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Quality Characteristics and Storage Properties of New Value-Added Rice (Rinse-Free Rice: Musenmai)

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Abstract. *Rinse-free rice, which can be cooked without rinsing, has recently become popular in Japan. In this study, we investigated quality characteristics and storage properties of two kinds of rinse-free rice processed by two different methods and those of conventional milled rice. Cooked rinse-free rice without rinsing had the same eating quality as that of cooked conventional milled rice with rinsing. Sensory tests performed after 4 months of storage at 25 °C showed that the eating quality of rinse-free rice with rinsing was better than that of rinse-free rice without rinsing.*

Keywords. bran granules, tapioca-starch granules, whiteness, percentage of bran remains, free fat acidity, viable aerobes count, turbidity of rinsed water, solids in rinsed water, eating quality.

Introduction

A new value-added rice called "Musenmai" in Japanese has recently become popular in Japan. Musenmai is rinse-free rice, rice that can be cooked without rinsing. The amount of rinse-free rice consumed in Japan in 2003 was estimated to be about 800,000 t. In the processing of rinse-free rice, bran residues are removed by polishing the surfaces of milled rice grains. There are several of methods for processing rinse-free rice.

Katsuragi (2003) classified the methods for processing rinse-free rice into three categories: a wet polishing method, a dry polishing method and a unique polishing method using supplements such as bran granules or tapioca-starch granules. We speculated that there are differences between the quality characteristics of rinse-free rice and those of conventional milled rice since the methods used for processing of rinse-free rice are different from that used for conventional milled rice. There are some reports on the quality characteristics and storage properties of rinse-free rice (Itoh, 1980; Fukai et al., 1997; Watanabe et al., 1999; Kainuma et al., 2003; Shoji and Kato, 2003). However, the differences between quality characteristics of rinse-free rice and those of conventional milled rice have not been clarified. In this study, we investigated the quality characteristics and storage properties of two kinds of rinse-free rice processed by two different methods and those of conventional milled rice.

Materials and Methods

Rice Samples

Japanese popular short-grain and non-waxy varieties of brown rice, "Hoshinoyume", "Akitakomachi" and "Koshihikari", were used in this study.

Conventional milled rice was processed from each brown rice sample (6 t of Hoshinoyume, 6 t of Akitakomachi and 1.5 t of Koshihikari) by using commercial vertical-type milling systems (models NCP-100B and NCP-150B, Satake Engineering, Tokyo, Japan) in a large-scale milling factory. Milling yields of conventional milled rice were 91.1% for Hoshinoyume, 89.0% for Akitakomachi and 89.3% for Koshihikari. Two kinds of rinse-free rice samples were processed from each conventional milled rice. One (rinse-free rice A) was processed by polishing the surfaces of conventional milled rice grains using bran granules. Milling yields of rinse-free rice A were 90.0% for Hoshinoyume, 88.1% for Akitakomachi and 88.1% for Koshihikari. The other sample (rinse-free rice B) was processed by polishing the surfaces of conventional milled rice grains using tapioca-starch granules. Milling yields of rinse-free rice B were 88.8% for Hoshinoyume, 87.2% for Akitakomachi, and 87.0% for Koshihikari.

Storage Experiment

Rice samples (about 6 − 10 kg) in polyethylene bags were stored in incubators controlled at 5°C, 15°C or 25°C for 4 months.

Quality Assessment

The following quality characteristics of rice samples were determined before storage.

Moisture content was determined by the JSAM (Japanese Society of Agricultural Machinery) standard method; about 10 g of whole grain rice was placed in a forced-air oven at 135°C for 24 h and moisture was computed on a wet basis. Fluidity was determined by dividing rice sample weight (150 g) by the time for the sample to fall through from a stainless-steel corn hopper. Bulk weight, whiteness, color, translucency, and protein content were measured by using a Brauer grain tester (Kiya Engineering, Tokyo, Japan), a whiteness meter (model C-100, Kett Electric Laboratory, Tokyo, Japan), a color difference meter (model CR-200b, Minolta Camera, Osaka, Japan), a rice segregator (model RS-2000x, Shizuoka Engineering, Shizuoka, Japan) and a near-infrared instrument (model Infratec 1241 Grain Analyzer, Foss Tecator, AB, Höganäs, Sweden), respectively. The 1000-kernel weight was determined by measuring the weight of 1000 kernels excluding broken kernels. Degree of bran removal was determined by dividing the 1000-kernel weight of milled rice by the 1000-kernel weight of brown rice and converting moisture content of milled rice into that of brown rice. Percentage of remaining bran on the surfaces of milled rice grains was determined by irradiating milled rice grain surfaces with visible light, measuring the fluorescent light from phytic acid in bran radiates and computing the percentage of remaining bran (Kanemoto, 2003). 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.

Viable aerobe counts and thermo-tolerant bacteria counts were measured. A rice sample (10 g) was mixed with 90 mL of sterile 0.85% sodium chloride solution in a sterile conical flask and was shaken for one min at 250 spm. The wash fluid was then serially diluted. Viable aerobe counts were determined by pouring one mL of diluted sample into plate count agar (Merck, Darmstadt, Germany). Plates were incubated at 35°C for 48 h, and the colonies were counted. To enumerate thermo-tolerant bacteria counts, 10 mL of the wash fluid was heated at 75°C for 15 min. The fluid was then serially diluted. Thermo-tolerant bacteria counts were determined by incubating and counting the colonies as for viable aerobes.

Turbidity of rinsed water was determined according to the JIS method (Japanese Standards Association, 1998). A rice sample (20 g) was mixed with 200 mL of distilled water (15-20 °C) in a conical flask and was shaken for one min at 250 spm. The fluid except rice was poured into a beaker, and 10 mL of the fluid was taken while stirring. The absorbance was measured with a spectrophotometer (model UV-1700, Shimadzu Corporation, Kyoto, Japan) at 660 nm with diluting the fluid ten times with distilled water. Turbidity was then computed using a calibration line determined in advance. Solids in rinsed water were determined according to the method of the Japan Rice Millers Association. A rice sample (20 g) was mixed with 30 mL of distilled water (15-20 °C) in a conical flask and was shaken for one min at 250 spm. The fluid (10 mL) except rice was pour into a container while stirring. The container was placed in a forced-air oven at 80°C for 20 h and at 105°C for 4 h , and solids in the rinsed water (g/100g) was computed. The pH of the rinsed water was also measured using a pH meter.

Surface structure of grains of milled rice was vapor-deposited with an Ion Sputter (Hitachi, Tokyo, Japan) and was then observed under an electron microscope (model JSM-5310LV, Japan Electron Optics Laboratory, 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 with rinsing. 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” equaling -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.

Free fat acidity of rice was measured during and after storage, and sensory tests were carried out again after storage.

Results and Discussion

Quality Characteristics of Rinse-Free Rice

Table 1 shows the results of quality assessment of Koshihikari variety before storage.

Moisture content of rinse-free rice increased because of water treatment during the rinse-free rice processing. Fluidity of rinse-free rice was higher than that of conventional milled rice because the coefficient of friction on the surfaces of rinse-free rice grains was reduced by removing bran residues. Bulk weight of rinse-free rice was heavier than that of conventional milled rice due to the decrease in the coefficient of friction and grain size by the processing of rinse-free rice. Whiteness of rinse-free rice was increased. The L* value (lightness) of rinse-free rice was also increased. Translucency of rinse-free rice was decreased. These results regarding the appearance of rice indicate that rinse-free rice looks whiter and less translucent than does conventional milled rice. The b* value (yellow-blue axis) of rinse-free rice decreased, indicating that bran residues on the surfaces of rinse-free rice grains were removed by the processing of rinse-free rice. Percentage of bran remaining of rinse-free rice decreased, and free fat acidity of rinse-free rice was therefore lower than that of conventional milled rice. Storage properties of rinse-free rice were accordingly thought to be better than those of conventional milled rice. There was no difference between rinse-free rice A and rinse-free rice B in percentage of remaining bran or the free fat acidity. The results were the same for both Akitakomachi and Hoshinoyume varieties. The results indicate the two methods used in this study for processing rinse-free rice A and rinse-free rice B had no effect on the percentage of remaining bran or on free fat acidity.

Viable aerobe count of rinse-free rice B was 2.6 log CFU/g, which was lower than that of conventional milled rice (3.2 log CFU/g), but the viable aerobe count of rinse-free rice A was 4.7 log CFU/g, which was higher than that of conventional milled rice. The materials used for the processing of the two kinds of rinse-free rice caused the difference in viable aerobe counts. Viable aerobe count of tapioca-starch granules after the processing was 3.8 log CFU/g, and they were sterilized at temperatures of 80-100°C before they were used again for the next processing. On the other hand, viable aerobe count of bran granules after the processing was 6.0 log CFU/g, the same level as that of brown rice, and there was no sterilizing process of the bran granules. Viable aerobes, however, do not cause any hygienic problems because they are sterilized when rice is cooked. Thermo-tolerant bacteria counts of the conventional milled rice and the two kinds of rinse-free rice were below the detectable threshold level.

Turbidity of rinsed water and solids in rinsed water of rinse-free rice were about half of those of conventional milled rice because of the small amounts of bran residues on the grain surfaces. The pH values of rinsed water of rinse-free rice were lower than that of conventional milled rice. The pH values of rinsed water decreased because of the rinse-free rice processing.

Table 1. Quality assessment before storage (Koshihikari).

Items	Brown rice	Conventional milled rice	Rinse-free rice A	Rinse-free rice B
Appearance yield (%)	100.0	89.3	88.1	87.0
Real yield (%)	100.0	91.1	90.1	89.8
Moisture content (%)	15.4	15.3	15.5	15.5
Fluidity (g/s)	20.7	24.3	26.7	27.9
Bulk weight (g/L)	811	868	877	900
1000-kernel weight (g)	22.59	20.55	20.36	20.29
Whiteness (-)	20.5	42.0	50.1	48.5
Color L^* (-)	55.7	61.4	65.7	65.1
Color a^* (-)	2.3	-0.6	-0.7	-0.6
Color b^* (-)	13.8	6.8	6.2	6.4
Translucency (-)	126	246	205	223
Protein content (%, DM)	6.9	5.7	5.3	5.3
Percentage of remaining bran (%)	100.0	1.9	1.3	0.9
Free fat acidity (mg)	22.3	4.4	2.5	2.4
Viable aerobe count (log CFU/g)	5.9	3.2	4.7	2.6
Thermo-tolerant bacteria count (log CFU/g)	3.0	*2	*2	*2
Turbidity of rinsed water (ppm)	*1	118	52	73
Solids in rinsed water (g/100g)	*1	1.15	0.40	0.55
pH of rinsed water (-)	*1	7.6	7.3	7.3

*1: No measurement *2: Below the detectable threshold level

Surface structures of rinse-free rice A, rinse-free rice B and conventional milled rice are shown in Figures 1, 2 and 3, respectively.

Endosperm cells of the aleurone layer were observed on the grain surfaces of the two kinds of rinse-free rice. On the other hand, endosperm cells were not observed on the grain surfaces of conventional milled rice, and the grain surfaces of conventional milled rice were covered with bran residues pounded by the milling pressure.

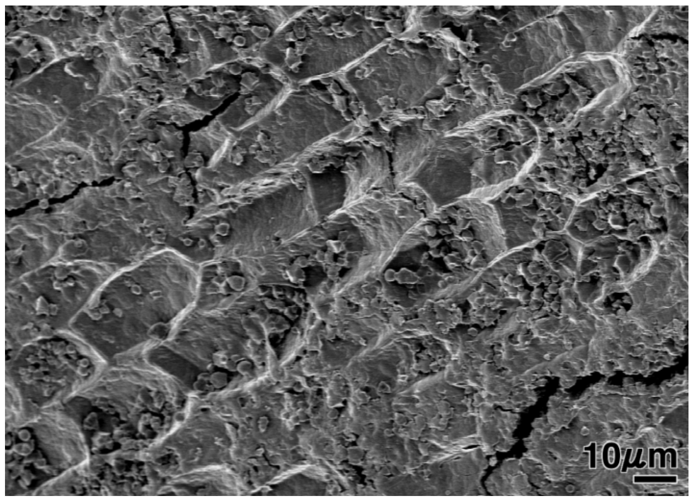

Figure 1. Surface structure of rinse-free rice A (Akitakomachi).

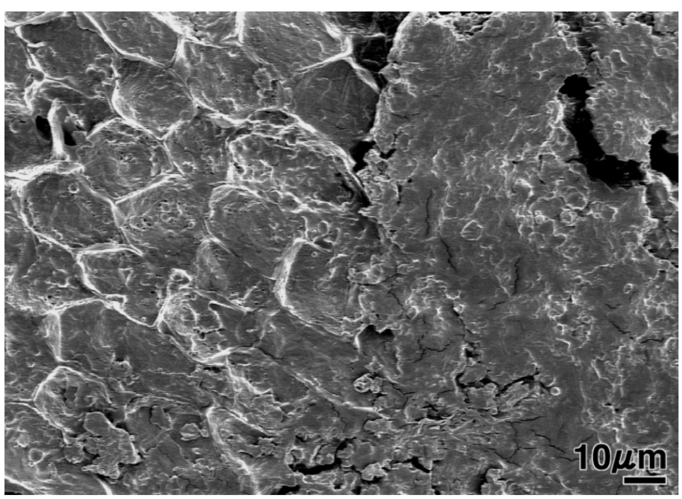

Figure 2. Surface structure of rinse-free rice B (Akitakomachi).

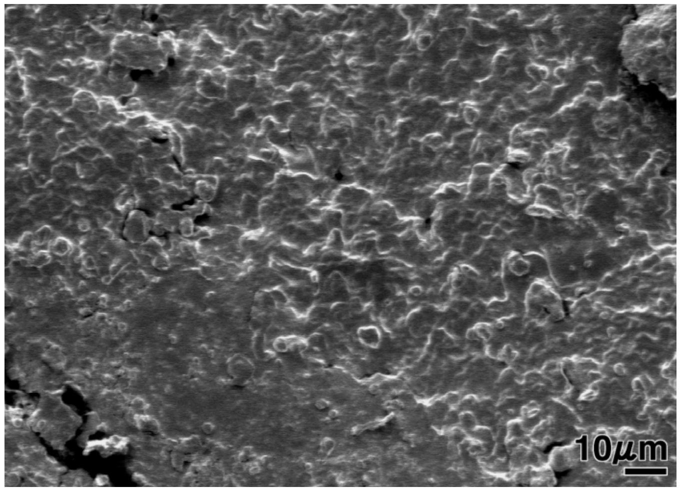

Figure 3. Surface structure of conventional milled rice (Akitakomachi).

Table 2 shows the results of assessment of the eating quality of Hoshinoyume variety before storage. The appearance of rinse-free rice was better than that of conventional milled rice in the sensory test because the whiteness of rinse-free rice was greater than that of conventional milled rice. The hardness of cooked conventional milled rice and cooked rinse-free rice without rinsing was greater than that of cooked conventional milled rice and cooked rinse-free rice with rinsing. The eating quality of cooked conventional milled rice with rinsing was higher than that of cooked conventional milled rice without rinsing. The eating quality of cooked rinse-free rice without rinsing was the same as that of cooked conventional milled rice with rinsing.

Table 2. Assessment of eating quality before storage (Hoshinoyume).

Samples	Appea-rance of milled rice	Rinsing	Cooked rice				
			Appea-rance	Aroma	Hard-ness	Cohesi-veness	Overall flavor
Conventional milled rice	-0.17	Done	0.09	-0.20	-0.22	0.13	-0.11
		Not done	-1.00	-0.82	0.87	-0.69	-0.96
Rinse-free rice A	1.11	Done	0.16	-0.16	0.31	-0.11	0.00
		Not done	-0.07	-0.20	0.58	-0.09	0.06
Rinse-free rice B	1.28	Done	0.18	-0.11	0.16	0.20	0.19
		Not done	0.09	-0.16	0.38	-0.13	-0.19

Storage Properties of Rinse-Free Rice

Free fat acidity of each rice sample increased during the 4-month storage period. Fig. 4 shows the changes in free fat acidity of Hoshinoyume variety during storage at 25°C. Free fat acidity of conventional milled rice after 4 months of storage at 25°C had increased to 16.6 mg. However, the free fat acidity levels of rinse-free rice A and rinse-free rice B after 4 months of storage at 25°C had increased to 9.7 mg and 7.4 mg, respectively, half as much as that of conventional milled rice. The results indicate that storage properties of rinse-free rice were better than those of conventional milled rice. The rate of increase in free fat acidity during storage at a low temperature was less than that during storage at a high temperature in both conventional milled rice and rinse-free rice. Samples after 4 months of storage at 25°C were used in sensory tests. Table 3 shows the results of assessment of the eating quality of Akitakomachi variety after storage. There was no difference between the eating qualities of rinse-free rice with rinsing and without rinsing before cooking at the beginning of storage. However, the eating quality of rinse-free rice with rinsing was better than that of rinse-free rice without rinsing after 4 months of storage at 25°C.

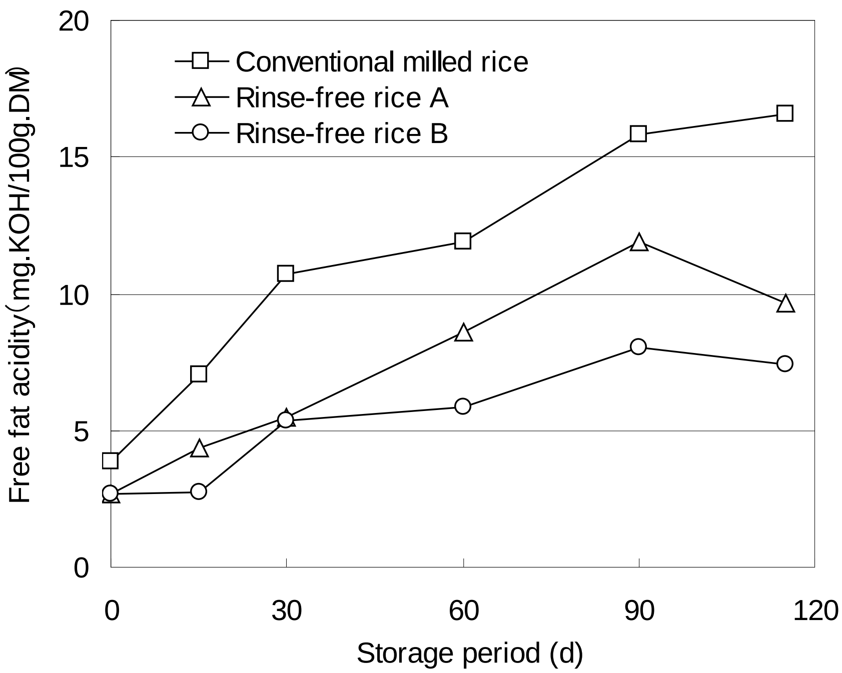

Figure 4. Changes in free fat acidity during storage at 25°C (Hoshinoyume).

Table 3. Assessment of eating quality after storage (Akitakomachi).

Samples	Appearance of milled	Rinsing	Cooked rice				
			Appea-rance	Aroma	Hard-ness	Cohesi-veness	Overall flavor
Conventional milled rice	-0.03	Done	-0.03	-0.13	-0.11	-0.10	-0.05
		Not done	-0.82	-0.72	0.42	-0.48	-0.83
Rinse-free rice A	1.55	Done	0.58	0.03	0.18	-0.03	0.43
		Not done	0.18	-0.08	0.45	-0.30	-0.20
Rinse-free rice B	1.23	Done	0.26	-0.05	0.29	0.13	0.28
		Not done	-0.11	0.21	0.24	0.05	-0.28

Conclusion

We investigated the quality characteristics and storage properties of two kinds of rinse-free rice processed by two different methods and those of conventional milled rice. Rinse-free rice was found to be statistically different from conventional milled rice in various quality assessments. The eating quality of cooked rinse-free rice without rinsing was the same as that of cooked conventional milled rice with rinsing. Free fat acidity of each rice sample increased during the 4-month storage period. However, the magnitude of increase in free fat acidity levels of rinse-free rice was only half that of conventional milled rice. The results indicate that storage properties of rinse-free rice were better than those of conventional milled rice. Sensory tests performed after 4 months of storage at 25°C showed that the eating quality of rinse-free rice with rinsing was better than that of rinse-free rice without rinsing.

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