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Varietal Difference in Retrogradation of Cooked Rice and Its Association with Physicochemical Properties of Rice Grain

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ABSTRACT

The experiments were carried out to elucidate the varietal variation of retrogradation in aged cooked rice and its association with some physicochemical properties of milled rice. The fifteen rice materials were selected from forty-three low-amylose japonica and Tongil-type rice cultivars based on palatability and retrogradation of cooked rice stratified by preliminary sensory evaluation of warm and cooled cooked rice. One japonica glutinous rice variety was included for comparison of retrogradation of cooked rice.

The α-amylase-iodine method was adopted for checking the varietal difference in retrogradation of cooked rice. The desirable checking time for evaluating the varietal difference in deterioration of aged cooked rice was four hours after storing in room temperature and two hours after preserving in refrigerator based on the largest coefficients of variations in degree of retrogradation of cooked rice. The rice cultivars revealing the relatively slow retrogradation in aged cooked rice were Ilpumbyeo, Chucheongbyeo, Sasanishiki, Jinbubyeo and Koshihikari. A Tongil-type rice, Taebaegbyeo, and a japonica cultivar, Seomjinbyeo, showed the relatively fast deterioration of cooked rice.

The retrogadation index represented by the percentage of retrogradation difference between warm and cooled cooked rice to original estimates of warm cooked rice was significantly affected by the degree of retrogradation of cooled cooked rice. Generally, the better rice cultivars in eating quality of cooked rice showed less retrogradation and much sponginess in cooled cooked rice. Also, the rice varieties exhibiting less retrogradation in cooled cooked rice revealed higher hot viscosity and lower cool viscosity of rice flour in amylogram. The sponginess of cooled cooked rice was closely associated with magnesium content and volume expansion of cooked rice. The hardness-changed ratio of cooked rice by cooling was negatively correlated with solids amount extracted during boiling and volume expansion of cooked rice. The major physicochemical properties of rice grain closely related to the palatability of cooked rice may be directly or indirectly associated with the retrogradation characteristics of cooked rice.

The varietal difference in retrogradation of cooked rice can be effectively classified by scatter diagram on the plane of upper two principal components based on some retrogradation properties of cooked rice. The deteriorated structural change in cooled cooked rice by observing through the scanning electron microscope was more conspicuous in the fastly retrograded cooked rice than in the slower one.

Keywords : rice, retrogradation of cooked rice, retrogradation index, physicochemical properties, varietal difference.

Retrogradation of starchy foods means the deterioration of texture and taste mainly caused by the crystallization of gelatinized starch molecules. The crystallization of gelatinized starch molecules by cold preservation is progressed through biphasical change, that is, the fast crystallization of amylose molecules and slow crystallization of amylopectin molecules. Accordingly, the cooked rice of high-amylose variety is more quickly hardened and deteriorated under room or low temperature conditions as compared with that of low-amylose rice. Also, the lipids, though the content is very little, are known as having some effects on the retrogradation of cooked rice(Hibi et al. 1990).

The retrogradation of paste or cooked rice is progressed more quickly under low temperature condition than under room or high temperature conditions (Hizukuri et al., 1972; Matsuda et al., 1990). Some evaluation method for the degree of retrogradation in starchy foods using enzymes were examined and introduced, but its applicability was different according to tested materials and experimental purpose. The enzymatic methods determining the degree of gelatinization are amperometric titration method(Hizukuri et al., 1971), α-amylase-iodine method (Tsuge et al., 1990), glucoamylase (Toyama et al., 1966), glucoamylase-modified Somogyi method(Minagawa et al. 1987 in Tsuge et al., 1990) and β-amylase-pullulanase(BAP) method(Kainuma et al., 1981). Kainuma et al.(1981) suggested that BAP method may be effective for determining the degree of gelatinization or retro-

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gradation of cooked rice, but Tsuge et al.(1990) recommended α-amylase-iodine method for detecting the degree of retrogradation in patato and wheat starch pastes through comparing the effectiveness among three enzymatic evaluation methods. The information for retrogradation of starch food stuffs is very limited and a desirable evaluation method for retrogradation of cooked rice was not suggested yet.

Therefore, a series of experiments were conducted to set up the protocol for checking the varietal difference in retrogradation of cooked rice and to clarify the varietal variation of retrogradation in aged cooked rice and its association with some physicochemical properties of milled rice using mainly low-amylose japonica rices.

MATERIALS AND METHODS

Fifteen rice varieties including a glutinous rice were selected from forty-three Korean and Japanese low-amylose rice cultivars(Japonica 32, Tongil-type 11) based on global palatability score and relative difference of palatability between warm and cooled cooked rice by preliminary sensory evaluation so as to include diverse rice materials evenly from fast to slow retrogradation of cooked rice(Table 1).

To set the appropriate time and condition for checking the varietal difference in retrogradation of cooked rice, change in hardness and degree of retrogradation of cooked rice for selected five cultivars were investigated under three different preservation conditions, that is, refrigerator(4~5℃), electronic hot container (70~80℃) and room temperature incubator(20~25℃) at 1, 2, 4, 8, 24 and 48hrs after cooking. The milled rice samples were cooked with an automatic electronic 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 replications of blind and randomized test adopting Chucheongbyeo (Akibare) as the check variety.

Amylose content of milled rice was determined by relative absorbency of starch-iodine color in digested solution of 100-mesh rice flour using Rapid Flow Autoanalyzer(RFA-300) along with the simplified recipe(Choi et al., 1993), a modified Juliano's procedure(Juliano, 1971). Alkali digestion value (ADV) was determined by 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 constant temperature of 30℃. Protein content was obtained by total nitrogen multiplied by 5.95 after determining the nitrogen content of rice material using Micro-Kjeldahl apparatus. Contents of magnesium(Mg) and potassium(K) were determined by atomic absorption spectrophotometry.

Gel consistency was measured by gel length of gelatinized cool rice paste runned for one hour according to the procedure of Cagampang et al.(1973). Amylogram characteristics were measured by Brabender Viscograph and physical properties of cooked rice were determined by Instron. Cooking test of milled rice was carried out by a modified method of Batcher et al.(1956). Cooking quality was represented

Table 1. Stratification of rice varieties according to the retrogradation and palatability of cooked rice.

Palatability \ Retrogradation	Low	Considerably low	Intermediate	Slightly high	High
Excellent	**Jinbubyeo**	**Ilpumbyeo**, Seoanbyeo, **Jinmibyeo**, **Odaebyeo**, **Koshihikari**	Keumobyeo		
Good	**Sasanishiki**, Namyang 7, Sobaegbyeo	Obongbyeo, Unbongbyeo, Jinbuolbyeo	**Chucheongbyeo**, Anjungbyeo, Sangpungbyeo, Cheongmyeongbyeo, **Dongjinbyeo**, **Hwaseongbyeo**, Kinuhikari	Daegwanbyeo, Tamjinbyeo, Namweonbyeo, Gyehwabyeo, Namyangbyeo	**Seomjinbyeo**
Fair			Daeseongbyeo, Daechangbyeo	Gwanagbyeo, **Nagdongbyeo**	
Acceptable		Dobongbyeo, Yongjubyeo, Yongmoonbyeo	Nampungbyeo, Shingwangbyeo		**Taebaegbyeo**
Poor		Cheongcheongbyeo, Seogwangbyeo	Chilseongbyeo, Samgangbyeo Bongwangbyeo, Baegyangbyeo		**Nongbaeg**

Retrogradation was stratified by the difference of palatability between the warm and cooled cooked rice.
Underlined varieties are Tongil-type rice.

by volume expansion of boiled rice, solids amount of extraction and iodine blue value of extracted cooking water.

The degree of retrogradation of cooked rice was determined by α-amylase-iodine method(Tsuge et al., 1990) and was figured out 100 - degree of gelatinization. The retrogradation index was represented by the percentage of retrogradation difference between initiation and aged cooked rice to retrogradation estimates of original warm cooked rice. The hardness-changed ratio of cooked rice was also represented by the percentage of hardness difference between initiation and aged cooked rice to the hardness of original warm cooked rice.

To observe the difference of retrograded change in fine structure of cooked rice between the fast- and low- retrograded rice varieties, cross-sectional status of cooked rice was taken for outer layer, adjacent inner part and core part of cooked rice by scanning electron microscope(SEM) at 3,000×magnification.

RESULTS AND DISCUSSION

The analysis of variance for hardness of cooked rice was done by analyzing three factors such as three preserved temperatures, six storage durations, and five rice materials. The hardness of cooked rice was significantly affected by preserved temperatures, storage durations, and varieties, and significant interactions were also found not only between preserved temperature and duration but also between preserved duration and rice variety in determining hardness of cooked rice(Table 2).

The largest varietal variation in hardness of cooked rice in terms of by coefficients of variation was appeared at one hour after keeping in refrigerator. This tendency was also the same under room and high temperature preservations (Table 3). There are relatively large varietal difference in fluctuation of hardness of cooked rice along with preserved duration(Fig. 1). Ilpumbyeo and Chucheongbyeo showed less changes in hardness of aged cooked rice than the other rice cultivars. The hardness of cooked rice was increased along with preserved duration under all low, room and high temperature conditions although its inflection point of the hardness was different. The cooked rice became generally harder under low or high temperature conditions compared with room temperature condition(Table 3 & 4).

The degree of retrogradation(DR) in cooked rice represented by relative changed ratio of retrogradation figured out with 100 - degree of gelatinization by α-amylase-iodine method was also significantly affected by preserved temperatures, storage durations and cultivars. Since the rice cultivars showed considerably different pattern in retrogradation of cooked

Table 2. Analysis of variance for hardness of cooked rice.

Source of variation	Degree of freedom	Sum of square	Mean sum of square	F-value
Preserved temperature(PT)	2	8,686	4,343	9.60**
Preserved duration(PD)	5	19,231	3,846.2	8.50**
Variety(V)	4	42,491	10,622.8	23.48**
PT × PD	10	9,537	953.7	2.11*
PT × V	8	2,645	330.6	0.73
PD × V	20	16,852	842.6	1.86*
PT × PD × V	40	6,171	154.3	0.34
Error	90	40,725	452.5	

*, ** : Significant at 5% and 1% levels, respectively.

Table 3. Changes in hardness of cooked rice and its varietal variation along with preserved duration under three different temperature conditions.

Item	Preserved temperature	Preserved duration(hrs.)					
		0	1	2	4	8	24
Hardness of cooked rice(g)	Room	270.7 ef	258.9 f	277.1 de	282.7 de	277.7 de	274.2 ef
	Low	270.7 ef	274.1 ef	278.0 de	274.5 ef	289.5 c-e	312.4 b
	High	270.7 ef	270.8 ef	294.8 b-d	295.3 b-d	308.6 b	302.9 bc
Varietal variation (C.V.%)	Room	6.0	8.2	6.3	4.5	1.8	6.8
	Low	6.0	12.0	7.9	8.6	7.6	10.1
	High	6.0	9.0	9.1	5.8	6.3	4.0

Same character on each column indicates no significant difference at 5% level.

rice, the changing aspect of DR along with storing duration was also significantly different among five rice materials(Table 5). Varietal variation in the DR of cooked rice became the largest at two hours after preserving in refrigerator and at four hours after preserving under both room and high temperature conditions. Ilpumbyeo, Jinbubyeo and Chucheongbyeo showed slower retrogradation of cooked rice under all three different storage conditions as compared with Nagdongbyeo and Nongbaeg(Fig. 2). Based on mean DR of five rice cultivars, the cooked rice preserved under high-temperature condition maintained relatively higher level of retrogradation during one to eight hours after treatment than those under room and low temperature conditions(Fig. 3).

Hizukuri et al.(1972) pointed out that the retrogradation rate of potato, wheat, stweet potato, and corn starch pastes increased rapidly as the temperature was lowered and was max at 0℃. The result that the DR of aged cooked rice preserved under high-temperature condition showed relatively higher score in our experiment may be due to drying up of cooked rice by high-temperature.

To understand the relationship between the retrogradation of cooked rice and physicochemical properties of rice grain, the varietal variation of physicochemical properties of milled rice in selected rice materials was investigated. In terms of coefficients of variation, palatability of cooked rice and absorbance of iodine-reacted color of extracted cooking water revealed markedly larger varietal variation as compared with amylose, ADV, protein, gel consistency, Mg/K ratio and volume expansion of cooked

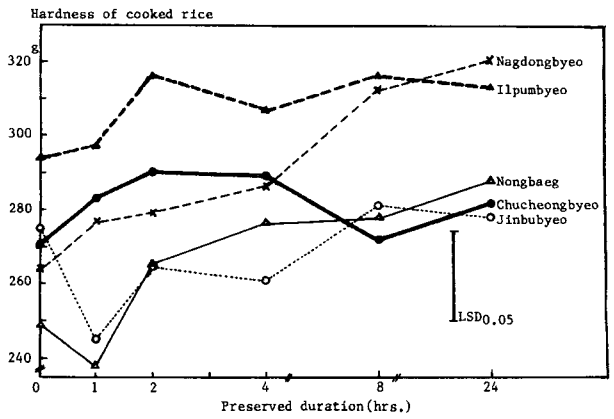

Fig. 1. Varietal difference in fluctuation of hardness of cooked rice along with preserved duration.

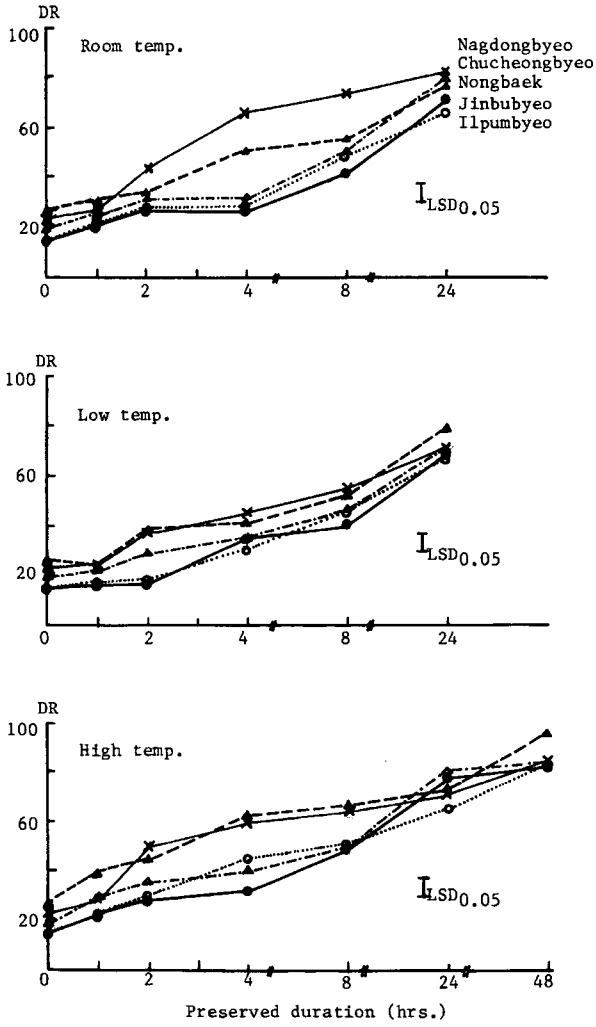

Fig. 2. Varietal difference in changing aspects of retrogradation of cooked rice along with preserved duration under three different temperature conditions. DR (degree of retrogradation) is figured out with 100 - degree of gelatinization.

Table 4. Varietal difference in hardness of cooked rice under the different preserved temperature conditions.

Preserved temperature	Hardness of cooked rice(g)					
	Jinbubyeo	Ilpumbyeo	Chucheongbyeo	Nongbaeg	Nagdongbyeo	Average
Room	263.4 fg	299.9 a-c	266.4 fg	258.5 g	279.6 ed	273.5
Low	259.9 g	307.8 ab	284.7 c-e	267.5 e-g	296.2 b-d	283.2
High	279.4 d-f	314.6 a	292.8 b-d	271.5 e-g	294.2 b-d	290.5

Same character on each row indicates no significant difference at 5% level.

Table 5. Analysis of variance for degree of retrogradation in cooked rice.

Source of variation	Degree of freedom	Sum of square	Mean sum of square	F-value
Preserved temperature(PT)	2	624.2	312.1	15.53**
Preserved duration(PD)	5	29,875.3	5,971.5	297.23**
Variety(V)	4	3,200.6	800.2	39.83**
PD × V	20	1,045.4	52.3	2.60**
Error	58	1,165.0	20.1	

** : Significant at 1% level.

Table 6. Varietal variation of fifteen rice varieties in physicochemical properties of rice grain.

Physicochemical properties	Mean	Range	Coefficients of variation(%)
Alkali digestion value(1-7)	6.8	6.6 ~ 6.9	1.2
Amylose content(%)	17.7	0.0 ~ 20.7	28.6
Protein content(%)	8.32	7.02 ~ 9.91	10.0
Mg/K ratio	0.527	0.210 ~ 0.313	13.9
Gel consistency(mm)	81.4	68 ~ 94	10.0
Volume expansion of cooked rice(ml/g)	2.18	1.82 ~ 2.53	10.3
Absorbance of iodine-reacted color of extracted cooking water	0.478	0.058 ~ 1.008	50.9
Palatability of cooked rice	-0.12	-1.0 ~ 0.52	423.3

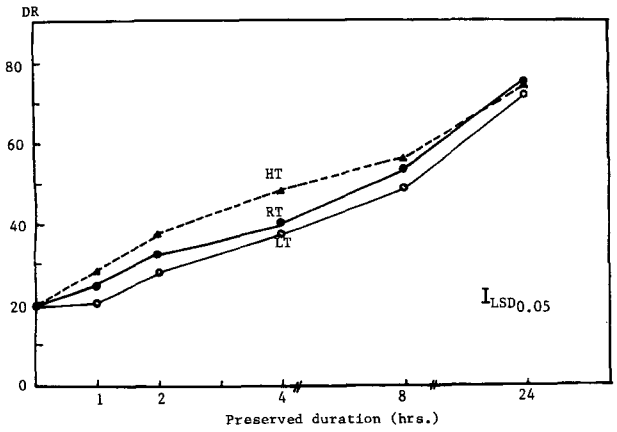

Fig. 3. Difference in retrogradation of cooked rice among three different preserved temperature conditions. HT : High temp., RT : Room temp., LT : Low temp.

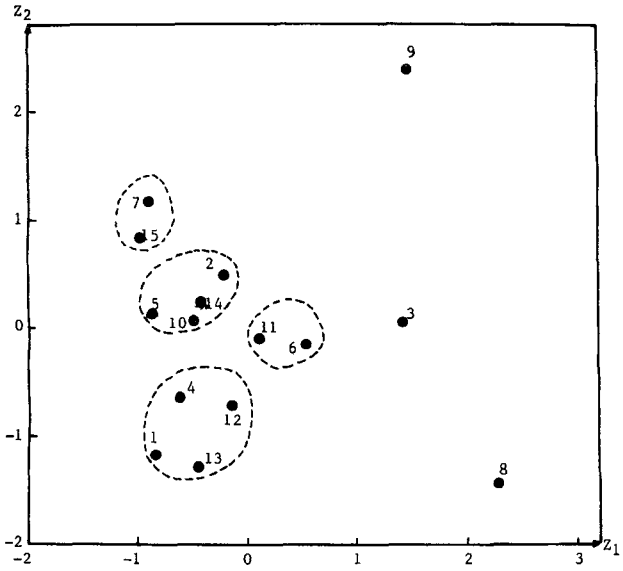

Fig. 4. Distribution of rice varieties on the plane of two different retrogradation indicators, 1st (Z_1) and 2nd principal components(Z_2) figured out from four retrogradation characteristics by principal component analysis. ① Dongjinbyeo, ② Jinbubyeo, ③ Taebaegbyeo, ④ Hwaseongbyeo, ⑤ Sasanishiki, ⑥ Nongbaeg, ⑦ Chucheongbyeo, ⑧ Seomjinbyeo, ⑨ Jinbuchalbyeo, ⑩ Nagdongbyeo, ⑪ Hwajinbyeo, ⑫ Odaebyeo, ⑬ Jinmibyeo, ⑭ Koshihikari, ⑮ Ilpumbyeo.

rice(Table 6). Also, the retrogradation properties of cooked rice such as DR of cooled cooked rice, retrogradation index and hardness-changed ratio of cooked rice by cooling showed relatively larger varietal variation compared with the physicochemical properties of milled rice(Table 7).

Fifteen rice cultivars were assorted by principal component analysis based on four retrogradation properties of cooked rice(Fig. 4). They could be classified seven groups by scatter diagram on the plane of upper two principal components scores which contribute to about 82% of total variance(Table 8). The 1st principal component score was mainly related to DR of

Table 7. Varietal variation of fifteen rice varieties in retrogradation properties of cooked rice.

Retrogradation characteristics	Mean	Range	Coefficients of varieation(%)
Degree of retrogradation of cooled cooked rice	34.9	26.4~ 55.8	25.1
Hardness of cooled cooked rice(g)	236.3	166.7~276.3	9.5
Retrogardation index(%)	76.7	34.9~165.5	49.5
Hardness-changed ratio of cooked rice by cooling(%)	19.6	6.6~ 30.5	36.5

Table 8. Eigen value of upper two principal components and its contribution to total variance based on retrogradation properties of cooked rice.

Item	1st principal component(Z_1)	2nd principal component(Z_2)
Eigen value	1.960	1.311
Contribution(%)	49.0	32.76
Cumulative contribution	49.0	81.76

Table 9. Correlation coefficients between retrogradation properties of cooked rice and upper two principal components.

Variables	1st principal component(Z_1)	2nd principal component(Z_2)
Degree of retrogradation of cooled cooked rice	0.913**	-0.168
Sponginess of cooled cooked rice	-0.598*	-0.645**
Retrogradation index	0.875**	-0.198
Hardness-changed ratio of cooked rice by cooling	-0.065	0.910**

*, ** : Significant at 5% and 1% levels, respectively.

Table 10. Correlation coefficients between retrogradation properties and palatability of cooked rice.

Character	HARD	RI	HDR	PA
Degree of retrogradation of cooled cooked rice(DR)	-0.393	0.720**	-0.296	-0.628*
Sponginess of cooled cooked rice(HARD)		-0.314	0.014	0.554*
Retrogradation index(RI)			-0.214	-0.373
Hardness-changed ratio of cooked rice by cooling(HDR)				0.274
Palatability of cooked rice(PA)				

*, ** : Significant at 5% and 1% levels, respectively.

Table 11. Interrelationship between retrogradation components of cooked rice and physicochemical properties of rice grain.

	Relevant characters	Correlation coefficients
Degree of retrogradation of cooled cooked rice	- Hot viscosity	-0.527*
	- Cool viscosity	0.636*
Sponginess of cooled cooked rice	- Magnesium content	0.556*
	- Volume expansion of cooked rice	-0.666**
Hardness-changed ratio of cooked rice by cooling	- Volume expansion of cooked rice	-0.581*
	- Solids amount extracted during cooking	-0.574*

cooled cooked rice and retrogradation index, while the 2nd principal component score was contracted from sponginess of cooled cooked rice and hardness -changed ratio of cooked rice by cooling(Table 9). Ilpumbyeo, and Chucheongbyeo were belonged to the most desirable rice group of slow-retrogradation in cooled cooked rice and the other high-quality rice cultivars such as Jinbubyeo, Sasanishiki, Nagdongbyeo and Koshihikari were followed as the next ones. A Tongil-type rice Taebaegbyeo and a japonica late

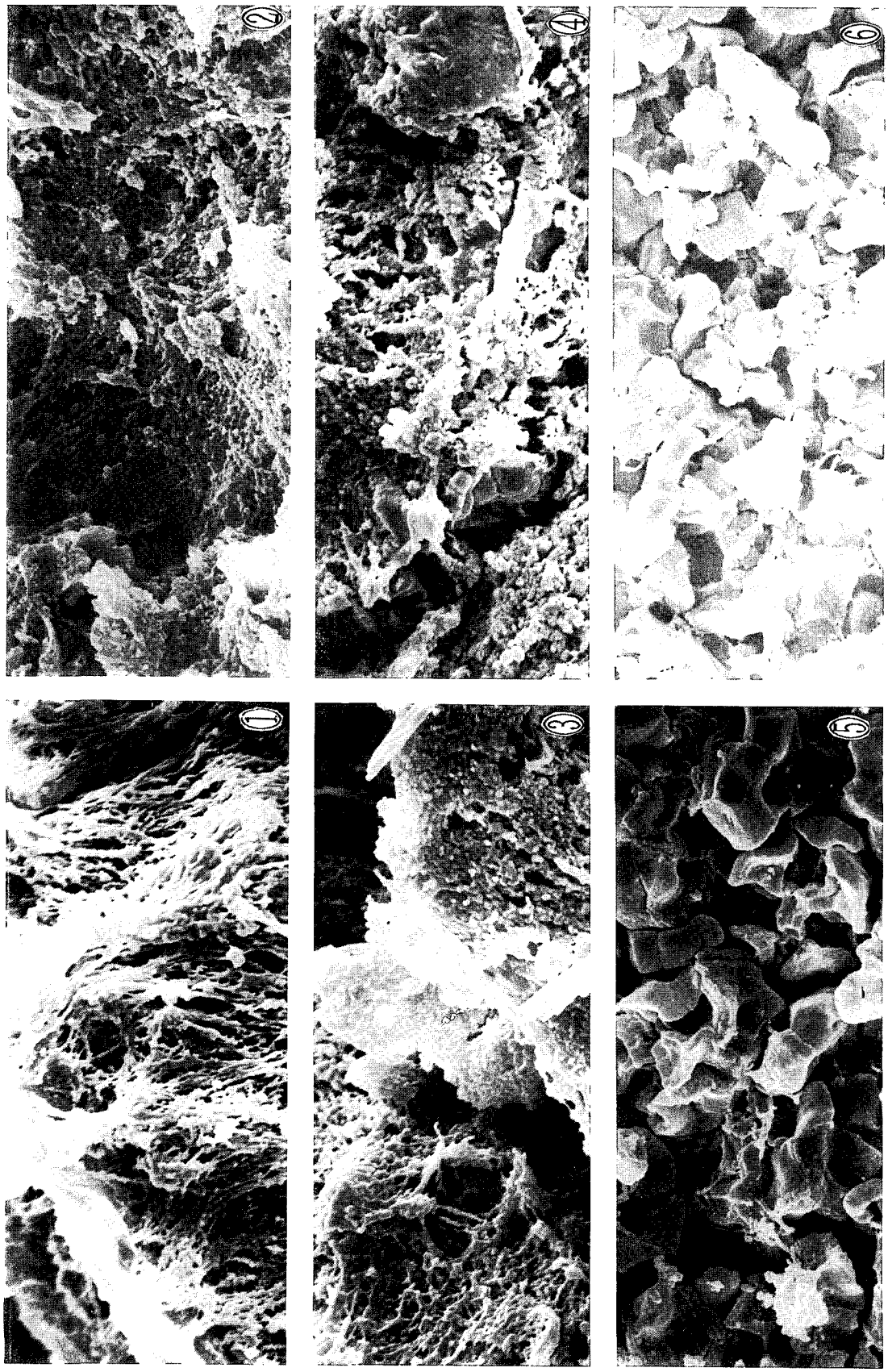

Photo. 1. Comparison of cross-sectional SEM photograph between warm and cooled cooked rice in the slow-retrograded rice variety, "Impumbyeo". ①, ③, ⑤ : Warm cooked rice, ②, ④, ⑥ : 6-hour cooled cooked rice, ①, ② : outer layer, ③, ④ : Adjacent inner part to outer layer, ⑤, ⑥ : Central part of cross-sectioned cooked rice.

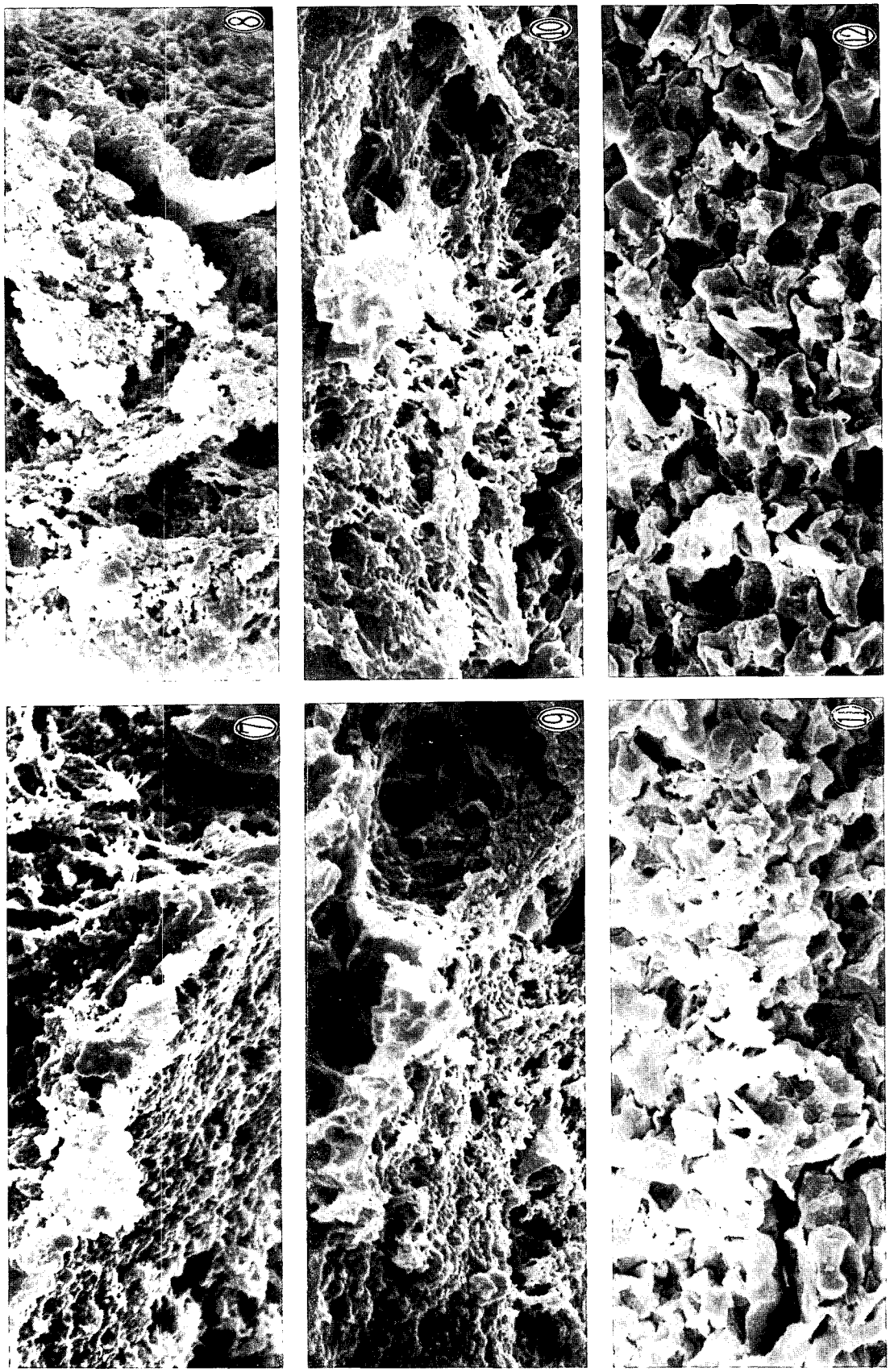

Photo. 2. Comparison of cross-sectional SEM photograph between warm and cooled cooked rice in the fast-retrograded rice variety, "Nongbaeg". ⑦, ⑨, ⑪ : Warm cooked rice, ⑧, ⑩, ⑫ : 6-hour cooled cooked rice, ⑦, ⑧ : outer layer, ⑨, ⑩ : Adjacent inner part to outer layer, ⑪, ⑫ : Central part of cross-sectioned cooked rice.

cultivar Seomjinbyeo revealed the undesirably faster deterioration of cooled cooked rice. Three rice cultivars including the above two undesirable ones and a glutinous rice were quite separately distributed with the other rice cultivars on the plane of upper two principal components(Fig. 4).

The slow-retrogradation rice variety such as Ilpumbyeo revealed less crystallization and cohesion in net structure of gelatinized starch granules especially in outer layer of cooled cooked rice as compared with the fast-retrograded rice cultivar such as Nongbaeg by comparison of cross-sectional SEM photograph between warm and cooled cooked rice (Photo. 1 & 2). The DR of cooled cooked rice was not significantly associated with the sponginess of cooled cooked rice and hardness-changed ratio of cooked rice by cooling, but the DR and sponginess of cooled cooked rice showed significant negative and positive correlations respectively with the palatability of cooked rice (Table 10). The DR of cooled cooked rice was closely associated with hot and cool viscosities of rice flour. The volume expansion of boiled rice had significantly negative correlation with sponginess of cooled cooked rice and hardness-changed ratio of cooked rice by cooling. Also, the sponginess of cooled cooked rice revealed the significantly positive correlation with magnesium content of milled rice, and the hardness-changed ratio of cooked rice by cooling showed the significantly negative correlation with the solids amount extracted during cooking(Table 11).

The present results suggest that the rice cultivar possessing the good palatability in cooked rice revealed less deterioration of texture in cooled cooked rice. Accordingly, the retrogradation components of cooked rice such as DR or sponginess of cooled cooked rice and hardness-changed ratio of cooked rice by cooling might be correlated with some major physicochemical properties of rice grain related to the palatability of cooked rice. Choi et al.(1997) reported that hot and consistency viscosities of rice flour were associated with the palatability of cooked rice, and the cooking qualities such as volume expansion of boiled rice and solids amount extracted during cooking were correlated with the texture properties of cooked rice.

Horino(1990) suggested some associations between magnesium content or Mg/K ratio of milled rice and the stickiness of cooked rice. Matsuda et al.(1990) also pointed out that the high-quality rice Koshihikari showed slower cohesion of net-structured gelatinized starch granules in cooled cooked rice through SEM observation compared with the low-palatable rice.

In conclusion, there was relatively large varietal difference in retrogradation of aged cooked rice among low-amylose japonica rices. The good-palatable rice cultivars generally revealed slower retrogradation of cooled cooked rice as compared with the low-palatable ones, and some viscogram and cooking characteritics were significantly associated with the retrogradation of cooked rice.

REFERENCES

Cagampang, G. B., C. M. Perez and B. O. Juliano. 1973. A gel consistency test for eating quality of rice. J. Sci. Food Agric. 24: 1589-1594.

Choi, H. C., Y. H. Son and S. Y. Cho. 1993. Simplified procedure of amylose analysis by Rapid Flow Autoanalyzer RFA-300. Korean J. Crop Sci. 38(1): 66-71.

Choi, H. C., H. C. Hong and B. H. Nahm. 1997. Physicochemical and structural characteristics of grain associated with palatability in japonica rice. Korean J. Breed. 29(1): 15-27.

Hibi, Y., S. Kitamura, and T. Kuge. 1990. Effect of lipids on the retrogration of cooked rice. Cereal Chem. 67(1): 7-10.

Hizukuri, S., T. Toyama and Z. Nikuni. 1971. Estimation of gelatinization and retrogradation of starch by an amperometric titration and its application. Denbungoji 18(4): 16-21.

Hizukuri, S., K. Ito, I. Maeda, and Z. Nikuni. 1972. Temperature dependence of retrogradation of starch pastes. Denpun Kagaku 19(2): 70-75.

Horino, T. 1990. Mineral components of milled rice and eating quality of cooked rice. J. Japan. Crop Sci. 59(3) : 605-611.

Juliano, B. O. 1971. A simplified assay for milled-rice amylose. Cereal Sci. Today 16: 334-340.

Kainuma, K., A. Matsunaga, M. Itagawa, and S. Kobayashi. 1981. New enzyme system -beta-amylase-pullulanase- to determine the digree of gelatinization or retrogradation of starch or starch products. J. Japan. Soc. Starch Sci. 28: 235~240.

Little, R. R., G. B. Hilder and E. H. Dawson. 1958. Differential effect of dilute alkali on twenty five varieties of milled white rice. Cereal Chem. 35: 111-126.

Matsuda, T., M. Otomo and N. Chonan. 1990. Change in fine structure of cooked rice along with storing time after cooking. Agri. Resear. Reports of Ibaraki Univ. 38: 1-9.

Toyama, T., S. Hizukuri and Z. Nikuni. 1966. Estimation of the digree of gelatinization of starch by glucoamylase. Denbungoji 13 : 69-75.

Tsuge, H., M. Hishida, H. Iwasaki, S. Watanabe, and G.Goshima. 1990. Enzymatic evaluation for the degree of starch retrogradation in foods and food - stuffs. Starch/Stärke 42(6): 213-216.