Food Sci. Technol. Res., **10** (3), 282–289, 2004

Effects of Harvesting Time on Sweetness of Cooked Rice and Activity of Starch-Degradation Enzymes of Rice Grains

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Received November 25, 2003; Accepted March 28, 2004

The effects of harvesting time on sweetness of cooked rice and activity of starch-degradation enzymes of rice grains were examined. In both Koshihikari and Nakateshinsenbon, the content of free sugars in cooked rice was the highest in the rice harvested extremely early (28 days after heading, DAH), and it decreased as the harvesting time was delayed. Maltotriose and maltotetraose were detected in the cooked rice when harvested early (28–34 DAH). On the contrary, in the cooked rice when harvesting time was standard (40 DAH) or late (43–49 DAH), maltoligosaccharides were not detected. In both varieties, α-amylase activity in rice grains of early harvesting (31 DAH) was higher than that of standard (40 DAH) and late harvesting (49 DAH). These findings suggested that the early harvesting of rice grains is an effective method of increasing the sweetness of cooked rice, because it activate α-amylase activity in rice grains.

Keywords: early harvesting, cooked rice, sweetness, maltoligosaccharides, α-amylase activity.

Introduction

The optimum time of harvesting rice grains has been most often determined to attain a good external appearance, to obtain a sufficient yield and to make harvesting work easier. On the other hand, due to the inferior quality of cooked rice of the grains harvested extremely early or extremely late, the optimum harvesting time to obtain superior quality of cooked rice has been assumed to be about 40 days after heading (DAH) (Ebata *et al.*, 1982).

Recent reports have shown that eating quality of cooked rice is also greatly influenced by the taste factors such as sweetness and deliciousness (Tamaki *et al.*, 1989; Matsuzaki *et al.*, 1992; Sugiyama *et al.*, 1995; Arai *et al.*, 1997). We therefore reevaluated the optimum time of harvest from the viewpoint of the taste factors of cooked rice. In a previous report (Arai and Itani, 2000), we compared the taste factors of cooked rice between the rice grains harvested at 42 DAH, which was considered as the most suitable harvesting time, and those harvested 10 days earlier. As a result, we found that the eating quality is improved by harvesting 10 days earlier than the optimum harvesting time (42 DAH). This was because free sugars such as maltoligosaccharides, which are produced in large quantities during soaking and/or heating, were greatly increased by harvesting 10 days earlier.

However, only one variety, Koshihikari, cultivated in one area was used in our previous study. The eating quality of cooked rice greatly varies not only with the variety but also with the cultivation conditions such as growing region, weather and fertilization. Therefore, it is necessary to examine whether the early harvesting of rice grains would be an effective way of improving the taste of cooked rice in other varieties and under different cultivation conditions.

In this study, we used Koshihikari and Nakateshinsenbon, which had genetically different characteristics. These two varieties were cultivated under a geographic condition different from that in our previous report and harvested at various times. Using the two varieties harvested at eight different times, we determined the content of free sugars in cooked rice and the activity of intrinsic starch-degradation enzymes related to the production of free sugars in the rice grains, to clarify whether harvesting time influences the sweetness of cooked rice.

Materials and Methods

Plant materials In 1999, two rice varieties (*Oryza sativa* L. cvs. Koshihikari and Nakateshinsenbon) were seeded in seed boxes on 5 May and on 4 June the seedling were transplanted at a density of three plants per hill in the rice fields of Hiroshima Prefecture University, Shobara, Hiroshima. Inter-row spacing was 30 cm and inter-plant spacing 15 cm in the paddy field. All fertilizers were applied as basal dressing at the ratio of N : P : K = 5 : 3.5 : 6.6 gm^{-2} The heading time of Koshihikari and Nakateshinsenbon was 9 August and 18 August, respectively. Developing grains were harvested at 28, 31, 34, 37, 40, 43, 46 and 49 days after heading (DAH). Grains harvested at 28, 31, 34 and 37 DAH are hereafter referred to as "early-harvest" rice grains, those harvested at 40 DAH are as "ordinary-harvest" rice grains, and those harvested at 43, 46 and 49 DAH are as "late-harvested" rice grains. All of the early-harvest, ordinary-harvest and late-harvest rice grains were air-dried

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in the hut with roof until the water content reached 15%, then dehulled and milled at a milling percentage of 90 ± 1%. To prevent decrease of enzymatic activity, milled rice grains were sealed in a polypropylene-coated alumina pouch and stored at 4°C.

Quality of brown rice Brown rice of 1000 grains was analyzed with a rice analyzer (RA-60A, SATAKE Co., Hiroshima, Japan). The light of halogen lamp was irradiated in the each grain, and the reflected and transmitted lights were measured by the sensor. The percentages of fully ripened kernels, immature kernels, damaged kernels, opaque kernels, colored kernels and cracked kernels were calculated by image processing of the signal from the sensor.

Protein and amylose contents of milled rice The nitrogen content of milled rice was determined by the semi-micro Kjeldahl method. The protein content of milled rice was obtained from the nitrogen content by multiplying it by a factor 5.95. Amylose content of the milled rice was estimated by the iodine colorimetric method of Juliano (Juliano, 1971).

Rice cooking For each sample of milled rice, 145 g of the early-harvest, ordinary-harvest and late-harvest was washed three times with distilled water (200 ml each) and soaked in distilled water of up to 1.5 times the weight of the grains at 25°C for 60 min. The samples were cooked in an electric rice cooker (SR-30F, Matsushita Electronic Co., Osaka, Japan) for 18 min, and then kept warm for 12 min.

Measurement of texture of cooked rice The hardness and stickiness of cooked rice were measured with a texturometer (GTX-2, General Foods-Zenken Co, Tokyo, Japan) by the three-grain method (Okabe, 1979). The conditions for the measurement were as follows: sample size, 3 grains; plunger, Lucite (18 mm in diameter); clearance, 0.2 mm; bite speed, 6 times/min; and sample temperature at the time of measurement, 25°C.

Free sugar content of cooked rice The glutinous substance was prepared from cooked rice (10 g) by extraction with boiling distilled water (100 ml) under gentle stirring (3 min). The mixture was filtered through a glass filter (11G-P100, Shibata Science Co., Tokyo, Japan) to separate a glutinous substance from cooked rice grains. The glutinous substance was centrifuged (19,000 × g, 20 min) and the supernatant was concentrated ten times by evaporation *in vacuo*. The concentrated sample was analyzed by a high performance liquid chromatography (HPLC). The conditions of HPLC were: apparatus, PU-980 (Japan Spectroscopic Co., Tokyo, Japan); column, Wakosil $5NH_2$ (Wako Pure Chemical Industries Ltd., Osaka, Japan); solvent, acetonitrile/water (7/3); flow rate, 1 ml/min; column temperature, 40°C; and detector, reflection indicator, 830-RI (Japan Spectroscopic Co.). The cooked rice grain separated from the glutinous substance (called residual grains hereafter) was mixed with distilled water (5 g/25 ml) and then homogenized (10,000 rpm, 5 min) with a homogenizer (500 AC-2, Sakuma Co., Tokyo, Japan). The homogenate was centrifuged (19,000 × g, 20 min) and the supernatant was concentrated ten times by evaporation *in vacuo*. The concentrated sample was also analyzed by the same HPLC as above.

Preparation of pulverized milled rice grains Milled rice grains were pulverized with a food mill (IMF-170G, Iwatani International Co., Tokyo, Japan) and sieved through a 50 mesh sieve.

Assay for α-glucosidase activity Pulverized milled rice grains (3 g) was added to 20 ml of 100 mM acetate buffer, pH5.0 and stirred at 40°C for 20 min. The mixture was centrifuged (19,000 × g, 20 min) and the supernatant was assayed. The assay mixture (1 ml in total) consisted of 400 µl of 0.25% maltose solution, 400 µl of acetate buffer and 200 µl of the supernatant. The reaction mixture was incubated at 40°C for 30 min. To stop the reaction, 2 ml of 2 M Tris-HCl buffer, pH7.0 was added. The content of glucose in the reaction mixture was measured with a commercial glucose assay kit (F-kit glucose, F. Hoffmann-La Roche Ltd., Basel, Switzerland). One unit of enzyme activity was defined as the amount of enzyme which released 1 µmol/min glucose from maltose.

Assay for α-amylase activity The α-amylase activity of pulverized milled rice grains was assayed using a commercial α-amylase assay kit (Megazyme International Ireland Ltd., Co. Wicklow, Ireland) according to the manufacturer's instruction. One unit of enzyme activity was defined as the amount of enzyme which released 1 µmol/min *p*-nitrophenyl from blocked *p*-nitrophenyl maltoheptaoside.

Assay for β-amylase activity The β-amylase activity of pulverized milled rice grains was assayed using a commercial β-amylase assay kit (Megazyme International Ireland Ltd.) according to the manufacturer's instruction. One unit of enzyme activity was defined as the amount of enzyme which released 1 µmol/min *p*-nitrophenyl from blocked *p*-nitrophenyl maltopentaoside.

Assay for debranching enzyme activity Pulverized milled rice grains (3 g) was added to 20 ml of 100 mM McLlvain buffer, pH5.6 and stirred at 40°C for 20 min. The mixture was centrifuged (19,000 × g, 20 min) and the supernatant was assayed for pullulanase activity by the small modified method of Takeuchi *et al.* (1999). The assay mixture (1 ml in total) consisted of 500 µl of 0.25% pullulan solution, 400 µl of McLlvain buffer, and 100 µl of the supernatant. The reaction mixture was incubated at 40°C for 30 min and mixed with 1 ml of Somogyi reagent (Somogyi, 1952) then incubated in boiling water for 20 min. After this was cooled on ice, 1 ml of Nelson regent (Nelson, 1944) was added to the mixture, and absorbance at 660 nm was measured. Maltotriose (zero to 5 mg/ml) was used as a standard. The activity of debranching enzyme was shown as the amount of maltotriose released from pullulan for 1 min.

Statistical analysis Differences between mean values were analyzed by Student's *t*-test (Fisher, 1958).

Results and Discussion

Effect of harvesting time on the quality of brown rice and the contents of protein and amylose in milled rice First, we examined the effect of harvesting time on the quality of brown rice (Figure 1). In both Koshihikari and Nakateshinsenbon, the water content and 1,000-kernel

weight did not vary with the harvesting time. However, at 28 DAH, the percentage of fully ripened kernels was lower and the percentage of opaque kernels was higher than at 40 DAH in both varieties. At 28 and 31 DAH in Koshihikari and at 28, 31 and 34 DAH in Nakateshinsenbon, the percentage of immature kernels was higher than at 40 DAH. At 28–37 DAH, the percentage of cracked kernels was high in Koshihikari. The percentages of damaged and colored kernels gradually increased as the harvesting time was delayed in both varieties. These results show that the quality of brown rice of early harvesting (28, 31 and 34 DAH) was inferior to that harvested at the standard time (40 DAH).

The protein and amylose contents of milled rice, which affect the eating quality of cooked rice, were determined (Figure 2). Differing from the report of Matsue *et al.* (1991), the protein content gradually increased as the harvesting time was delayed in both varieties. The amylose content gradually decreased as the harvesting time was delayed in both varieties, as reported by Matsue *et al.* (1991). Therefore, we consider that the protein and amylose contents are hardly affected in the harvesting time in this experiment, because the change of protein and amylose contents was slight.

Effect of harvesting time on the texture of cooked rice

Texture (hardness and stickiness) is an important factor of the palatability of cooked rice. As compared with the standard harvesting time (40 DAH), extremely early harvesting (28 DAH) or extremely late harvesting (49 DAH) significantly increased the hardness value of cooked rice of both varieties (Figure 3). This is in agreement with the report of Ebata *et al.* (1982).

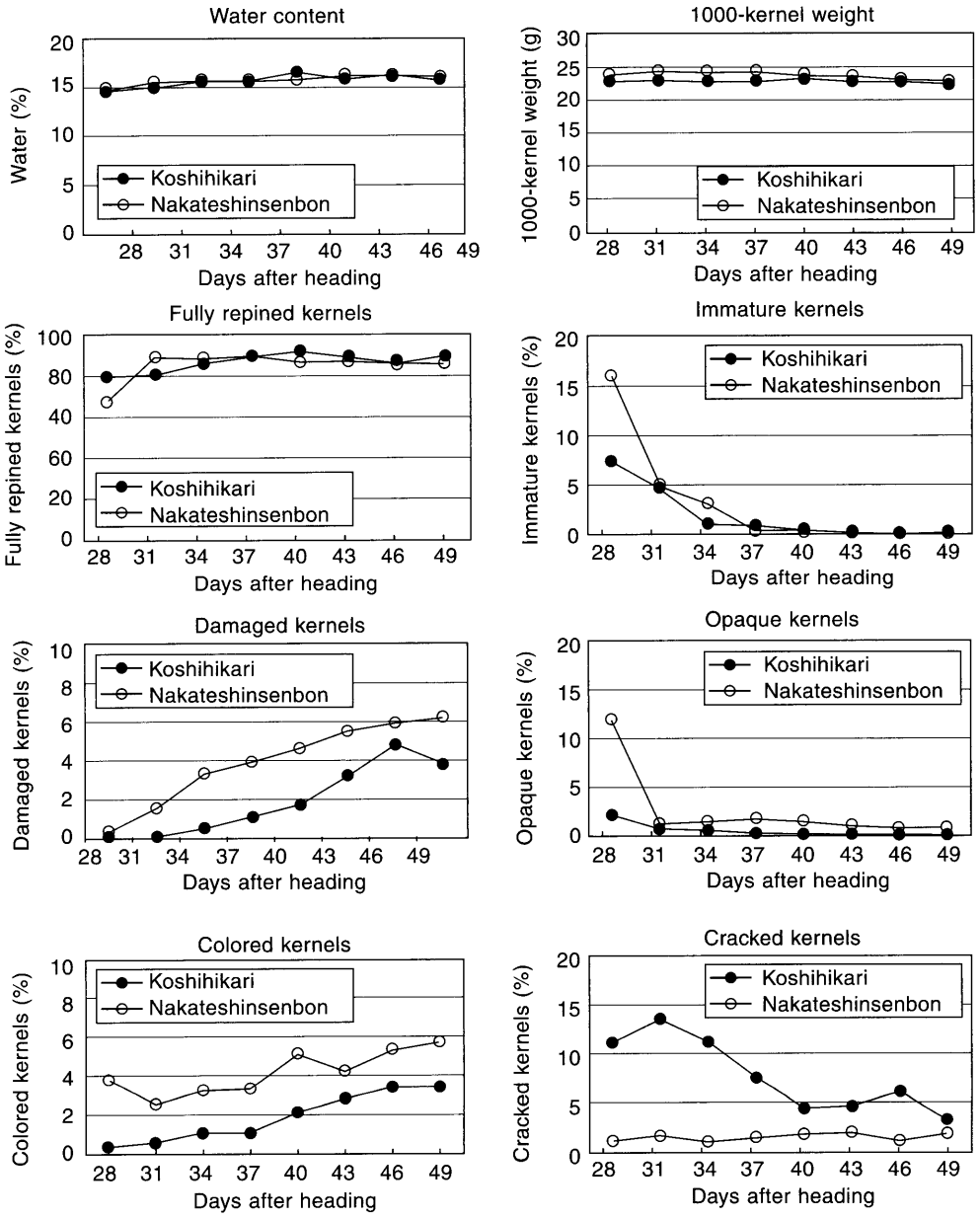

Fig. 1. Quality of brown rice. The percentages of fully repined kernels, immature kernels, damaged kernels, opaque kernels, colored kernels and cracked kernels were measured with a rice analyzer. Data are presented as means of two separate measurements.

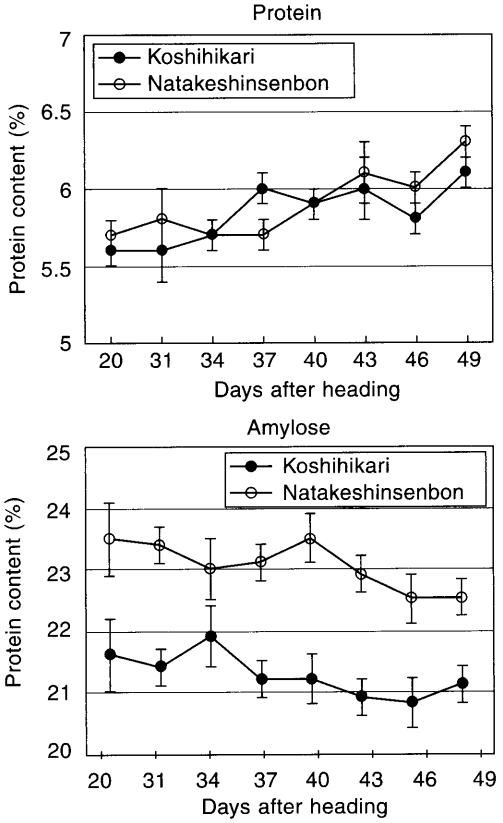

Fig. 2. Protein and amylose contents of milled rice grains. Milled rice grains harvested at 40 DAH is a control. Data are presented as mean ± SD of three separated measurements.

The stickiness of the cooked rice of Koshihikari was significantly increased by early harvesting (28, 31 and 34 DAH) as compared with the standard harvesting time. In our previous experiment with Koshihikari also, harvesting 10 days earlier than the standard harvesting time significantly increased the stickiness of cooked rice. In the present experiment under different cultivation conditions, the same result was obtained. In the contrary, the cooked rice of Nakateshinsenbon harvested extremely early (28 DAH) was significantly less sticky than that harvested at the standard harvesting time, although the stickiness of this variety harvested at other days in this experiment was not significantly different from that harvested at the standard harvesting time.

The stickiness/hardness ratio is considered as an important index of the texture of cooked rice (Okabe, 1979). In Koshihikari, the ratio was significantly increased by early harvesting (31 and 34 DAH). This might be caused by an increase in stickiness. In Koshihikari, therefore, advancing the harvesting time by about 6 to 9 days is effective in improving the texture of cooked rice. In Nakateshinsenbon, the stickiness/hardness ratio of the rice harvested 28 and 49 DAH (referred to as 28- and 49-DAH rice hereafter) was significantly lower than that of 40-DAH rice. Thus in Nakateshinsenbon, the extremely early- or late-harvesting caused deterioration of the texture of cooked rice. From these results, we concluded that the effect of early harvesting on the texture of cooked rice varies with the rice variety.

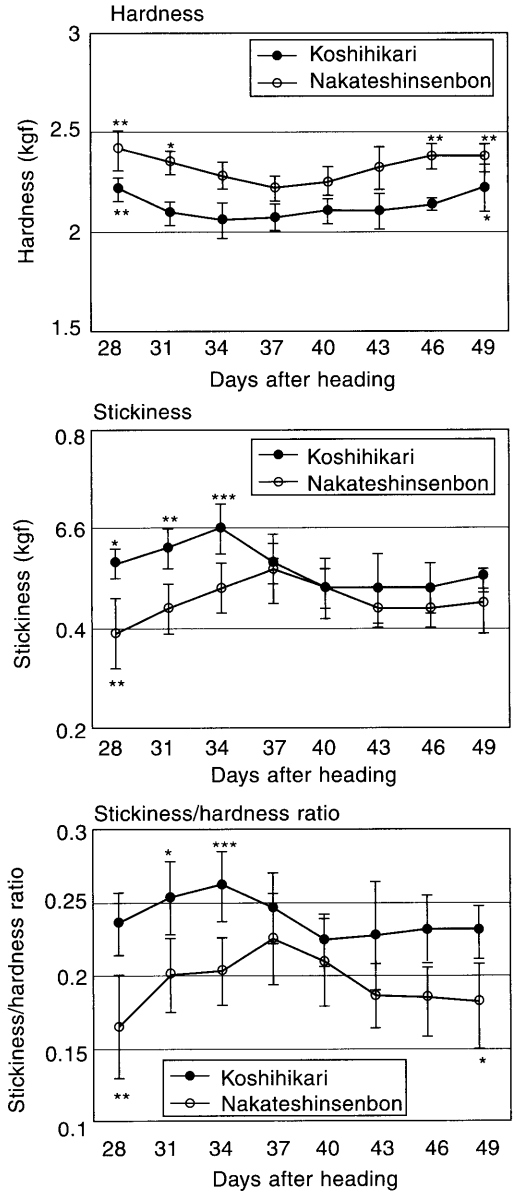

Fig. 3. Texture parameters of cooked rice. The hardness and stickiness of cooked rice were measured with a texturometer by the three-grain method. Milled rice grains harvested at 40 DAH is a control. Data are presented as mean ± SD of ten separated measurements. Mean significance at 5*, 1**, and 0.1%*** levels, respectively, between the values obtained for rice grains of the 28, 31, 34, 46 and 49 DAH and the control.

Effect of harvesting time on free-sugar content of cooked rice In this study, we measured the content of free sugars in the outer layer (glutinous substance) and remaining rice grains (residual grains) of cooked rice separately, because we previously observed a difference between them (Arai and Itani, 2000).

In Koshihikari (Figure 4), the content of free sugars in the glutinous substance of cooked rice was the highest in the rice harvested extremely early (28-DAH rice), and it decreased as the harvesting time was delayed. Particularly the difference between 28- and 34-DAH rice was large. On the other hand, the rice harvested late (43- to 49-DAH rice) had a content of free sugars in the cooked rice similar to that in the standard harvest rice (40-DAH rice).

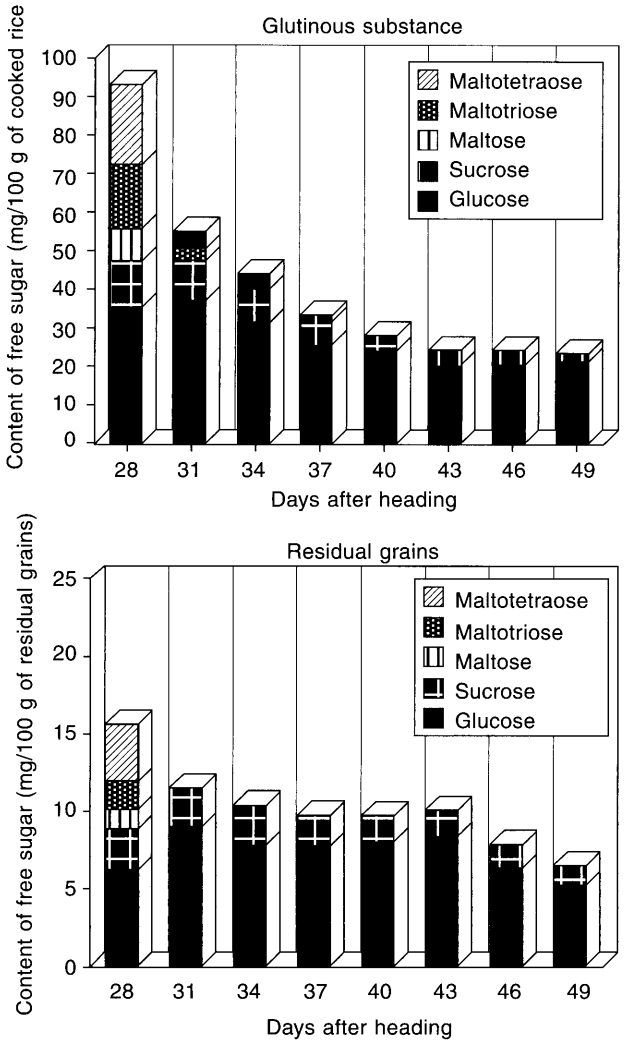

Fig. 4. Content of free sugars in the cooked rice of Koshihikari. Glutinous substance was prepared from cooked rice by extraction with boiling distilled water. Residual grains of cooked rice were excluding the glutinous substance. Data are presented as means of three separate measurements.

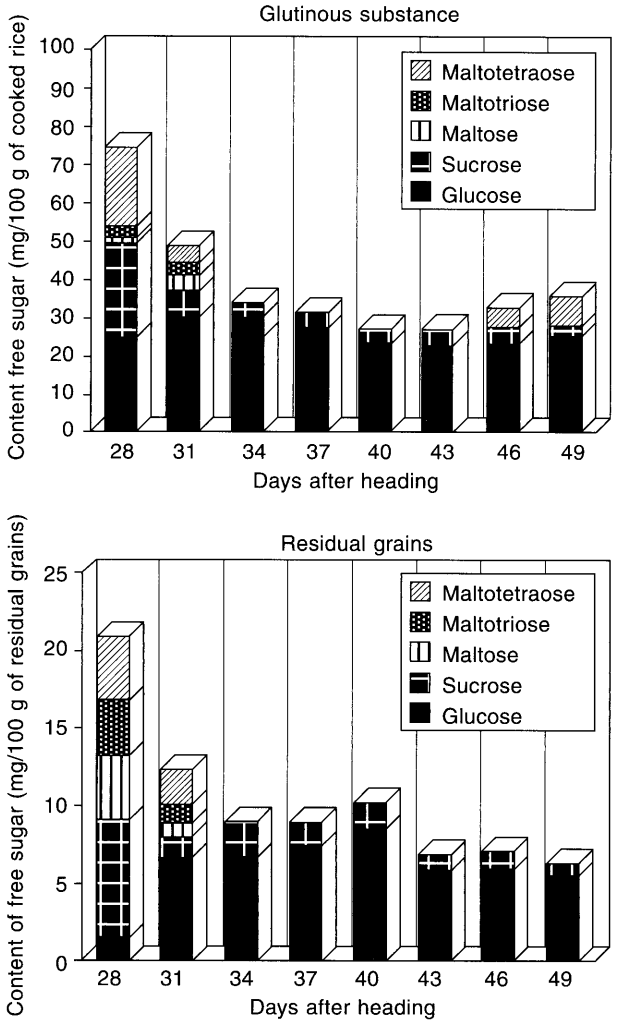

Fig. 5. Content of free sugars in the cooked rice of Nakateshinsenbon. Glutinous substance and residual grains were prepared as described in Figure 4. Data are presented as means of three separate measurements.

In Nakateshinsenbon (Figure 5), the content of free sugars in the glutinous substance was the same as that in Koshihikari. It was the highest in 28-DAH rice, and decreased as harvesting time was delayed until 40 DAH.

In the glutinous substance from the grains of both varieties, glucose and sucrose were detected irrespective of harvesting time. The glucose content did not vary so much with the harvesting time but sucrose content rapidly decreased after 28 DAH. Sucrose has a sweeter taste than the other free sugars, and the sweetness of the cooked rice when harvested early may be attributed to high sucrose content. Besides glucose and sucrose, maltose and maltoligosaccharides such as maltotriose and maltotetraose, which add a refined sweetness to cooked rice, were detected in the cooked rice when harvested early. Maltoligosaccharides in cooked rice are assumed to be produced by the action of α-amylase during soaking and/or cooking (Arai *et al.*, 1997; Arai and Itani, 2000; Tajima *et al.*, 1994; Maruyama, 2002). Particularly in 28-DAH rice, the content of maltoligosaccharides was high suggesting a high activity of α-amylase. On the other hand, in the cooked rice when harvesting time was standard or late, maltoligosaccharides were not detected. These results are in agreement with a previous report (Arai and Itani, 2000). In Nakateshinsenbon, however, maltotriose was again detected in 46- and 49-DAH rice. We assumed that the rice grains got wet by rain or mist during maturing, and it caused induction of the enzymes such as α-amylase during the germination of the rice grain.

The content of free sugars in the residual grains was the highest in the rice harvested at 28 DAH and decreased as the harvesting time was delayed with some fluctuation in both varieties. The content of free sugars in the cooked rice was lower when the harvesting time was late than when it was the standard harvesting time.

The residual grains of the cooked rice when harvested early (Koshihikari harvested at 28 DAH and Nakateshinsenbon harvested at 28 and 31 DAH) contained maltoligosaccharides, but those of rice harvested at the standard harvesting time or later did not.

A large amount of sucrose was detected besides the maltoligosaccharides in the cooked rice of Nakateshinsenbon harvested at 28 DAH. Sucrose synthesized by photosynthesis in stems and leaves is translocated to endosperm,

decomposed to triose phosphate there, and taken into the amyloplast (Nakamura *et al.*, 1989). Thereafter, triose phosphate in the amyloplast is converted to ADP- (or UDP-) glucose, which is synthesized via glucose-1-P to serve as the substrate of starch synthesis (Murata *et al.*, 1964; Murata and Akazawa, 1966). In Nakateshinsenbon, sucrose before decomposed into triose phosphate was considered to be accumulated in the endosperm. In Koshihikari, sucrose was not accumulated so much. Since Koshihikari is an early-ripening variety, the mean daily temperature in the ripening stage is higher than in Nakateshinsenbon which is a variety of common midseason ripening. Therefore, more of the sucrose may be converted to starch in Koshihikari than in Nakateshinsenbon at 28 DAH. Contrary to sucrose, the content of glucose after cooking in rice harvested early (28-DAH rice) in Nakateshinsenbon was quite low.

These results show that the rice harvested early is sweet irrespective of the variety and cultivation conditions. Particularly in the rice harvested at 28 DAH, this tendency was strong though the quality of brown rice and the texture of cooked rice were poor. On the other hand, late harvesting is one of the decisive factors for decreasing the sweetness of cooked rice.

Effect of harvesting time on starch-degradation enzyme activity in rice grains Since nearly all of the free sugars except for sucrose are produced by hydrolysis of starch by the intrinsic starch-degradation enzymes, we predicted that the harvesting time affects the starch-degradation enzyme activity in rice grains. The intrinsic starch-degradation enzymes in rice seeds include α-amylase (Tanaka *et al.*, 1970; Shin *et al.*, 1985; Sakamoto and Maruyama, 1990; Terashima *et al.*, 1994; Mitsui *et al.*, 1996), β-amylase (Matsui *et al.*, 1977; Okamoto and Akazawa, 1980; Nandi *et al*, 1995), α-glucosidase (Takahashi *et al.*, 1971; Takahashi and Shimomura, 1973; Awazuhara *et al.*, 2000; Iwata *et al.*, 2001), and debranching enzyme (Yamada, 1981; Yamada, 1981; Toguri, 1991; Nakayama *et al.*, 1996; Takeuchi *et al.*, 1999). Therefore, we compared the activities of these four enzymes in rice grains harvested early (31 DAH), late (49 DAH) and at the standard harvesting time (40 DAH).

As shown in Table 1, α-glucosidase activity in rice grains of 31 DAH was slightly higher than that in 40 DAH but the activity in 49 DAH was the same as that in 40 DAH. The activity of α-amylase in 31 DAH was significantly higher and that in 49 DAH was significantly lower than that in 40 DAH. Debranching enzyme activity was, however; significantly lower in 31 DAH than that in 40 DAH.

The relative activities of the four enzymes (percentage to those in 40 DAH) were obtained. In both varieties, early harvesting activated α-amylase (Koshihikari, 182%; Nakateshinsenbon, 116%) and inactivated β-amylase (Koshihikari, 91%; Nakateshinsenbon, 61%) and the debranching enzyme (Koshihikari, 88%; Nakateshinsenbon, 65%). On the contrary, the late harvesting inactivated α-amylase (Koshihikari, 90%; Nakateshinsenbon, 93%) and activated the debranching enzyme (Koshihikari, 112%; Nakateshinsenbon, 118%). β-Amylase activity was the highest in the standard harvest rice, but α-glucosidase activity was not affected by the harvesting time as much as the other enzymes.

In rice seeds, α-amylase is synthesized in epithelical cells of the blastodisc and in aleurone cells, and then it is secreted and transferred to the endosperm (Akazawa *et al.*, 1990). Baum *et al.* (1970) reported that α-amylase activity increased from around 10 DAH, then decreased from around 14 DAH and disappeared at the fully ripened stage, although it was activated again at the time of germination. This was also the case in the present experiment, in which α-amylase activity in 31 DAH was higher than that in 40 DAH.

According to the report of Yamada (1981), the activity of the debranching enzyme in rice seed increases during the early stage of ripening, decreases during the maturation stage and increases again during germination. Takeuchi *et al.* (1999) reported that the debranching enzyme was activated when the enzyme protein was solubilized in the presence of reducing agents such as dithiothreitol and 2-mercalptoethanol. Therefore, the high debranching enzyme activity in 49 DAH might not be due to the increased synthesis of enzyme protein but to the increased reductivity, which improved the solubility of enzyme proteins in the grains.

α-Glucosidase in rice seed has two isoenzymes (Takahashi *et al.*, 1971). Awazuhara *et al.* (2000) clarified the distribution in rice grains and the optimum temperature of these isoenzymes. We assumed that glucose detected in the glutinous substance of cooked rice was produced by the isoenzyme in the outer layer of the endosperm, and that glucose detected in the residual grains was produced by the isoenzyme in the inner part of the endosperm. The optimum temperature for these isoenzymes was under 40°C and under 60°C, respectively. The content of glucose in cooked rice did not vary with the time of harvest as much as that of

Table 1. Activities of starch-degradation enzymes in rice grains.

Variety	DAH	α-Glucosidase (U/g)	α-Amylase ($\times 10^{-3}$·U/g)	β-Amylase (U/g)	Debranching enzyme (maltotriose produced/g)
Koshihikari	31	43.3 ± 0.2*	16.2 ± 0.1***	0.15 ± 0.01*	0.65 ± 0.02**
	40	41.0 ± 0.5	8.9 ± 0.2	0.17 ± 0.01	0.75 ± 0.03
	49	41.9 ± 0.9	8.0 ± 0.6**	0.13 ± 0.01**	0.84 ± 0.01*
Nakate-	31	43.4 ± 0.4*	47.7 ± 1.1***	0.52 ± 0.02**	0.23 ± 0.03*
shinsenbon	40	41.2 ± 0.7	41.3 ± 1.3	0.84 ± 0.01	0.36 ± 0.02
	49	41.6 ± 0.8	38.2 ± 0.7*	0.72 ± 0.01**	0.42 ± 0.01***

Milled rice grains harvested at 40 days after heading is a control. Data are presented as mean ± SD of three separated measurements. Mean significance at 5*, 1** and 0.1%*** levels, respectively, between the values obtained for rice grains of 31 and 49 days after heading and the control.

maltoligosaccharides. We confirmed that the activities of both isoenzymes hardly vary with the time of harvest from the content of reaction products.

The present results indicated that the harvesting time greatly affect the activity of the starch-degradation enzyme, particularly α-amylase and the debranching enzyme, in the rice grains. In the rice harvested early, the α-amylase activity is assumed to be higher than in the rice harvested at the standard harvesting time or later, and therefore, a large amount of maltoligosaccharides may be produced during the cooking process. We inferred that the change in α-amylase activity was influenced by the existence of immature kernels. In the near future, we would clarify this hypothesis. On the other hand, in rice harvested late, the debranching enzyme activity is assumed to be high but the activity of the enzymes that produce free sugars may be low; and therefore, the content of free sugars in cooked rice is low. The cooked rice contained a fixed amount of glucose irrespective of harvesting time, probably because α-glucosidase activity was hardly affected by the time of harvest.

The varietal difference in the activity of starch-degradation enzyme was also observed in this study. In Koshihikari, α- and β-amylase activities were lower than those in Nakateshinsenbon irrespective of the harvesting time, but the content of free sugars in cooked rice was higher. This is probably because the activity of the debranching enzyme was 2-fold higher in Koshihikari than in Nakateshinsenbon at any harvesting time. We suppose that in Koshihikari, α-1,6-amylopectin was hydrolyzed by the debranching enzyme more easily than in Nakateshinsenbon, and large quantities of the substrates for α- and β-amylase were produced, and thus the content of free sugars in cooked rice was high despite the low amylase activity. The high activity of the debranching enzyme seemed to improve the texture of cooked rice of Koshihikari.

In conclusion, we assume that the early harvesting of rice grains is an effective method of increasing the sweetness of cooked rice, because it activates α-amylase activity in rice grains. From the viewpoints of free-sugar content and texture (stickiness/hardness ratio) of cooked rice, it is suggested that the optimum harvesting time of Koshihikari is 6 to 9 days earlier than the standard harvesting time. On the other hand, the texture of cooked rice was not improved by advancing of harvesting time in Nakateshinsenbon. Therefore, from the viewpoint of free-sugar content of cooked rice, it is suggested that the optimum harvesting time of Nakateshinsenbon is 6 days earlier than the standard harvesting time.

These findings obtained from the present experiment are the results of two varieties cultivated under the specific area and condition. In the near future, we would report some interesting results on the features of other varieties and different cultivation conditions.

Acknowlegement We are deeply grateful to SATAKE Corporation (Japan) for analysis of quality of brown rice. This study was supported by a Grant-in-Aid for Scientific Research (C) (11680130) from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

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