

Physico-ecological Studies on Quality Formation of Rice Kernel

IV. Effect of storage on eating quality of rice*

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Abstract : We examined the effects of short and long-term storage on the eating quality of rice. The texture of cooked rice became harder and less sticky after being stored at higher temperatures and moisture contents for 90 days. The texture of rice stored under excessively dry conditions deteriorated only during the early stages of storage, and became better than rice stored under normal moisture conditions with prolonged storage. The eating quality of rice stored for 6 years was also analyzed. Most of the change in texture occurred during the first 1 to 2 years, and very little change was observed thereafter. Water-insoluble protein and amylose contents showed no significant changes. Fat-by-hydrolysis content, however, increased; this may be a contributing factor in the deterioration of cooked rice texture during storage. A reduction was also observed in the amount of glutamic acid in milled rice as well as a decrease in the ratio of glutamic acid both in milled rice and in the exterior of cooked rice. The pH in the cooking liquid also decreased. These seemed related to the deterioration of the taste of rice.

Key words : Eating quality, Fat-by-hydrolysis, Glutamic acid, Rice, Storage, Taste, Texture.

米の品質形成に関する生理・生態学的研究 第4報 貯蔵が米の食味に及ぼす影響: 玉置雅彦・田代 亨・石川雅士・江幡守衛 (名古屋大学農学部)

要 旨 : 短期および長期貯蔵が米の食味に及ぼす影響を調べた。米飯のテクスチャーは、90日間高温かつ高含水率で貯蔵すると硬く粘りが乏しくなった。過乾燥条件下で貯蔵した米のテクスチャーは貯蔵初期においてのみ劣り、通常の水分条件下で貯蔵した米よりも貯蔵にともない優れた。6年間貯蔵した米の食味も分析した。テクスチャーの変化の大部分は最初の1、2年以内に起こり、その後はほとんど変化しなかった。難溶性タンパク質およびアミロース含有率には有意な変化はなかった。しかし結合脂質含有率は増加した。この結合脂質の増加が、貯蔵中の米飯テクスチャーの低下と関係している要因かもしれない。白米と米飯付着のグルタミン酸の割合の減少と同様に、白米中のグルタミン酸含量も減少した。炊飯液中のpHも低下した。これらは米の味の低下と関係しているようであった。

キーワード : 味, グルタミン酸, 結合脂質, 米, 食味, 貯蔵, テクスチャー。

It is well known that eating quality of rice undergoes remarkable change during storage. Deterioration of eating quality is mainly related to the change in texture, flavor and taste, especially texture. Among the main chemical components of rice kernels, lipids decompose most quickly. Yasumatsu et al.¹⁹⁾ suggested that free fatty acids which are produced by hydrolysis of neutral fat during storage cause deterioration of rheological property of cooked rice.

Most reports on eating quality of rice are

focused on the short-term (within 1 year) storage and the storage form of brown or milled rice^{3,12,19)}. There are few studies on the long-term storage of rough rice. The study on long-term storage would reveal more clearly the nature of change in eating quality of rice.

Recently, with the spread of combine harvester in Japan, newly harvested paddy is dried at mechanical paddy drying centers called “Rice Center” or “Country Elevator”. At these facilities, there is the necessity for temporary storage of paddy dried to 18% moisture content. Several experiments have been undertaken on the preservability of semi-dried paddy in terms of apparent kernel quality^{4,7)} and cooking quality¹¹⁾ of milled rice. However, there are very few studies on eating quality.

For this reason, this study was conducted to determine the effects of the short-term storage

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under different storage temperatures and moisture contents on texture of cooked rice. And, to clarify the effects of the long-term storage on the eating quality of rice, the change during prolonged storage was investigated in terms of texture and chemical composition such as protein, amylose, fat-by-hydrolysis, fat acidity, pH and glutamic acid. Because we thought that protein, amylose, fat-by-hydrolysis and fat acidity were the properties which affected texture, and pH and glutamic acid were those which related to taste.

Materials and Methods

Exp. 1. Effects of the short-term storage under different temperatures and moisture contents on texture

Nonwaxy rice plant (*Oryza sativa* L.), cv. Sasanishiki, was used in Exp. 1. It was grown at the experimental field of Nagoya University in 1987. The moisture contents of rough rice were regulated at 12, 15 and 18% with forced-air drier and silica gel, put in 200 ml plastic vessels and sealed. After keeping at 5°C for a week, they were stored at 10°C, 20°C and 30°C. Samples were taken out at 0, 30, 60 and 90th days, dehusked, and milled with a small test mill (Kett Pālest) to a milling rate of 91%.

The texture of cooked rice was measured in a General Foods-Zenken GTX-2-1-N texturometer. Cooking method, measuring procedure and analysis of parameters of texture were the same as Ebata et al.⁶⁾

Exp. 2. Effects of the long-term storage on eating quality of rice

Rice plants in Exp. 2 consisted of 4 japonica nonwaxy, cvs. Koshihikari, Sasanishiki, Nipponbare and Akibare, 2 indica nonwaxy, cvs. Te-Tep and Bluebonnet, and 2 waxy, cvs. Koganemochi and Iwaimochi. They were grown at the experimental field of Nagoya University in 1981, 1984, 1985, 1986 and 1987 under the same cultural conditions. After harvesting, dried rough rice were stored in the crop shed under ambient temperatures for 0, 1, 2, 3 and 6 years. These samples were dehusked and milled to a milling rate of 91%.

Cooking method of japonica nonwaxy and waxy rice was as in Exp. 1. For indica nonwaxy rice, however, it was modified as follows; milled rice (10 g) was cooked with distilled water in the ratio of 1 : 2.5 in an aluminium

cup in a rice cooker for 7 min. Protein, amylose, fat-by-hydrolysis and glutamic acid both in milled rice and in the exterior of cooked rice were analyzed by the same methods as previous papers^{14,16)}. Fat acidity was measured by AACC method¹⁾. The measurement of pH in the cooking liquid was the same as Chikubu et al.²⁾ Protein and amylose contents, fat acidity, pH and glutamic acid values were shown as average values of two replications. The content of fat-by-hydrolysis was indicated by three replications.

Results

Exp. 1. Effects of the short-term storage under different temperatures and moisture contents on texture

Chewiness (Fig. 1), which shows hard characteristics of texture, was the highest at 12% at the beginning of storage, followed by 15% and 18%. It increased a little at 12% and 15%

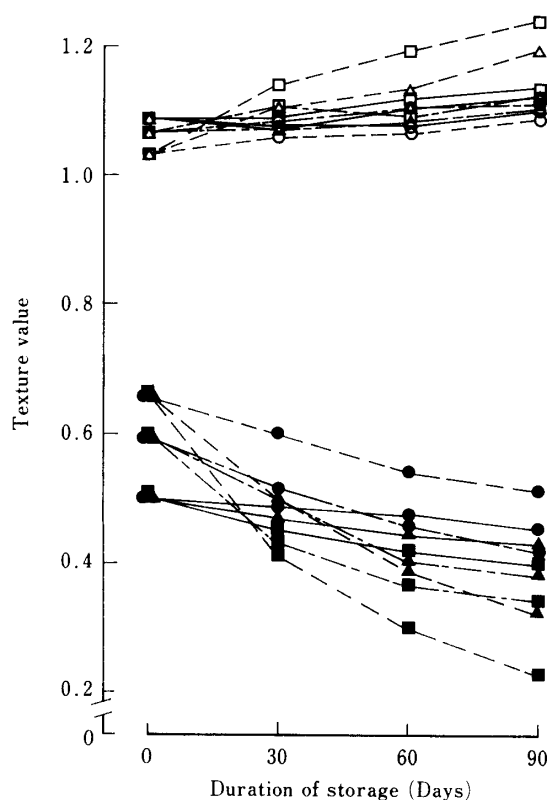


Fig. 1. Change in chewiness and stickiness under different storage temperature and moisture regimes (cultivar Sasanishiki). Moisture content; —: 12%, ---: 15%, ...: 18%. Temperature; ○, ●: 10°C, △, ▲: 20°C, □, ■: 30°C. ○, △, □: chewiness; ●, ▲, ■: stickiness.

despite storage temperatures. At 18%, the change was slight at 10°C, but remarkable at 20°C and more so at 30°C.

Stickiness (Fig. 1), which indicates sticky natures of texture, was the highest at 18% at the beginning of the experiment, followed by 15% and 12%. It decreased in higher temperatures and moisture contents, but the change was the least at 12%. There was only a little decrease at 10°C.

Ebata et al.⁶⁾ considered TPI (i.e. textural palatability index, which is the value multiplied chewiness by stickiness) as a suitable index for texture of japonica nonwaxy rice. TPI changed similarly to stickiness (Fig. 2). At the beginning of storage, the texture at 12% was less than that at 15% and 18%. However, the change in the former was the least even at high temperature. Initially, TPI was the highest at 18% but deteriorated rapidly. It was remarkable at higher temperature.

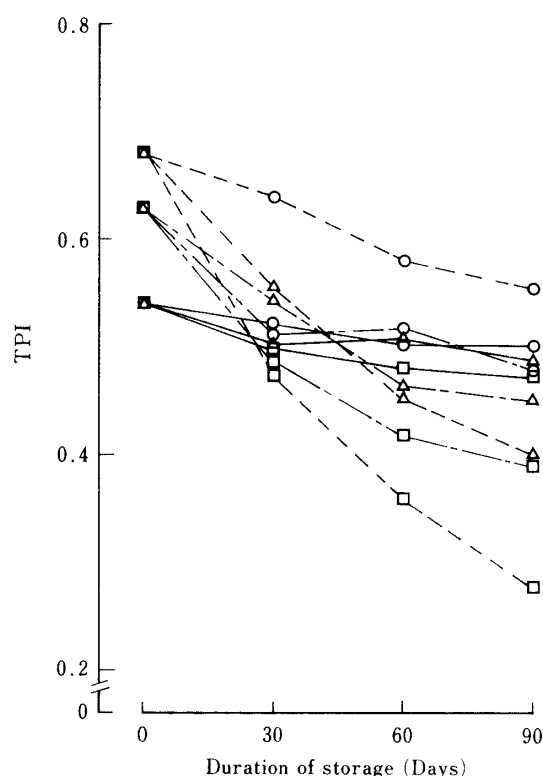


Fig. 2. Change in the textural palatability index (TPI) under different storage temperature and moisture regimes (cultivar Sasanishiki).

Moisture content ; — : 12%, - - - : 15%, ··· : 18%.

Temperature ; ○ : 10°C, △ : 20°C, □ : 30°C.

Exp. 2. Effects of the long-term storage on eating quality of rice

Chewiness consistently increased for all the nonwaxy cultivars, except for waxy rice (Fig. 3). On the other hand, both stickiness and TPI decreased (Figs. 3 and 4). TPI of waxy rice was not shown. Most of the change in texture occurred during the first 1 to 2 years, and very little change was observed thereafter. The texture of japonica nonwaxy rice deteriorated more than indica one. In japonica nonwaxy rice, the texture deterioration tended to be less in high eating quality cultivars (Koshihikari and Sasanishiki) than in standard eating quality cultivars (Nipponbare and Akibare) (Figs. 3 and 4).

Although data were not shown, water-insoluble protein and amylose contents remained almost unchanged.

Fat-by-hydrolysis content (Fig. 5) was the highest in indica nonwaxy rice, followed by

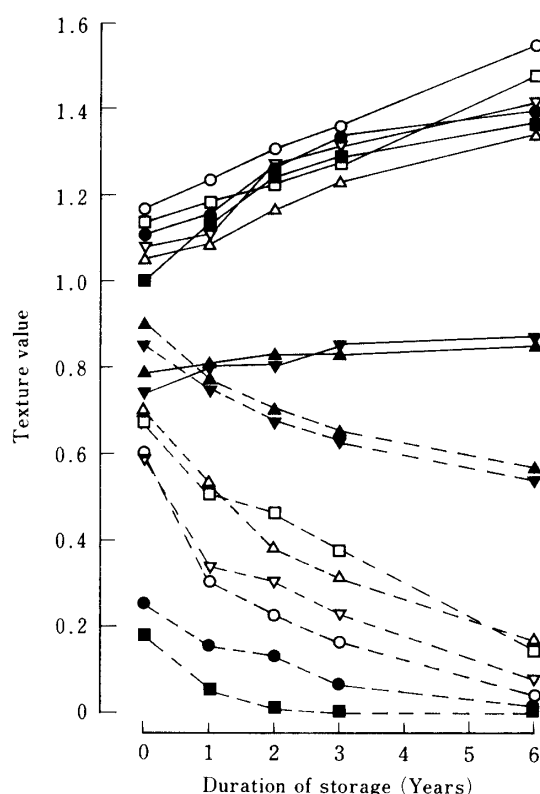


Fig. 3. Change in chewiness and stickiness with storage.

□ : Sasanishiki, △ : Koshihikari, ▽ : Nipponbare, ○ : Akibare, ■ : Te-Tep, ● : Bluebonnet, ▲ : Koganemochi, ▼ : Iwaimochi.

— : chewiness, - - - : stickiness.

japonica nonwaxy and waxy rice. Japonica nonwaxy rice, however, increased in the content more than indica nonwaxy rice. In waxy rice, the content was relatively constant.

Fat acidity is said to be a reliable index of deterioration in rice kernel because it significantly increases during the early stages of spoilage. In this experiment, fat acidity (Fig. 6) consistently increased. Japonica nonwaxy rice increased the most, followed by indica nonwaxy and waxy rice.

The pH (Fig. 7) in the cooking liquid

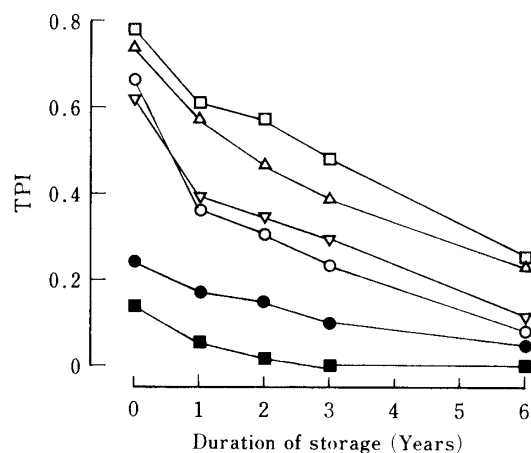


Fig. 4. Change in the textural palatability index (TPI) with storage. Symbols are the same as in Fig. 3.

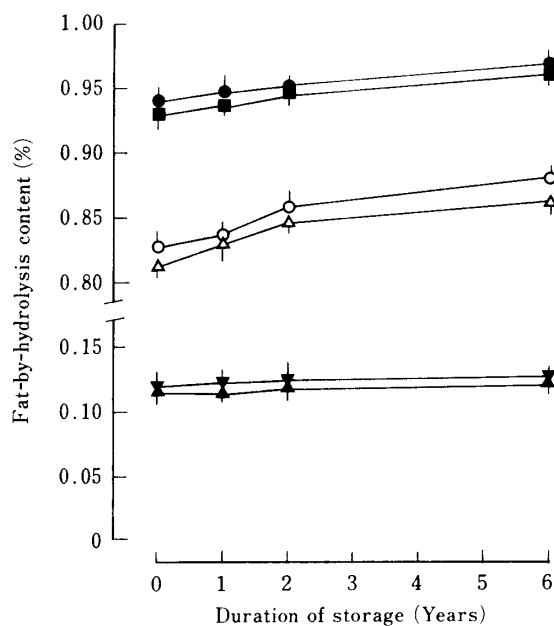


Fig. 5. Change in the fat-by-hydrolysis content with storage. The vertical bars represent $\pm$ SE of three replicates. Symbols are the same as in Fig. 3.

decreased. Japonica nonwaxy rice decreased the most, followed by waxy and indica nonwaxy rice.

The amount of glutamic acid in milled rice kernels decreased, especially during the first 1 year (Fig. 8). However, no remarkable change was found in the exterior of cooked rice kernels (Fig. 8). In high eating quality cultivars, the amount of glutamic acid tended to remain higher both in milled and in cooked rice. The ratio of glutamic acid content to total free amino acids content decreased both in milled and in cooked rice, particularly during the first 1 year (Fig. 9). No clear relationships were found between varieties on change in glutamic acid ratio in milled and in cooked rice.

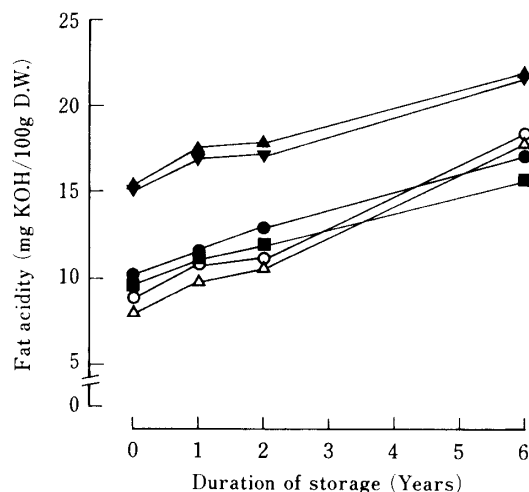


Fig. 6. Change in fat acidity with storage. Symbols are the same as in Fig. 3.

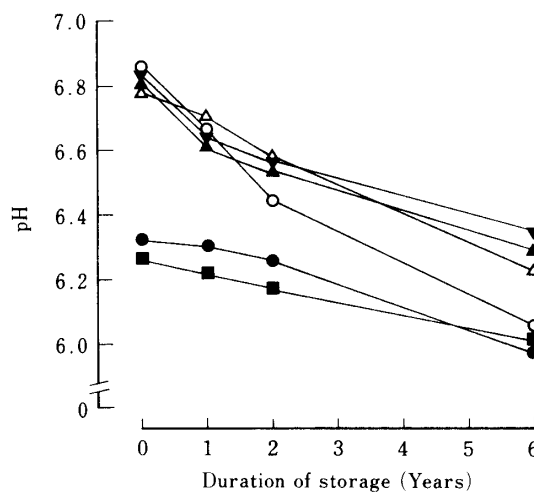


Fig. 7. Change in pH in cooking liquid with storage. Symbols are the same as in Fig. 3.

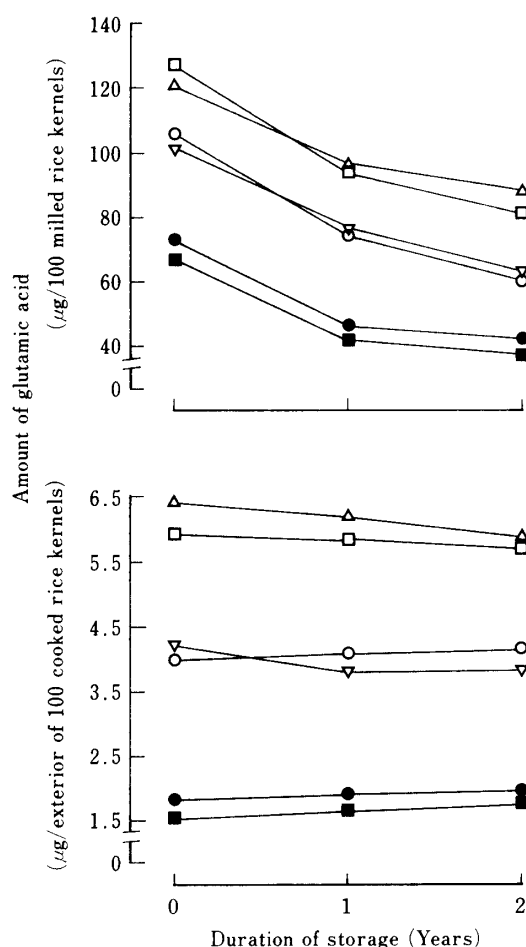


Fig. 8. Change in the amount of glutamic acid in 100 milled rice kernels and in the exterior of 100 cooked rice kernels with storage.

Upper ; milled rice, Lower ; cooked rice.
 Symbols are the same as in Fig. 3.

Discussion

The texture of cooked rice became harder and less sticky after being stored at higher temperatures and moisture contents. The deterioration of texture was very slight at 10°C, though it was remarkable at 30°C. Chikubu et al.³⁾ also suggested that brown rice stored at low temperature might keep its eating quality high for a long time, judging from cooking quality. The effects of storage temperatures on the texture were more obvious in higher moisture contents, but were very slight in rice stored under excessively dry conditions.

It was suggested that the texture might be deteriorated even during the drying process of paddy after harvest. Excessive-drying seemed to make the texture worse. On the contrary,

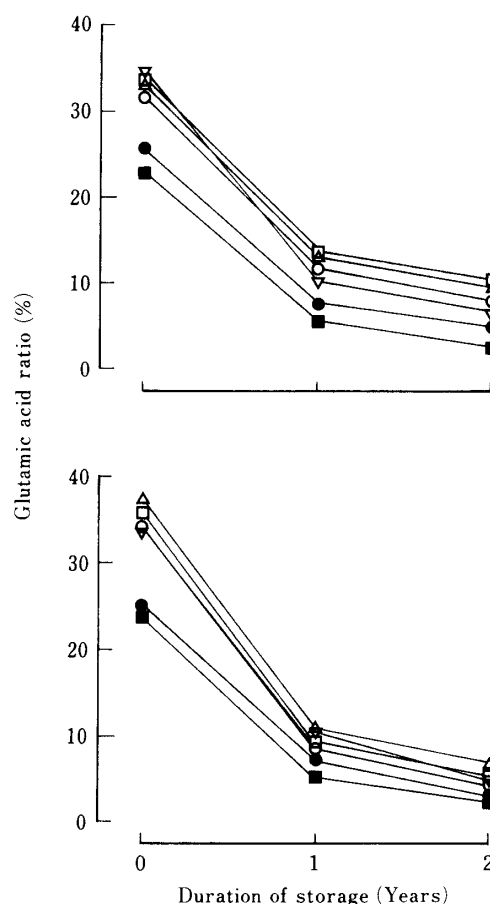


Fig. 9. Change in the ratio of the amount of glutamic acid to total free amino acids in 100 milled rice kernels and in the exterior of 100 cooked rice kernels with storage. Upper ; milled rice, Lower ; cooked rice. Symbols are the same as in Fig. 3.

the texture of rice stored under excessively moisture conditions was better. This may be related to the decrease in the swelling quality during the drying process. However, the texture of rice stored under excessively moisture conditions became almost the same as rice stored under normal moisture (15% moisture content) and excessively dry conditions after 30 days of storage at 20°C and 30°C. Ishikura and Masuo⁷⁾ indicated that rice of 18% moisture content could be preserved only 30 days without any deterioration in the apparent kernel quality. Our experiment on texture could ascertain their findings.

The texture of rice stored under excessively dry conditions was hard and not sticky at the beginning of storage and did not change so much even after 90 days. This implies that the texture of rice stored under excessively dry

conditions deteriorated only during the early stages of storage and became better than rice stored under normal moisture conditions with prolonged storage. Rice stored under excessively dry conditions is very prone to kernel cracking. If this could be overcome, excessive drying would be worthy of note in long-term storage.

Ebata and Ishikawa⁵⁾ reported that cooking quality changed during the first 1 to 2 years of storage. In this experiment, the texture also changed remarkably within the first 1 to 2 years during long-term storage. From these results, it was suggested that both cooking quality and texture deteriorated especially during the first 2 years of storage.

In waxy rice, chewiness was almost unchanged, although stickiness remarkably decreased. The texture deterioration in waxy rice was found to be mainly caused by the deterioration of its sticky property, but not so much by the hard one. From the change in textural properties, storability of waxy rice seemed to be better than nonwaxy rice. Yanase et al.¹⁸⁾, however, reported that the preservability of waxy rice was less than nonwaxy rice, based on the decrease of viability of the embryo and the increase of fat acidity. Ebata and Ishikawa⁵⁾ also showed that the long-term storability of waxy rice was less than nonwaxy rice judging from cooking quality. Therefore, more detailed study is needed on eating quality such as texture for the preservability of waxy rice.

In the previous papers^{14,15)}, we admitted that the texture was closely related to the contents of water-insoluble protein, amylose and fat-by-hydrolysis. However, in this experiment water-insoluble protein and amylose contents showed no significant change. Hence, deterioration of the texture during storage seemed difficult to be explained by the change in water-insoluble protein and/or amylose contents. Fat-by-hydrolysis content, however, increased with storage. This may suggest a contributing factor in the deterioration of texture, particularly of the hard features. Texture deterioration of indica nonwaxy rice was less than japonica nonwaxy rice. This may be related to the small change in fat-by-hydrolysis content in the former. Maniñgat and Juliano⁹⁾ reported that the content of starch lipids was the lowest for waxy rice and the

highest for intermediate-amylose rice. Moreover, starch lipids content of the low-amylose rice was between that of waxy and intermediate-amylose rice. Japonica and indica rice in this study belonged to low and intermediate-amylose rice, respectively⁹⁾. Our experiment ascertained results of Maniñgat and Juliano⁹⁾. Higher amylose content of indica rice has been considered to be the cause of its harder and less sticky texture⁸⁾. Besides amylose, fat-by-hydrolysis content should also be noted. Fat-by-hydrolysis content in waxy rice remained nearly unchanged during storage. This was suggested to be related to small change in hard texture of waxy cooked rice.

Increase in fat acidity is caused by the decomposition of fatty substances, and thought to be correlated with both the increase in fat-by-hydrolysis content and the decrease of pH in the cooking liquid. Yasumatsu et al.¹⁹⁾ suggested that free fatty acids increase during storage and bind with amylose in starch, and the increase in fatty acid-amylose complex may affect maximum viscosity of amylogram. Therefore, a certain extent of free fatty acid increased during storage are considered to be binded with amylose and amylopectin in starch, and affect the texture. Remaining part is thought to cause the decrease in pH in the cooking liquid. Fat acidity in waxy rice was about 1.5 to 2-fold greater than that in nonwaxy rice at the beginning of storage. Villareal et al.¹⁷⁾ suggested that higher amount of free fatty acid in waxy rice might be correlated with its lower amount of amylose which could be binded with fatty acids. Change in fat acidity was the least in waxy rice. This may be related with the small change in fat-by-hydrolysis content.

The decrease in pH in the cooking liquid seemed to be related to the deterioration of the taste of cooked rice. It has been said that glutamic acid is an important taste substance of rice. Recently, Saikusa et al.¹³⁾ reported that glutamic acid content in the exterior of milled rice kernels was above the threshold value. In a previous paper¹⁶⁾, we clarified that high eating quality cultivars contained higher amount of glutamic acid, particularly in the exterior of cooked rice. Matsuzaki et al.¹⁰⁾ also suggested that high eating quality cultivars had a higher rate of glutamic acid. Therefore, the decrease in the amount of glutamic acid

and its ratio may also be correlated with the deterioration of the taste. In our previous paper¹⁶⁾, we showed that the easiness of dissolving out the “umami” taste substance was closely related to the sticky texture through the easy dissolving out of solids from cooked rice. In this study, stickiness of texture decreased during storage. However, the amount of glutamic acid in the exterior of cooked rice did not show remarkable change. Long-stored rice expands more during cooking and increases in its surface area as compared to newly harvested rice. The resulting old cooked rice may easily dissolve out its glutamic acid.

Indica nonwaxy rice showed less change in texture, fat acidity and pH than japonica nonwaxy rice. This suggests that indica rice may have better storability than japonica rice.

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