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Grain Quality Improvement in Japonica Rice : Achievements and Prospects

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ABSTRACT

Several high grain quality rice varieties have been developed during the 2000's. These varieties showed translucent, zero white-core, glossy and uniform milled-grain appearance, high palatability score of cooked rice and high percentage of whole grain after milling. The high eating quality variety group was lower in protein content, softer in gel consistency, and higher in breakdown and lower in consistency and setback viscosity measured by rapid visco-amylogram. In order to produce the low protein rice grain, the nitrogen fertilizer level has to be reduced to 90-110 kg per hectare with no nitrogen top dressing after heading. Rotational irrigation during rice growing season and delayed drainage after heading was found as effective in raising the whole grain yield and eating quality of cooked rice. Slow drying to 15-16% of grain moisture is recommended with air flow temperature below 50^{o}C.

Three hundred and ninety four native rice core collections were tested for their grain appearance, eating quality determining factors, and nutritional compounds. Health- enhancing potential and second metabolite contents were also evaluated. The native collections selected for high grain quality resources were used as cross parents and two new rice varieties having dark red pericarp color were developed from the crosses using Korean native varieties. The new variety had higher phenolic compounds in brown rice and the brown rice extract of this variety induced apoptotic cell deaths in H4II cells to a larger extent than the control rice extracts.

Key words: rice, grain quality, variety improvement, native variety, red pericarp

INTRODUCTION

The category and components of rice grain quality are summarized as the grain appearance, the palatability of cooked rice, and the nutrition value. The grain appearance is determined by grain size and shape, translucency, degree of white core, gloss, and uniformity. The palatability is dependent upon taste, texture, smell, stickiness and gloss of cooked rice. The nutrition value of rice grains involves calorie supply potential, protein content and amino acid composition, vitamin and mineral contents, and the amount of second metabolite products (Kim *et al*., 1994, Choi, 2002a).

To improve rice grain quality in Korea, efforts to develop a new variety of high grain quality rice and improve of cultural practices and post-harvest managements have continued for more than thirty years (Kim, 2009, Hwang and Kim, 2009). Among them the use of breeding techniques to develop a new high quality variety, which can ensure the best eating quality of cooked rice and attractive grain appearance, have been much emphasized during the period. Cultural practices in paddy fields were improved and efforts to provide adequate post-harvest management for high grain quality were accelerated after the mid-1990's when rice grains began to be imported from foreign countries under the agreement with the WTO (Hwang *et al*., 2004).

Achievements in grain quality improvement breeding of Japonica rice in Korea during the last 30 years, and the cultural practices and post-harvest managements emphasized to improve grain quality are reviewed in this paper. The new approaches for high grain quality and prospects for the future are also mentioned.

ACHIEVEMENTS IN GRAIN QUALITY IMPROVEMENT

Variety development

The most important breeding objective in Korea in recent years has been producing high grain quality, and therefore the strict standards for selecting a new variety have been adopted. They are for example, zero white-core in milled rice grain, the highest sensory score of cooked rice, and higher whole grain percentage above 65% after milling. Multiple resistance to several diseases and insects and high grain yield potential are also required for selecting new rice variety (Lee *et al*., 2006, Hwang and Kim, 2009).

Changes in grain quality of rice varieties developed in different years (Table 1) indicate the achievements of breeding efforts to improve grain quality of Korean rice. Most rice varieties released after

2004 showed good grain appearance and whole grain uniformity. Their palatability score of cooked rice of them were placed above average. One of the rice varieties developed in the 1990's, Ilpum, received the highest eating quality score tested by Korean and Japanese consumers in 1995 (Choi, 2002a). This variety showed both high yield potential and high eating quality, but was susceptible to major diseases and insects. The whole grain percentage and degree of white-core of milled rice are below standards for selecting high quality variety.

Table 1. Changes of grain quality of rice varieties developed in different years

Variety	Year developed	White c./b. 0-9	Amylose %	Protein %	Palatability of Cooked Rice
Jinheung	1962	1/1	19.8	7.7	good
Dongjin	1981	0/1	18.0	7.3	better
Ilpum	1990	0/1	18.9	6.7	best
Kopum	2004	0/0	19.6	6.1	best
Chilbo	2007	0/0	18.3	6.4	best

Several high grain quality varieties; Samkwang, Kopum, Unkwang, Hopum, Chilbo, Jinsumi and High-amy, have been developed during the 2000's. These varieties showed translucent, zero white-core, glossy and uniform milled-grain appearance, high palatability score of cooked rice and high percentage of whole grain after milling (Hwang and Kim, 2009).

The difference of physicochemical property of rice grain among 3 variety groups divided by sensory score of cooked rice was tested (Table 2). The high eating quality group showed lower protein content, softer gel consistency, and higher breakdown and lower consistency and setback values measured by rapid visco-amylogram (Choi, 2002a, Choi, 2002b) However, the best eating quality Ilpum variety did not show any consistent tendency in physicochemical traits compared with other varieties among the same group (Kim *et al*., 1994).

Table 2. Physicochemical property of rice grain of variety groups showing different Sensory score of cooked rice

Quality Group	No. of varieties	Sensory score (-3~+3) Apearance	Overall	ADC 1-7	Amylose %	Protein %	Mg/K ratio
I	5	0.53	0.53	6.8	19.1	6.87	0.242
II	4	0.19	0.15	6.8	19.1	7.00	0.237
III	4	-0.16	-0.33	6.8	18.9	7.06	0.253
Quality Group	No. of varieties	Gel con. mm	Solid m. mg/g	Gelatinization p. (BU) Break d.	Consis.	Setback	
I	5	65.5	50.0	490	410	-81	
II	4	64.3	55.4	452	427	-25	
III	4	61.7	49.9	437	437	-1.0	

Note : Sensory score was tested for cooked rice. Gel con = gel consistence of rice flour, Solid m = solid materials in cooking water, Gelatinization p = gelatinization property of rice flour tested by rapid visco-amylogram, Break d = break down viscosity, and Consis. = consistency viscosity.

Cultural practice improvement

Growing conditions such as fertilizer level, irrigation period, temperature during maturing period and disease and insect occurrences, have an impact on grain appearance, eating quality of cooked rice and nutrition value of rice grain. Korean rice farmers used to apply as much as 150 kg of nitrogen fertilizer per hectare to harvest higher grain yield. It was found that the protein content of milled rice exceeded 7% above 110kg/ha level of nitrogen fertilizer (Table 3). It was recommended by food technologists that the grain protein content be controlled to around 6.5% for the best eating quality. Thus, in order to produce rice grain with a protein content around 6.5%, the nitrogen fertilizer level has to be reduced from 110~150 kg to 90~110 kg per hectare with no nitrogen top dressing after heading (Shin *et al*., 2006). Reduced nitrogen fertilization in rice fields is now becoming more prevalent.

Rotational irrigation during rice growing season and delayed drainage after heading was found to be an effective cultural method for raising the whole grain yield and eating quality of cooked rice. Selection of optimum growing season, disease and insect control at ripening period, and harvest at optimum ripening stage are important for higher rice grain quality (Shin *et al*., 2006).

Table 3. Protein content and whole grain yield at different N levels

Observation	Variety Group	N levels (kg/10a)						
		0	5	7	9	11	14	17
Protein %	EMV[2)]	6.33	6.56	6.73	6.92	7.26	7.45	8.22
	MLMV[3)]	6.10	6.23	6.34	6.60	7.16	7.35	8.10
W. Grain[1)] kg/10a	EMV	298	368	385	397	407	399	405
	MLMV	360	410	424	455	459	452	450

Note : 1) Whole Grain Yield, 2) Early Maturing Variety, 3) Medium-late Maturing Variety

Post-harvest management

Most harvested rice grains are usually sent to regional RPC (rice processing center) and dried by heated air flows in drying facilities. The moisture content of harvested rice grain varied 22 to 25% and the optimum moisture content for safe storage is known to be below 15%. But because rice grains with moisture content of 15-16% showed good eating quality of cooked rice, slow drying to 15-16% of grain moisture is recommended with air flow temperature below 50^{o}C. High temperature air flow drying usually increases the cracking and broken rice percentage (Table 4). It is the reason why air flow temperature in drying bin or other drying facilities is recommended at below 50^{o}C (Sohn and Lee, 2006).

Rice grain quality gradually deteriorates with prolonged storage period. Respiration and chemical metabolism of the grain, and insect and microorganism infection during storage are the causes of quality deterioration. Lower grain moisture content below 15%, lower storage temperature at around 15^{o}C, and lower relative humidity below 70% are recommended to RPC to keep high grain quality of rice (Sohn and Lee, 2006).

Table 4. Effect of drying temperature on grain cracking of rice

Observation	Drying Temperature ^{o}C						
	40	45	50	55	60	65	70
Cracked grain, %	3	5	7	10	19	28	38
Germination, %	98	93	86	82	75	60	30

Table 5. Phenol compound contents in brown rice of red pericarp variety

Variety	Phenol compound (μg/g)							SOD (%)	DPPH (%)
	Chl	Cat	Syr	Fer	Hes	Cin	Cou		
Jachechal	345.1	39.8	449.3	834.3	280	384.6	183.2	78	87.5
Hwasunchabyeo	18.9	4.4	21.7	32.4	136.3	0	11.5	61.6	45
Ilpum	87	5.9	9.7	24.7	32.8	0	41.9	66.3	19.6

Note : Chl : Chlorogenic acid, Cat : Catechin, Syr : Syringic acid, Fer : Ferulic acid, Hes : Hesperedin, Cin : t-cinnamic acid, Cou : p-coumaric acid

NEW APPROACHES FOR GRAIN QUALITY IMPROVEMENT

Recombination breeding has widely been used to develop the new high quality varieties. Most of the genes related to the high grain quality varieties developed were introduced from Japanese rice (Choi, 2002b). This makes it difficult for rice scientists to distinguish Korean rice varieties from Japanese rice in terms of grain quality. One of the new approaches to distinguishing Korean rice is the utilization of native collections as breeding materials.

There are more than one thousand native rice collections in the national plant germplasm bank. No systematic study on grain quality, eating quality, nutritional value, and health enhancing compounds, was conducted prior to 2000. Few cross combinations using native varieties were made and only 3 special purpose pigmented rice varieties derived from native collections were registered in the national variety list (Kim, 2008).

Characterization of Korean native rice core collection

Three hundred and ninety four native rice core collections were selected and tested for their grain appearance and eating quality determining factors, nutritional compounds, and health enhancing potential and second metabolite compounds were also evaluated (Kim *et al*., 2007). Variations were found in all the characteristics measured. Among them 5 collections for high palatability index of cooked rice, 2 for high lysine and threonine content, 2 for high Fe, Mg, Zn and K content, 3 for special fatty acid composition were identified. The pigmented pericarp rice varieties showed high antioxidant activity, and 21 and 11 accessions showed higher oryzanol and octacosanol content, respectively. The core collections showing higher tocopherol, tocotrienol, vitamin E, squalene, and phytosterol content were also selected. The native collections selected for high grain quality resources were used as cross parents at different breeding institutes.

Rice varieties developed from native varieties

Two rice varieties having dark red pericarp color were developed from the crosses using Korean native varieties as one of the parents. A native variety having dark red pericarp, Jakwangdo, had been cultivated in the central region of the Korean peninsula on a very small scale. This native variety was tall in height, easy to lodge, low in grain yield, and unacceptable in terms of eating quality of cooked rice. I collected this native variety and made several crosses with modern glutinous rice to improve its lodging resistance, yield potential and endosperm characteristics.

A new red percarp glutinous rice "Jakwangchal" was selected among F11 lines which showed stable agronomic characteristics and high antioxidative activity in a cross of Jinbuchal/Jakwangdo. The new variety had higher phenolic compounds and the brown rice extract of this variety induced apoptotic cell death in H4II cells to a large extent than the control rice extracts (Chi *et al*, 2006, Kim, 2008). The other dark red pericarp glutinous rice "Jachaechal" was developed following "Jakwangchal". The content of phenolic compound of brown rice was also higher in the newly developed rice variety than check varieties (Table 5). The red pericarp gene from a Korean native rice variety produced more phenolic compounds and might show the biological activity of antioxidation and apoptotic cell death in human body.

PROSPECTS

Despite the decline in per capita rice consumption, the needs for high quality rice grain will increase more and more in the future. So a more integrated approach based on the close cooperation of rice breeding, cultural techniques and post-harvest management is needed to improve the rice grain appearance and eating quality of cooked rice in Korea. Conventional and molecular breeding efforts are on going to develop new rice varieties of high grain quality as well as high grain yield and multiple resistance to diseases and insects. Rice varieties for diverse processing needs; for wine, rice cake, noodle, bread, cookie added on cooked rice, will be developed and spreading throughout the world. Biofortified rice like such as high antioxidative activity, anticancer activity, and adult disease preventing rice will be developed and produced much more widely in the future around the world.

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