinuhikari, Jinmibyeo
126 ~ 130	Jinbubyeo, Nampungbyeo, Gwanagbyeo

Proper water amount for cooking on dry milled rice basis (ml)	Corresponding rice cultivars
141 ~ 145	Cheongcheongbyeo
146 ~ 150	Odaebyeo, Anjungbyeo, Yongjubyeo, Obongbyeo, Chucheongbyeo, Chilseongbyeo, Jinmibyeo
151 ~ 155	Sasanishi, Nampungbyeo, Ilpumbyeo, Dongjinbyeo, Hwaseongbyeo, Samgangbyeo, Kinuhikari
156 ~ 160	Gwanagbyeo, Nagdongbyeo
161 ~ 165	Dobongbyeo, Jinbubyeo

The cultivars underlined are Tongil-type rices.

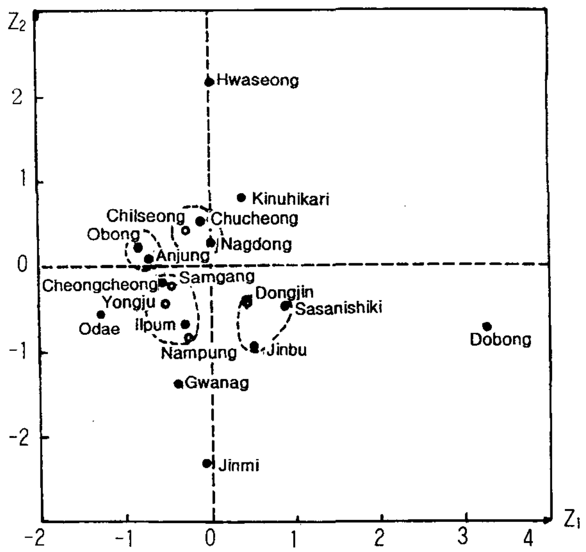


Fig 4. Scatter diagram of selected nineteen rice cultivars on the plane of 1st(Z_1) and 2nd(Z_2) principal components contracted from eight characteristics including the water absorbability of milled rice grain in normal and boiling water, and gelatinization or volume expansion of cooked rice. (● : Japonica, ○ : Tongil-type).

ration rate than japonica ones although there were large varietal variation in both rice groups. They minutely classified the Korean rice varieties into six groups according to hydration rate of milled rice at room temperature.

Panels' mean acceptability about hardness of cooked rice were checked at five levels of water amount ranging from 100 to 140% as w/w ratio of water/dry milled rice. The proper water amount for optimum cooking in each rice cultivar was determined by the calculated peak point of parabolic regression curves between water amount and acceptability about hardness of cooked rice(Fig. 3). Varietal variation of selected rice materials in proper water amount for cooking as w/w ratio between water amount and dry milled rice ranged from 114 to 128% with the average of 122% based on soaked milled rice and ranged from 145 to 161% with the average of 152% based on dry milled rice(Table 3).

Chikubu(1987) also suggested that the proper amount of water added for rice cooking was about 1.5 times in weight-base or 1.2 times in volume-base of milled rice.

The tested rice cultivars were classified by the proper water amount for rice cooking based on soaked and dry milled rice, respectively(Table 4). Two Tongil-type rices Cheongcheongbyeo and Yongjubyeo, and a japonica rice Chucheongbyeo demanded relatively less water amount for optimum rice cooking compared with japonica rices Nagdongbyeo, Gwanagbyeo and Jinbubyeo in both conditions of soaked and dry milled rice. Sasanishiki demanded the lowest water amount for optimum cooking of soaked milled rice although it demanded the average level of water amount for cooking based on dry milled rice.

The selected nineteen rice cultivars were classified by scatter diagram on the plane of the 1st(Z_1) and the 2nd(Z_2) principal components based on eight characteristics including the water absorbability of milled rice grain in normal and boiling water, and gelatinization or volume expansion of cooked rice using principal component analysis(Fig. 4). The two upper principal components covered 72.8% of contribution to total information of eight characters(Table 5). The 1st principal component scores were closely associated with water absorbability and alkali digestibility of milled rice, while the 2nd ones were mainly contracted with the water uptake and volume expansion of boiled rice(Table 6).

The rice materials can be classified into six or seven groups. Especially, three japonica rices, Do

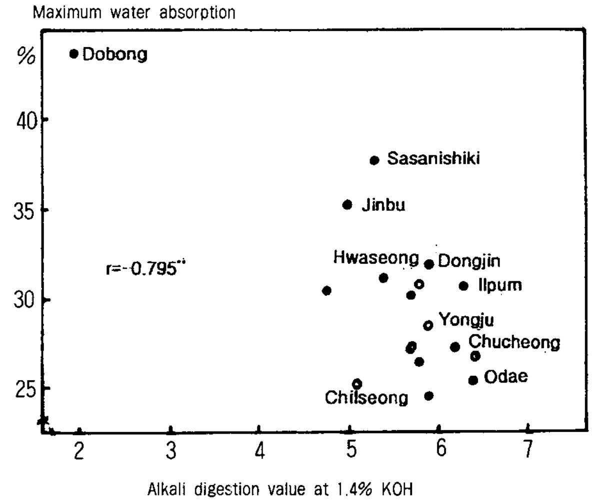
Table 5. Eigen value and contribution of the 1st (Z_1) and the 2nd (Z_2) principal components extracted from some water absorption behaviors of milled rice in the normal and boiling water.

Item \ Principal component	Z_1	Z_2
Eigen value	3.94	1.88
Contribution (%)	49.3	23.5
Cumulative contribution (%)	49.3	72.8

Table 6. Correlation coefficients between variables and principal components.

Variable \ Component	Z_1	Z_2	Z_3
Water absorption rate at 20MAS	0.875**	0.063	-0.164
Water absorption rate at 40MAS	0.900**	0.059	-0.207
Maximum water absorption	0.904**	-0.211	0.104
Alkali digestion value	-0.857**	0.060	-0.277
Moisture content of milled rice	-0.694**	0.044	-0.509*
Water uptake ratio of boiled rice	0.237	0.940**	0.098
Volume expansion of boiled rice	-0.212	0.927**	0.206
Proper water amount for rice cooking	-0.481*	-0.286	0.696**

MAS : Minutes after soaking, *, ** : Significant at 5% and 1% levels, respe ctively.



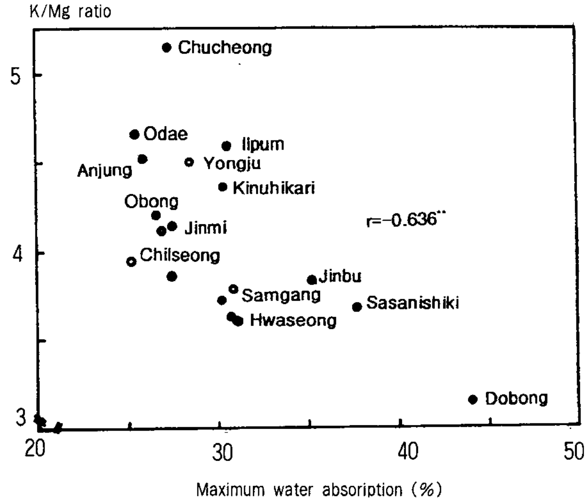


Fig 5. Interrelationships between maximum water absorption and alkali digestion value or K/Mg ratio of milled rice grain (● : Japonica, ○ : Tongil-type).

bongbyeo, Hwaseongbyeo and Jinmibyeo, were scattered away from the other rice varieties, indicating that they have quite different behavior in water absorbability, gelatinization and volume expansion of milled rice under room temperature or boiling conditions. All Tongil-type rice cultivars were located on the negative direction of the 1st principal component score, while the jaonica ones dispersed on the whole four planes(Fig. 4).

Kim et al.(1985b) reported that Dobongbyeo and Cheongcheongbyeo belonged to the highest hydration-rate group at 23°C and Tongil-type rices showed relatively rapider hydration-rate than japonica ones.

Maximum water uptake rate was negatively correlated with alkali digestion value (ADV) and K/Mg ratio of milled rice in japonica rices. Especially, a low ADV japonica rice, Dobongbyeo, showing the highest water uptake rate for saturation largely affected the significance in these interrelationships(Fig. 5). Water absorption rate of milled rice at twenty minutes after soaking in 25°C tap water was associated positively with maximum water uptake ratio and negatively with moisture content of milled rice and ADV. Water uptake ratio during cooking was closely associated with the volume expansion of boiled rice. But these water uptake characteristics did not have any significant correlation with amylose, protein content and the palatability of cooked rice(Table 7).

The effective determination of appropriate water amount for cooking a milled rice sample is not so easy since much time and labor should be needed for cooking and sensory evaluation of cooked rice. So, a multiple regression fromula for estimating proper amount of added water for rice cooking may be useful in preparing the cooked rice samples to serve in sensory evaluation test. Multiple regression formula for indirect determination of proper water amount for rice cooking could be obtained by stepwise regression analysis adopting some water-uptake and physicochemical properties of milled rice as the independent variables with about 70% fittness of determination on dry(12% moisture) milled rice basis(Table 8).

Kim & Oh(1992) reported that ADV was positively correlated with water uptake rate of milled rice under both room temperature and hot water conditions. Halick & Kelly(1959) and Bhattacharya(1979) also

Table 7. Correlation coefficients between water uptake characteristics of milled rice soaked in the normal or boiling water and some physicochemical properties of rice grain or palatability of cooked rice

	Relevant character	Correlation coefficients
Water absorption rate at 20 MAS	- Water absorption rate at 40 MAS	0.907**
	- Maximum water absorption	0.645**
	- Moisture content of milled rice	-0.469*
	- Alkali digestion value	-0.751**
	- Amylose content	-0.436
	- Palatability of cooked rice	-0.090
Maximum water absorption ratio	- Moisture content of milled rice	-0.708**
	- Alkali digestion value	-0.795**
Water uptake ratio of boiled rice	- Volume expansion of boiled rice	0.793**
	- Palatability of cooked rice	0.115

MAS : Minutes after soaking, *, ** : Significant at 5% and 1% levels, respectively.

Table 8. Effective multiple regression formulae for the indirect determination of proper water amount adding for rice cooking calculated by stepwise regression analysis using some physicochemical properties of rice grain as the independent variables.

Milled rice status for cooking	Effective formulae for determining the proper water amount adding on milled rice for cooking	Coefficients of determination (R^2)
Dry milled rice (about 12% moisture)	$Y = 147.5 + 0.63 X_1 - 13.34 X_2 + 1.13 X_3 - 2.79 X_4 - 0.29 X_5$	0.699
Fully soaked milled rice	$Y = 122.3 + 1.36 X_3 - 9.92 X_2 + 0.40 X_6 - 0.35 X_7 - 1.37 X_4$	0.439

Y : Proper water amount adding on milled rice for cooking, X_1 : Maximum water absorption ratio of milled rice, X_2 : Water uptake ratio of cooked rice in cooking test, X_3 : Amylose content of milled rice, X_4 : Alkali digestion value of milled rice, X_5 : water absorption rate of milled rice for 20 minutes, X_6 : Protein content of milled rice, X_7 : Water absorption rate of milled rice for 40 minutes. Fully soaked milled rice indicates the milled rice soaked in about 20°C tap water for one hour.

pointed out that the water uptake of milled rice in hot water was negatively correlated with the gelatinization temperature of rice grain. Kim et al. (1985b) suggested that the relative crystallinity of rice starch and surface area of milled rice were negatively correlated with ADV and the hydration rate of milled rice.

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[Appendix]

Table 1. Water absorbability and other physicochemical properties of milled rice grain in selected rice materials

Variety	Ecotype	Water absorption rate at ♩ 20MAS (%)	Water absorption rate at ♩ 40MAS (%)	Maximum water absorption (%)	Alkali digestion value (1~7)	Moisture content of milled rice (%)	WUR ♪ A20MB (%)
Dobongbyeo	J	25.3	38.4	43.8	2.0	11.2	124
Sasanishiki	〃	15.3	29.1	37.7	5.3	11.8	118
Jinbubyeo	〃	12.4	24.4	35.3	5.0	11.5	106
Obongbyeo	〃	7.6	20.3	26.4	5.8	12.2	117
Gwanagbyeo	〃	8.7	20.3	30.1	5.7	11.8	103
Jinmibyeo	〃	14.9	26.4	27.4	5.7	12.1	141
Odaebyeo	〃	7.5	21.0	25.4	6.4	12.7	107
Dongjinbyeo	〃	17.4	29.3	31.9	5.9	12.0	112
Hwaseongbyeo	〃	9.4	24.5	31.1	5.4	11.8	142
Kinuhikari	〃	14.8	26.9	30.2	5.7	11.6	125
Chucheongbyeo	〃	15.5	25.5	27.4	6.2	12.0	122
Nagdongbyeo	〃	9.7	22.3	30.7	4.8	11.8	121
Anjungbyeo	〃	7.6	16.4	27.1	5.9	11.8	124
Ilpumbyeo	〃	8.2	23.0	30.7	6.3	11.6	108
Chilseongbyeo	T	13.7	21.9	25.2	5.1	12.1	120
Cheongcheongbyeo	〃	10.7	24.9	26.8	6.4	12.2	116
Samgangbyeo	〃	9.3	24.0	30.8	5.8	12.5	117
Yongjubyeo	〃	9.2	20.5	28.4	5.9	11.9	112
Nampungbyeo	〃	14.0	25.3	27.4	5.7	12.3	106

Variety	Volume expansion of boiled rice (%)	Proper water amount for rice cooking (%)	Gel consistency (mm)	Protein content (%)	K/Mg ratio	Amylose content (%)	Palatability of cooked rice (-3~3)
Dobongbyeo	240	161	58	10.7	3.14	15.0	-0.54
Sasanishiki	253	152	53	6.7	3.66	17.6	0.48
Jinbubyeo	257	161	55	5.4	3.83	16.7	0.77
Obongbyeo	271	146	63	7.7	4.20	18.5	-0.10
Gwanagbyeo	243	158	63	10.0	3.72	17.9	-0.53
Jinmibyeo	300	148	64	6.7	4.14	18.0	0.20
Odaebyeo	257	150	56	7.7	4.66	19.3	0.16
Dongjinbyeo	257	152	-	-	-	-	-
Hwaseongbyeo	300	154	61	7.0	3.59	19.3	0.25
Kinuhikari	279	153	68	8.0	4.36	17.4	-0.13
Chucheongbyeo	271	146	66	7.3	5.15	19.4	0.19
Nagdongbyeo	271	156	64	8.3	3.63	18.6	-0.10
Anjungbyeo	257	149	60	6.7	4.52	18.3	0.13
Ilpumbyeo	257	155	75	6.7	4.60	19.8	0.56
Chilseongbyeo	271	149	52	11.0	3.94	17.2	-1.22
Cheongcheongbyeo	257	145	51	9.3	4.08	15.2	-0.53
Samgangbyeo	257	153	44	10.0	3.78	16.6	-1.30
Yongjubyeo	257	146	50	9.0	4.50	16.7	-0.64
Nampungbyeo	250	155	61	9.0	3.86	19.5	-0.73

J : Japonica, T : Tongil-type, ♩ MAS : Minutes after soaking in water, ♪ WUR A20MB : Water uptake ratio of milled rice after 20 minutes boiling