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Determination of Shelf Life of Milled Rice Stored at Different Temperatures

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Abstract. *An experiment on milled rice storage was conducted to investigate storage properties and determine "best before" date. Conventional milled rice and rinse-free rice were stored in incubators controlled at temperatures from -20°C to 25°C for one year. Physicochemical properties such as free fat acidity, appearance of cooked rice, hardness and stickiness of cooked rice were examined. Sensory tests were also carried out to assess eating quality. There was very little quality deterioration of rice stored at low temperature. The higher the temperature was, the greater quality degradation was. Best before date of milled rice at each storage temperature was shown by eating quality assessed by a sensory test, which was considered the most important measurement item to determine best before date. In this study, best before dates of conventional milled rice stored at 25°C, 15°C and 5°C and less were one month, five months and seven months, respectively. Those of rinse-free rice stored at 25°C and 15°C and less were one month and seven months, respectively.*

Keywords. milled rice, rinse-free rice, free fat acidity, physicochemical properties, eating quality, low temperature

Introduction

Shelf life of food is the “best before” date that the food remains fresh and of good quality. In Japan, best before date or both best before date and processed date must be indicated. However, in the case of milled rice, only milled date needs to be indicated.

There are some reports on the storage of rice (Yasumatsu et al., 1965; Shibuya et al., 1974; Shimada, 1986; Hokkaido Prefectural Agricultural Experiment Stations, 1990; Toyoshima et al., 1998). Studies on milled rice storage conducted 30-40 years ago in Japan showed that there was deterioration in eating quality at one month after milling. The period before deterioration in eating quality should be longer now due to the recent development of a milling technique by which bran is completely removed and the development of new value-added rice (rinse-free rice) of which bran residues are removed by polishing the surface of milled rice. However, there has been no storage experiment using commercial milled rice by the recent milling technique. An experiment on milled rice storage was therefore carried out to investigate storage properties and determine best before date.

Materials and Methods

Rice Samples and Storage conditions

The rice used in this study was "Kirara397" and "Akitakomachi" harvested in 2004. Kirara397 and Akitakomachi are Japanese popular short-grain and non-waxy varieties.

Conventional milled rice was processed from each brown rice by using commercial vertical-type milling systems (models NCP-100B and NCP-150B, Satake Engineering, Tokyo, Japan) in a large-scale milling factory. Milling yield of each conventional milled rice was 90.9%. Rinse-free rice was processed from each conventional milled rice by polishing the surfaces of conventional milled rice grains using bran granules. Milling yields of rinse-free rice were 89.3% for Kirara397 and 90.1% for Akitakomachi. The conventional milled rice and rinse-free rice used in this study were commercial products.

Rice samples (about 80 − 150 kg) in polyethylene bags were stored in incubators controlled at -20°C, -5°C, 5°C, 15°C or 25°C for one year.

Quality Assessment

The following quality characteristics of milled rice samples were periodically measured.

Free fat acidity was determined by the rapid method of the American Association of Cereal Chemists (AACC): free fat acid was extracted from ground milled rice in a benzene solution, and the extracted solution was then titrated with potassium hydroxide solution.

Cooked rice appearance was measured by using a measurement system developed at Hokkaido Central Agricultural Experiment Station (Yanagihara, 2000). A total of 24 rice samples (15 g each) with water (22.5 g each) in stainless-steel Petri dishes (75 mm in diameter, 18 mm in depth) were cooked in an autoclave. Digital images of the surface of cooked rice samples (4.3 cm×4.5 cm=19.35 cm^2 in area and 114175 pixels) were taken using a CCD camera and fed into a computer. The measurement items were average of brightness of cooked rice surface, luster area and luster strength. Brightness of cooked rice surface was measured in 256 steps in each pixel. The average of brightness means whiteness of cooked rice. The luster area, which is the number of pixels of more than 170 in brightness, means extent of luster of cooked rice. The luster strength, which is the average of brightness in the luster area, means degree of luster of cooked rice.

The hardness and stickiness of cooked rice were measured by using a rheo meter (model NRM-2000J, Fudo Giken Industry Co., Tokyo, Japan).

Sensory tests were carried out according to the Japanese official rice taste testing method standardized by the Japan Food Agency. About 40 panelists were selected with gender and age balance. The sensory test was a multiple comparison test. The reference sample in each test was cooked conventional milled rice that had been stored in an incubator controlled at -20°C. It was considered that the quality of milled rice stored at -20°C was the same as that at the beginning of storage. Panelists were asked to compare three samples with the reference sample on the basis of six sensory determinations: the appearance of milled rice and the appearance, aroma, hardness, cohesiveness and overall flavor of cooked rice. The directions of difference (+ or -) between the reference sample and the three compared samples in overall flavor, for instance, were "good" and "bad", and the degrees of difference were "no difference", "very slight difference", "slight difference", "moderate difference", "large difference" and "very large difference". Numerical scores were assigned to the directions and degrees, with "much better than the reference" being +5, "no difference to the reference" being zero, and "much worse than the reference" being -5. The reference sample was always scored zero. For appearance, aroma and overall flavor, the values ranged from +5 to -5, and for hardness and cohesiveness, the values ranged from +3 to -3 on a discrete scale.

Results and Discussion

Free Fat Acidity

Radical free fat acidity combined with starch interferes with the swelling of rice. Cooked rice with high free fat acidity therefore becomes hard and less sticky. Oxygen in the air oxidizes fat and radical free fat acidity to a carbonyl compound, causing rancidity and interfering with starch swelling by reaction with protein. The increase in free fat acidity therefore causes deterioration of the quality of rice during storage.

Fig. 1 and Fig. 2 show the changes in free fat acidity of conventional milled rice and rinse-free rice (Kirara397). Free fat acidity of rinse-free rice was lower than that of conventional milled rice at the beginning of storage because rinse-free rice whose bran residues had been removed by polishing the surfaces of milled rice grains. Free fat acidity of rice stored at 5°C increased slightly. The increase in the free fat acidity of rice stored at 25°C was the largest and that of rice stored at 15°C was the second-largest. However, the free fat acidity of rice stored at -20°C and that of rice stored at -5°C were almost the same as that of rice at the beginning of storage. The rate of increase in free fat acidity of rinse-free rice was less than that of conventional milled rice.

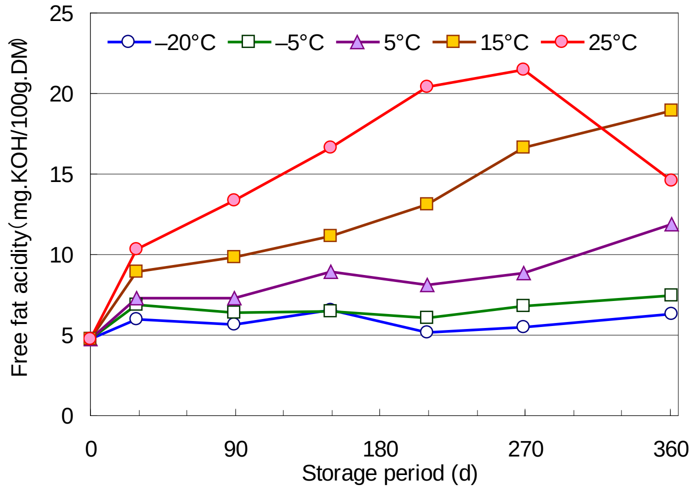

Figure 1. Changes in free fat acidity of conventional milled rice stored at five different temperatures (Kirara397).

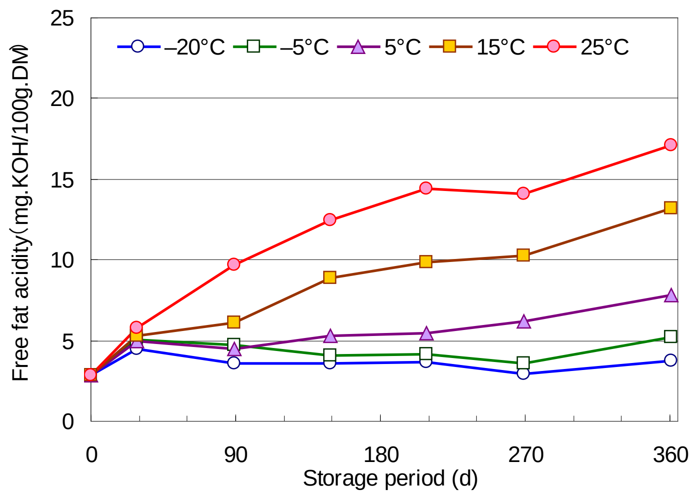

Figure 2. Changes in free fat acidity of rinse-free rice stored at five different temperatures (Kirara397).

Cooked Rice Appearance

Generally, cooked appearance correlates with eating quality (Fujimaki, 1975). Fig. 3 and Fig. 4 show the changes in luster area of Kirara397 and Akitakomachi (rinse-free rice). Fig. 5 and Fig. 6 show the changes in luster strength of Kirara397 and Akitakomachi (rinse-free rice). The luster area of Kirara397 and Akitakomachi stored at 25°C decreased after five months of storage. The luster area of rice stored at temperatures less than 15°C was almost the same as that of rice at the beginning of storage. The change in luster strength was the same as that in luster area. Fig. 7 and Fig. 8 show the changes in average of brightness of Kirara397 and Akitakomachi (rinse-free rice). The average of brightness of Kirara397 stored at all temperatures was almost the same as that of rice at the beginning of storage. The average of brightness of Akitakomachi stored at 25°C dramatically decreased after seven months of storage. The changes in the average of brightness were slight during storage for one year. On the other hand, the changes in luster area were large compared to those of brightness. Accordingly, the luster of cooked rice can be used as a sensitive indicator of cooked rice appearance during storage.

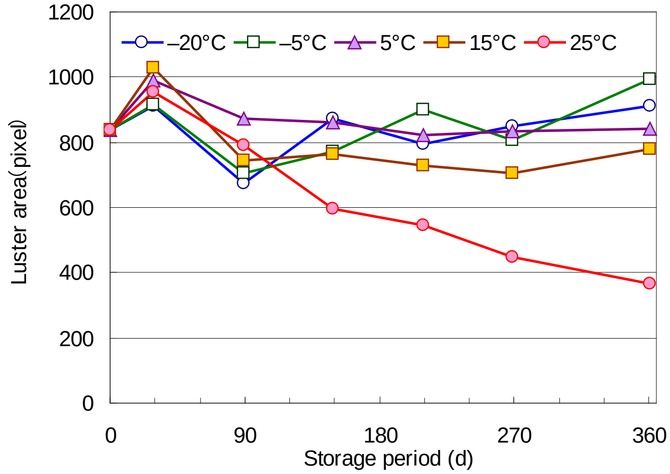

Figure 3. Changes in luster area of cooked rinse-free rice stored at five different temperatures (Kirara397).

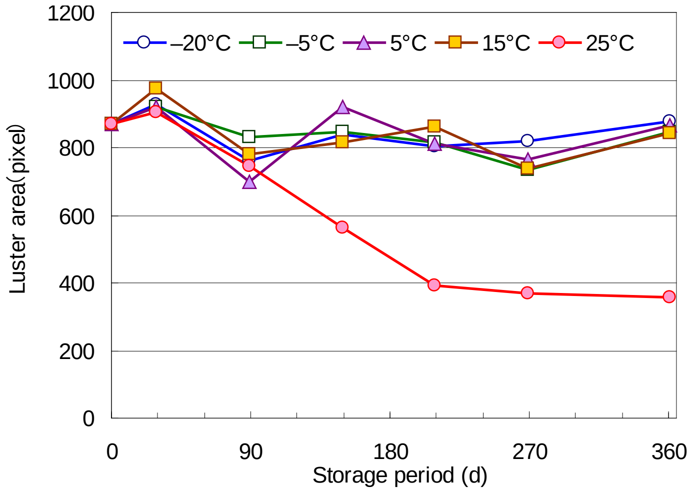

Figure 4. Changes in luster area of cooked rinse-free rice stored at five different temperatures (Akitakomachi).

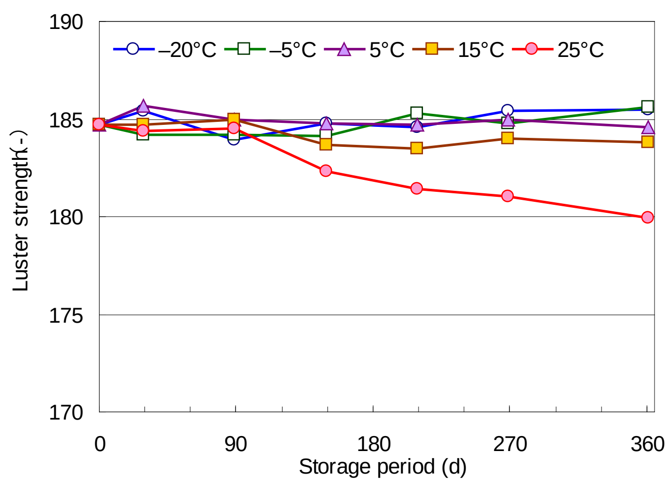

Figure 5. Changes in luster brightness of cooked rinse-free rice stored at five different temperatures (Kirara397).

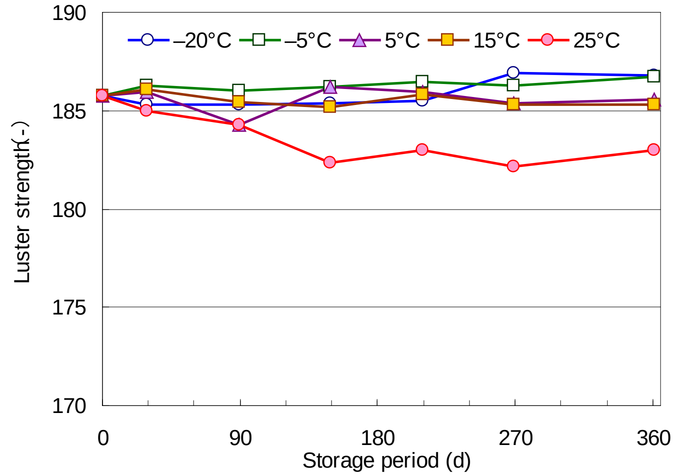

Figure 6. Changes in luster strength of rinse-free rice stored at five different temperatures (Akitakomachi).

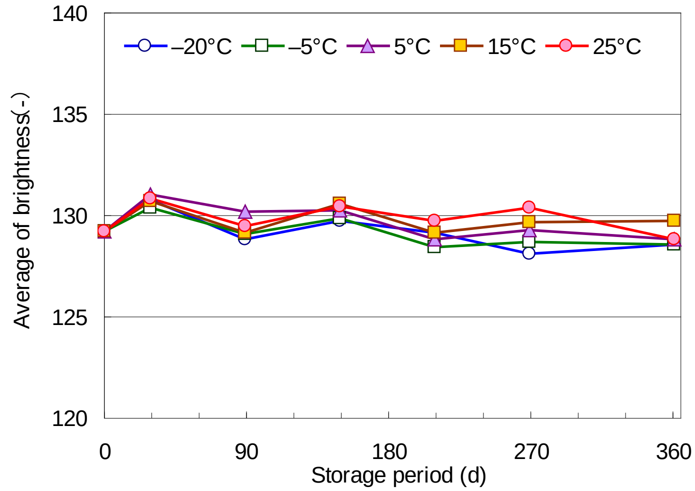

Figure 7. Changes in average of brightness of cooked rinse-free rice stored at five different temperatures (Kirara397)

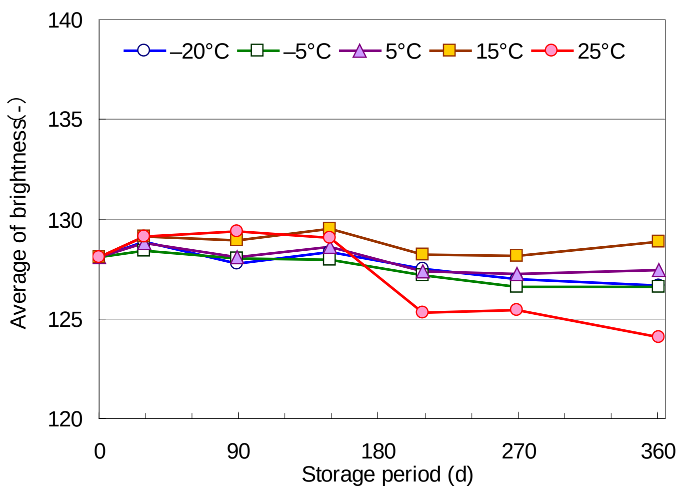

Figure 8. Changes in average of brightness of cooked conventional milled rice stored at five different temperatures (Akitakomachi).

Hardness and Stickiness of Cooked Rice

Generally the hardness of cooked rice increases and the stickiness of cooked rice decreases after storage. Fig. 9 and Fig. 10 show the changes in hardness of conventional milled rice of Kirara397 and that of Akitakomachi. Fig. 11 and Fig. 12 show the changes in stickiness of conventional milled rice of Kirara397 and that of Akitakomachi. Fig. 13 and Fig. 14 show the changes in hardness-stickiness ratio, which is hardness divided by stickiness, of conventional milled rice of Kirara397 and that of Akitakomachi.

The hardness of Akitakomachi stored at 25°C had increased at three months of storage and had decreased at nine months of storage, while that of Kirara397 stored at 25°C had increased at nine months of storage and had decreased at one year of storage. The growth of mold on rice samples stored at 25°C might the reason for the decrease in hardness. The stickiness of cooked rice of Akitakomachi and Kirara397 stored at 25°C had decreased at seven months of storage. The rate of decrease of Akitakomachi was greater than that of Kirara397. The hardness-stickiness ratios of Akitakomachi and Kirara397 stored at 25°C had increased at 7-months of storage.

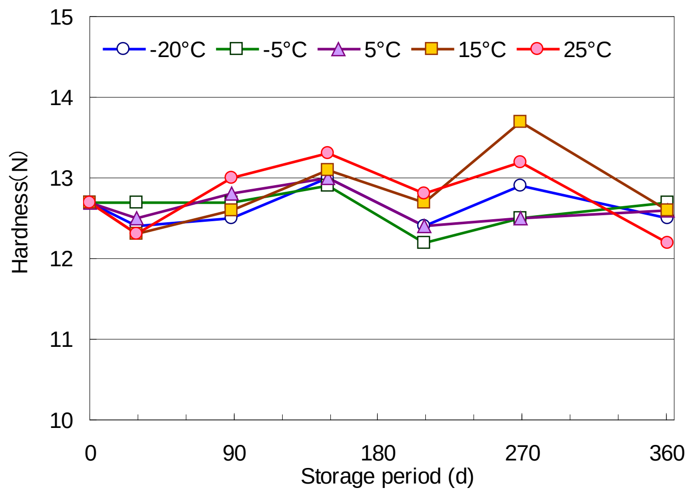

Figure 9. Changes in hardness of conventional milled rice stored at five different temperatures (Kirara397).

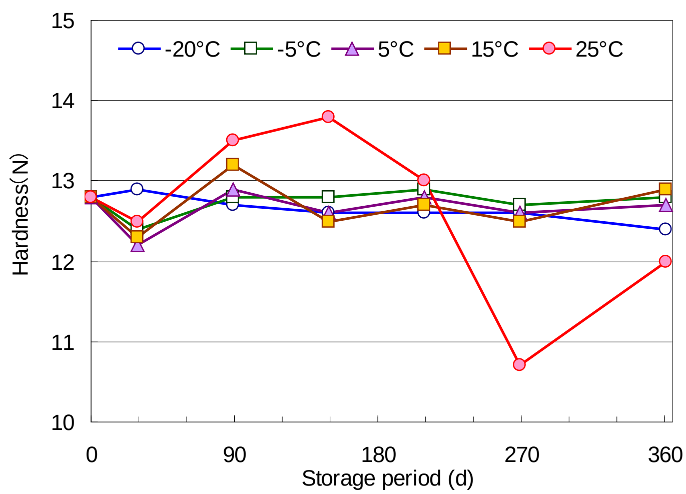

Figure 10. Changes in hardness of conventional milled rice stored at five different temperatures (Akitakomachi).

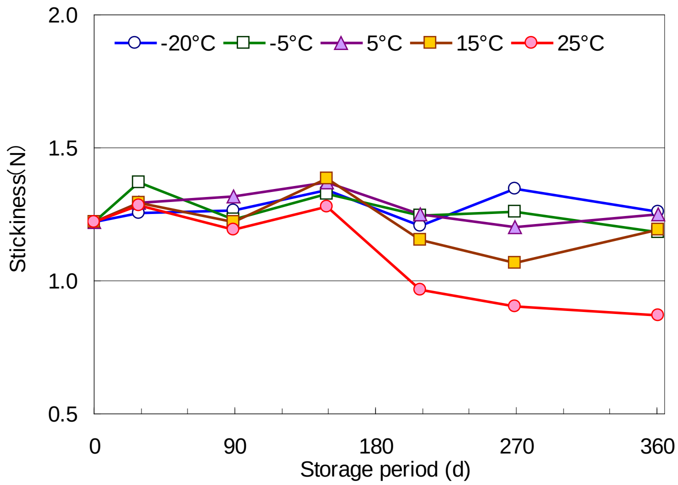

Figure 11. Changes in stickiness of cooked conventional milled rice stored at five different temperatures (KIrara397).

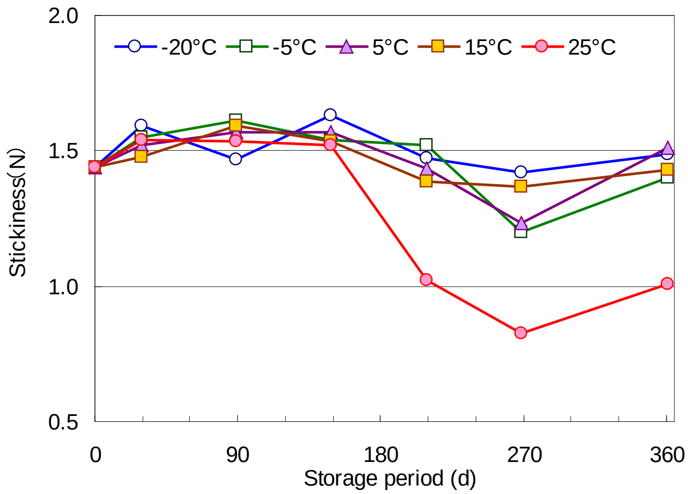

Figure 12. Changes in stickiness of cooked conventional milled rice stored at five different temperatures (Akitakomachi).

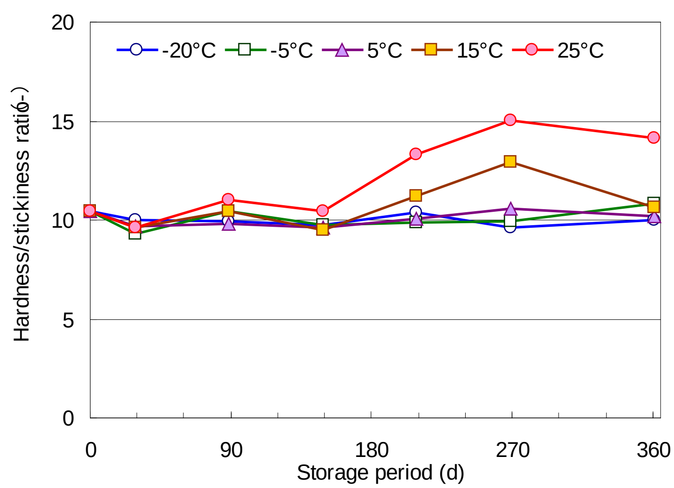

Figure 13. Changes in hardness-stickiness ratio of cooked conventional milled rice stored at five different temperatures (Kirara397).

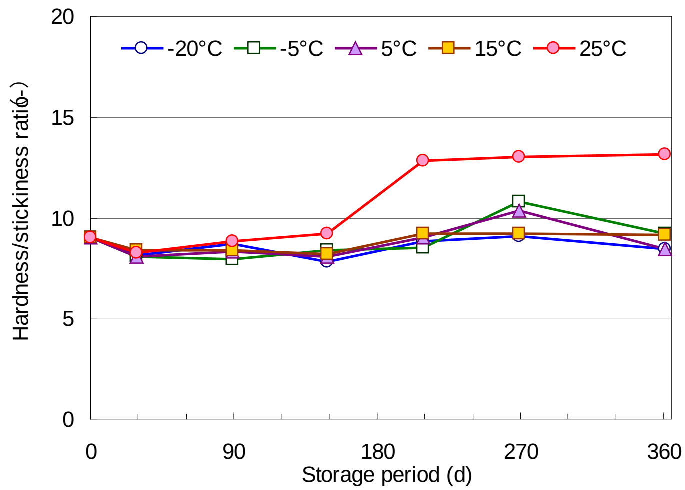

Figure 14. Changes in hardness-stickiness ratio of cooked conventional milled rice stored at five different temperatures (Akitakomachi).

Sensory Evaluation

It has been found that the eating quality of cooked rinse-free rice without rinsing was the same as that of cooked conventional milled rice with rinsing (Yokoe, 2005).

Table1 shows the changes in eating quality of cooked rice.

There was no deterioration in eating quality of conventional milled rice and rinse-free rice stored for one month at any temperature, indicating that eating quality of cooked rice does not decrease until more than one month of storage even if the storage temperature of rice is comparatively high. After three months of storage, the eating quality of conventional milled rice and rinse-free rice of Akitakomachi stored at 25°C were worse than that of the reference sample. After seven months storage, the eating quality of conventional milled rice of Akitakomachi stored at 15°C had deteriorated. The eating quality of rinse-free rice of Akitakomachi stored at 15°C had deteriorated after nine months of storage. The eating quality of conventional milled rice and rinse-free rice of Akitakomachi stored at 5°C and 15°C also had deteriorated after nine months of storage.

There was a difference between the levels of deterioration in eating quality of Kirara397 and Akitakomachi at each storage temperature. The quality of rice at the beginning of storage has an effect on storage properties. The deterioration in the quality of Akitakomachi was greater than that of Kirara397 because the quality of Akitakomachi was worse than that of Kirara397 at the beginning of storage.

Table 1. Changes in eating quality (overall flavor) of cooked rice.

Samples		Storage temperature (°C)	Storage period (months)						
			0	1	3	5	7	9	12
Kirara397	Conventional milled rice	-5	0.17	-0.05	0.05	-0.32	-0.03	0.03	†1
		5		0.00	-0.39	-0.05	-0.18	-0.30	-0.17
		15		-0.05	0.07	-0.30	0.05	-0.27	-0.27
		25		0.14	-0.17	-0.49	-0.24	-0.58 *	†1
	Rinse-free rice	15	†1	-0.20	-0.17	-0.41	-0.29	-0.21	-0.54 **
		25		-0.11	-0.44	-0.49	-0.50 *	-1.21 **	†1
Akitakomachi	Conventional milled rice	-5	0.02	-0.20	0.05	-0.38	-0.47	-0.56 *	†1
		5		-0.12	-0.21	-0.54	-0.33	-0.61 **	-0.63 **
		15		-0.05	-0.28	-0.22	-0.53 *	-0.67 **	-0.76 **
		25		-0.02	-0.62 *	-1.30 **	-2.05 **	-2.64 **	†1
	Rinse-free rice	15	†1	-0.15	-0.10	-0.32	-0.16	-0.61 **	-0.68 **
		25		-0.22	-0.62 *	-0.59 *	-1.33 **	-2.31 **	†1

†1:No measurement

Double asterisks (**) and a single asterisk (*) on the right side of evaluation values indicate that each value is statistically significant at less than 1% or 5% of the critical rate, respectively, compared to the reference sample. The evaluation value of the reference sample ia always zero.

Determination of Shelf Life of Milled Rice

Physicochemical properties, such as free fat acidity, cooked rice appearance, hardness and stickiness, changed during storage. Each physicochemical measurement can be an indicator of quality deterioration, but the quality of rice can not be determined only by them. There was little difference between the sensitivity of physicochemical measurements and that of the sensory test when storage temperature was 25°C, at which the deterioration was great. However, the sensory test was more sensitive than physicochemical measurements when storage temperatures were less than 15°C, at which there was little deterioration. The sensory test is therefore considered the most sensitive means for determining the best before date of milled rice. There was no deterioration in eating quality of conventional milled rice and rinse-free rice stored for one month at any temperature. When storage temperature of rice was 25°C, eating quality of conventional milled rice and rinse-free rice of Akitakomachi had deteriorated at three months of storage. Therefore, it is thought that the best before date of conventional milled rice and rinse-free rice stored at 25°C was one month in this study. When storage temperature of rice was 15°C, eating quality of conventional milled rice of Akitakomachi had deteriorated at seven months storage and that of rinse-free rice of Akitakomachi had deteriorated at nine months of storage. Therefore, it is thought that the best before date of conventional milled rice stored at 15°C was five months and that of rinse-free rice stored at 15°C was seven months in this study. At nine months of storage, eating quality of all samples of Akitakomachi variety had deteriorated. Therefore, it is thought that the best before date of milled rice stored at 5°C and -5°C was seven months in this study.

Conclusion

An experiment on milled rice storage was conducted to investigate storage properties and determine best before date of milled rice. There was very little quality deterioration of rice stored at low temperatures. The higher the temperature was, the greater quality deterioration was. A sensory test is considered to be the best means for determining best before date of milled rice because sensory tests were found to be more sensitive than physicochemical measurements. In this study, best before dates of conventional milled rice stored at 25°C, 15°C and 5°C and less were one month, five months and seven months, respectively. Those of rinse-free rice stored at 25°C and 15°C and less were one month and seven months, respectively.

References

Toyoshima, H., Kimura, T., Yoshizaki, S., Fujii, S., Okadome, H., Tsukane, Y., Moruta, M., Tazima, Y., Ohtsubo, K (1998). Changes in Qualities of High-palatability Rice Grains during Storage. Journal of the Japanese Society for Food Science and Technology, 44(11), 683-691.

Shimada, K (1986). Effects of Storage Humidity on Deterioration of Rice. Journal of Domestic Science, 37(7), 579-583.

Yasumatsu, K., Moritaka, S., Ishii, K., Shimazono, H., Fujita, E (1965). Studies on Cereals (I). Journal of Nutrition and Food, 18(2), 123-129.

Hokkaido Prefectural Agricultural Experiment Stations (1990). Experiment on Storage Methods of Hokkaido Rice. Report of Hokkaido Prefectural Agricultural Experiment Stations, 1-30.

Shibuya, N., Iwasaki, T., Yanase, H., Chikubu, S (1974). Studies on Deterioration of Rice during Storage. Journal of the Japanese Society for Food and Technology, 44(11), 683-691.

Fujimaki, H., Kushibuchi, K (2003). The ability of selection of taste with the luster of cooked rice (in Japanese). Agricultural and horticulture, 50(2), 253-257.

Yanagihara, T (2000). Measurement of the visual characteristics of cooked rice using image analysis. Journal of the Japanese Society for Food Science and Technology, 47, 516-522

Yokoe, M., Kawamura, S., Himoto, J., Itoh, K (2005). Quality Characteristics and Storage Properties of Rinse-Free Rice (Part 1). Journal of Japanese Society of Agricultural Machinery, 67(4), 113-120.