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Development of a New Technique for Fine Sorting of Brown Rice by Use of a Combination of a Thickness Grader and a Color Sorter

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Abstract. *A research project was conducted to develop a new technique for fine sorting of brown rice by the use of a combination of a thickness grader and a color sorter in order to increase sorting yield and improve rice quality. It was found that a greater sorting yield and processed rice of high quality can be obtained by reducing sieve slot width of the thickness grader by 0.10 mm from the conventional standard slot width and then removing immature, damaged and discolored kernels by the combined use of a color sorter. By using the brown rice fine sorting technique developed in this study, rice farmers' income can be increased and high-quality rice can be supplied to consumers.*

Keywords. sieve slot width, sorting yield, percentage of sound whole kernels, brown rice grade, milling yield, eating quality

Introduction

Rough rice storage is a widely used system in the world for the postharvest process of rice. For historical reasons, however, brown rice storage systems are common in Japan. Soon after drying of rough rice, the rough rice is hulled into brown rice, which is sorted and packed. After inspection of brown rice quality (rice grade), packed brown rice is stored in storehouses, which are usually located in the countryside in Japan. After storage, brown rice is transported to rice milling factories, which are usually located in the outskirts of large cities. After removing bran, white rice (milled rice) is distributed to consumers.

After hulling, a thickness grader has been used in Japan for sorting brown rice to remove immature kernels. The sieve slot width of the thickness grader has gradually become larger to increase the percentage of sound whole kernels and to improve rice grade. For example, the standard sieve slot widths have been set to 2.00 mm for Kirara 397 cultivar and 1.95 mm for Hoshinoyume cultivar. However, even if a sieve with a larger slot width is used, it is still difficult to process no. 1 grade rice. Moreover, a sieve with a lager slot width decreases sorting yield. A color sorter has been used for sorting white rice to remove discolored kernels and foreign materials.

The objectives of this study were to develop a new technique for fine sorting of brown rice by the use of a combination of a thickness grader and a color sorter and to improve brown rice quality.

Methods

Materials

Brown rice samples used in this study were collected from rice drying and processing facilities in Hokkaido, Japan and included samples of (1) Kirara 397 cultivar produced in Kitamura in 2001, (2) Kirara 397 cultivar produced in Kitamura in 2002, (3) Kirara 397 cultivar produced in Naganuma in 2002 and (4) Hoshinoyume cultivar produced in Bibai in 2001. Kirara 397 and Hoshinoyume are very popular Japonica type nonglutinous rice cultivars in Hokkaido. The raw brown rice samples were obtained immediately after hulling process (and before thickness grading) in each facility, and quantities of samples were 60 to 140 kg.

Thickness Grader

The thickness grader used in this study was a TWS model manufactured by Satake Co. (Tokyo, Japan). The sieve of the thickness grader is a horizontally rotating octagonal slotted screen (about 300 mm in diameter and 200 mm in length) with long and narrow slots on the peripheral surface of the screen. The width of sieve slot can be changed from 1.70 mm to 2.10 mm in 0.05-mm steps. Raw brown rice introduced into the rotating screen is separated on the basis of grain thickness into two groups: rice grains thinner than and rice grains thicker than the sieve slot. The small thickness group contains many more immature and chalky kernels than does the large thickness group, and the large thickness group therefore has more sound whole kernels than does raw brown rice.

Color Sorter

The color sorter used in this study was a GDM-120 model manufactured by Anzai Manufacturing Co. (Chiba, Japan). Each single brown rice kernel slides down an inclined chute and then the kernel freely falls down from the end of the chute. Color and moisture of the kernel are detected using visible and near-infrared rays during the free fall. Immature, chalky, damaged (with dark color) and discolored kernels and foreign materials such as small stones, pieces of grass and plastic (with no moisture) are removed from the raw brown rice using an air ejector based on color and moisture information.

Method of Sample Preparation and Sample Names

The method of sample preparation and sample names are shown in Figure 1. Conventional standard sieve slot widths of a thickness grader for Kirara 397 and Hoshinoyume cultivars are 2.00 mm and 1.95 mm, respectively. Raw brown rice of Kirara 397 was sorted using a thickness grader (TG) with a sieve slot width of 1.80 mm, 1.90 mm or 2.00 mm. Kirara 397 products obtained from the TG (sorted brown rice samples) were named “TG 1.80”, “TG 1.90” and “TG 2.00”. Raw brown rice of Hoshinoyume was sorted using a thickness grader with a sieve slot of 1.75 mm, 1.85 mm or 1.95 mm. Hoshinoyume products obtained from the TG were named “TG 1.75”, “TG 1.85” and “TG 1.95”. TG 2.00 of Kirara 397 and TG 1.95 of Hoshinoyume are conventional products obtained from the TG. Sorting yield after passage through the TG was defined as percentage of the product weight after passage through the TG divided by raw brown rice weight.

Products obtained from the TG were then further sorted using a color sorter (CS). The color sorter was adjusted in two or three trial runs to obtain high performance. Kirara 397 products obtained from the CS (sorted brown rice samples) were named “TG 1.80 CS”, “TG 1.90 CS” and “TG 2.00 CS”, and Hoshinoyume products were named “TG 1.75 CS”, “TG 1.85 CS” and “TG 1.95 CS”. Sorting yield after passage through the TG and CS was defined as percentage of product weight after passage through the CS divided by raw brown rice weight.

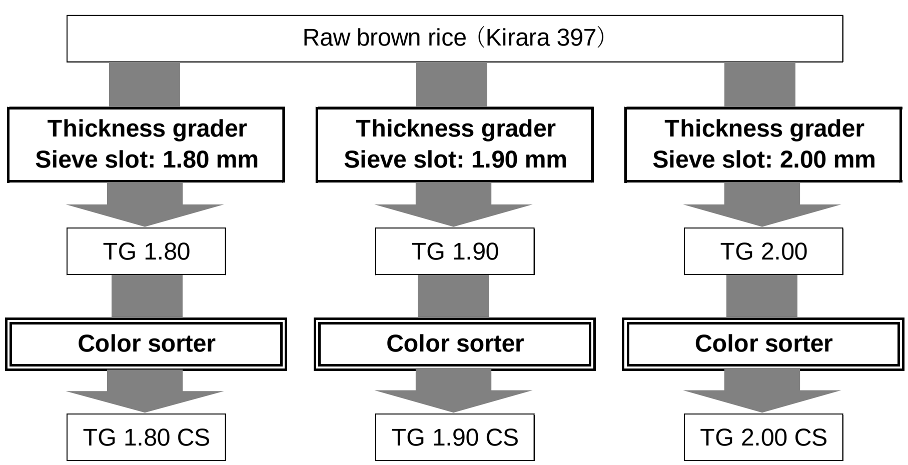

Figure 1. Sample preparation and sample names.

Quality Assessment

Quality characteristics of brown rice and milled rice samples were determined by the following methods.

Moisture content was determined using the standard method of the Japanese Society of Agricultural Machinery; about 10 g of whole grain was placed in a forced-air oven at 135C for 24 h, and moisture content was calculated on a wet basis.

Components of brown rice were divided by human observation into six categories: sound whole kernels, immature kernels, chalky kernels, damaged kernels, discolored kernels and broken kernels. The components were expressed as a percentage of weight.

Thickness distribution of brown rice was determined using a shaker with sieves of long-narrow slots (Tokyo Testing Machine Inc., Toyohashi, Japan). Brown rice was divided into six categories in 0.1-mm steps from less than 1.80 mm to more than 2.20 mm based on kernel thickness. The thickness distribution was expressed as a percentage of weight. Weighted mean of thickness was calculated by the thickness distribution.

Grade of brown rice was determined by a professional human inspector into four categories (no. 1, no. 2, no. 3 and out of grade) according to the Japan Agricultural Standards.

Milled rice samples were processed from brown rice samples using a commercial friction mill (MCM-250, Satake Co., Tokyo, Japan). Milling yield was calculated as percentage of milled rice weight divided by brown rice weight. Milling of samples was performed under the same milling conditions (same milling pressure and four passages through the mill) using a friction mill.

A sensory test was carried out according to the Japanese official rice taste testing method standardized by the Japan Food Agency. The sensory test was a multiple comparisons test. Sensory evaluation items were appearance, aroma, taste, hardness, cohesiveness and overall flavor. The evaluation value ranged from -3 to +3 for each item.

Results

Moisture content, components and grade of raw brown rice are shown in Table 1. Moisture contents of the four raw brown rice samples ranged from 15.9 to 16.5%, less than the upper limit of the moisture standard (17%, w.b., 135C) in Japan.

According to the Japanese agricultural standards, the highest grade (no. 1) of brown rice has a minimum of 70% of sound whole kernels and a maximum of one discolored kernel per 1000 kernels (0.1%). If the brown rice contains two discolored kernels per 1000 kernels, the rice is downgraded to a no. 2 rice, even if all other specifications of no. 1 rice are met. If the brown rice contains more than seven discolored kernels per 1000 kernels (0.7%), the rice is downgraded to an out-of-grade rice. Percentages of sound whole kernels and percentages of discolored kernels in the four raw brown rice samples ranged from 69.7 to 73.6% and from 0.5 to 1.6%, respectively. One of the samples (2002, Kitamura, Kirara 397) was accordingly graded no. 3 and three of them were out of grade. Therefore, fine sorting of brown rice is an important step in producing a high-quality brown rice.

Thickness distributions and mean thicknesses of raw brown rice kernels are shown in Table 2. Thickness distribution of brown rice kernels is one of the characteristics of each rice cultivar. The thickness of Kirara 397 kernels is usually larger than that of Hoshinoyume kernels. The conventional standard sieve slot width of a thickness grader for Kirara 397 is hence 2.00 mm and that for Hoshinoyume is 1.95 mm. However, the thickness distribution of a rice cultivar often varies with cultivation conditions such as crop year (weather) and production place (soil).

Among the four rice samples, the mean kernel thickness of raw brown rice was largest for Kirara 397 produced in Kitamura in 2001 (2.134 mm) and smallest for Kirara 397 produced in Naganuma in 2002 (2.066 mm) .

Table 1. Moisture contents, components and grades of raw brown rice samples.

Sample			Moisture content (%, w.b., 135C)	Percentage of weight (%)						Grade
Variety	Production place	Crop year		Sound whole kernels	Immature kernels	Chalky kernels	Damaged kernels	Discolored kernels	Broken kernels	
Kirara 397	Kitamura	2001	16.3	72.6	16.0	1.3	8.4	1.3	0.4	OG
Kirara 397	Kitamura	2002	16.3	69.7	21.0	0.3	8.1	0.5	0.4	No.3
Kirara 397	Naganuma	2002	15.9	73.6	12.6	0.2	12.0	1.2	0.4	OG
Hoshinoyume	Bibai	2001	16.5	72.8	13.7	0.4	10.3	1.6	1.1	OG

OG: Out of grade

Table 2. Thickness distributions and mean thicknesses of raw brown rice kernels.

Sample			Percentage of weight (%)						Mean thickness (mm)
Variety	Production place	Crop year	Less than 1.80 mm	More than 1.80 mm Less than 1.90 mm	More than 1.90 mm Less than 2.00 mm	More than 2.00 mm Less than 2.10 mm	More than 2.10 mm Less than 2.20 mm	More than 2.20 mm	
Kirara 397	Kitamura	2001	2.0	1.3	4.4	12.9	61.3	18.2	2.134
Kirara 397	Kitamura	2002	1.3	1.9	9.1	26.0	52.0	9.7	2.104
Kirara 397	Naganuma	2002	2.1	4.0	15.3	35.1	41.0	2.5	2.066
Hoshinoyume	Bibai	2001	2.7	2.1	8.0	26.7	56.8	3.7	2.092

Sorting yields, percentages of sound whole kernels and grades of brown rice samples sorted by a thickness grader or by a combination of a thickness grader and a color sorter are shown in Table 3. When sieve slot width of the thickness grader was reduced by 0.1 mm from the conventional standard sieve slot width (2.00 mm for Kirara 397 and 1.95 mm for Hoshinoyume), sorting yields increased by 10.1 - 20.2%. When samples were sorted by a thickness grader with sieve slot width of 0.1 mm smaller than the standard and then sorted by a color sorter, the sorting yields increased by 4.2 - 11.3%. These results indicate that sorting yield was increased by the use of a combination of a thickness grader with reduced sieve slot width from the conventional standard width and a color sorter.

When sieve slot width was reduced by 0.1 mm or 0.2 mm, percentages of sound whole kernels decreased. However, when samples were sorted by a thickness grader with sieve slot width of 0.1 mm or 0.2 mm smaller than the standard and then sorted by a color sorter, percentages of sound whole kernels increased.

Grades of brown rice samples improved after passage through a thickness grader with the conventional standard sieve slot width. When sieve slot width was reduced by 0.1 mm or 0.2 mm from the standard, there was little improvement in rice grades and some samples still remained out of grade. However, when samples were sorted by a thickness grader and then sorted by a color sorter, the samples were upgraded to no. 1 or no. 2. In case of the samples of Kirara 397 produced in Kitamura in 2001, grades of the samples were no. 2 because there were two or more discolored kernels per 1000 kernels even though all other specifications of no. 1 rice were met.

The results for sorting yield, percentage of sound whole kernels and grade of brown rice indicate that sorting yield increased, percentage of sound whole kernels increased and rice grade improved when raw brown rice was sorted by a thickness grader with sieve slot width smaller than the conventional standard and then sorted by a color sorter.

Table 3. Sorting yields, percentages of sound whole kernels and grades of brown rice samples.

Sample	Combination	Sorting yield (%)			Sound whole kernel (%)			Grade		
		Sieve slot of TG			Sieve slot of TG			Sieve slot of TG		
		1.80 mm	1.90 mm	2.00 mm	1.80 mm	1.90 mm	2.00 mm	1.80 mm	1.90 mm	2.00 mm
Kirara 397 Kitamura 2001	Only TG	97.3	94.1	**84.0**	73.4	74.9	**78.4**	OG	OG	**No. 3**
	TG and CS	88.2	**88.2** ↙	81.5	80.6	**80.8** ↙	79.3	No. 1	**No. 2** ↙	No. 2
Kirara 397 Kitamura 2002	Only TG	98.5	95.9	**84.5**	70.6	72.3	**75.8**	No. 3	No. 2	**No. 2**
	TG and CS	89.6	**89.5** ↙	81.9	75.5	**75.9** ↙	75.9	No. 1	**No. 1** ↙	No. 1
Kirara 397 Naganuma 2002	Only TG	98.1	92.5	**72.3**	74.0	76.4	**81.8**	OG	OG	**No. 3**
	TG and CS	84.9	**83.6** ↙	67.3	85.6	**84.6** ↙	85.3	No. 1	**No. 1** ↙	No. 1
		Sieve slot of TG			Sieve slot of TG			Sieve slot of TG		
		1.75 mm	1.85 mm	1.95 mm	1.75 mm	1.85 mm	1.95 mm	1.75 mm	1.85 mm	1.95 mm
Hoshinoyume Bibai 2001	Only TG	97.5	94.1	**79.7**	68.7	69.8	**75.2**	No. 3	No. 3	**No. 2**
	TG and CS	85.9	**85.6** ↙	76.9	77.5	**78.1** ↙	77.0	No. 1	**No. 1** ↙	No. 1

CS: Color sorter TG: Thickness grader OG: Out of grade

Figure 2 shows milling yields of samples of Kirara 397 produced in Kitamura in 2001 milled under the same milling conditions. Milling yield of the sample sorted by a thickness grader with a sieve slot width of 2.00 mm (TG 2.00) was 90.1%. On the other hand, milling yield of the sample sorted by a thickness grader with a slot width of 1.90 mm and then sorted by a color sorter (TG 1.90 CS) was 90.4%. Milling yields of TG 1.90 and TG 1.80 were lower than that of TG 2.00 because of the lower percentage of sound whole kernels and larger percentage of kernels with small thicknesses. Milling yield of TG 1.80 CS was lower than that of TG 1.90 CS because of the larger percentage of kernels with small thicknesses. The sample with the highest milling yield was TG 1.90 CS.

Figure 3 shows results of sensory evaluation (overall flavor) of samples of Kirara 397 produced in Kitamura in 2001. Sensory evaluation was highest for TG 1.90 CS.

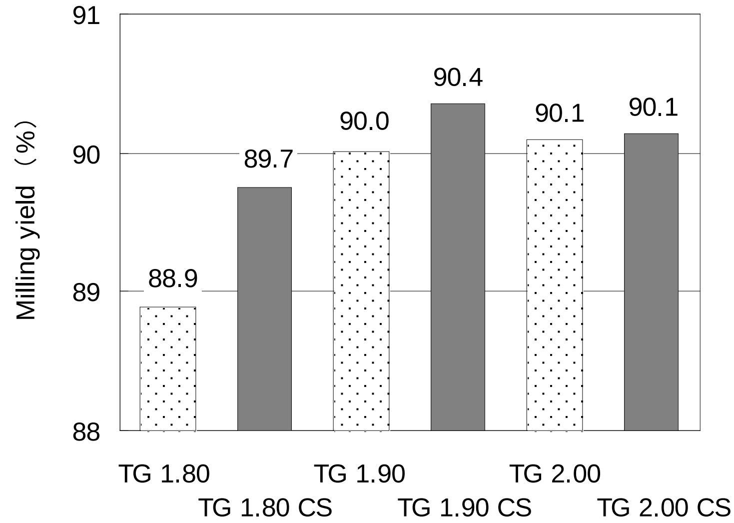

Figure 2. Milling yields (Kirara 397 produced in Kitamura in 2001).

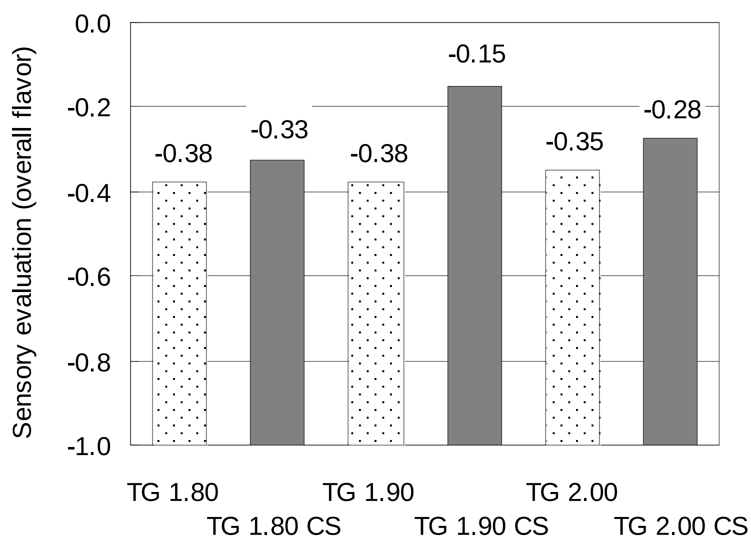

Figure 3. Sensory evaluation of cooked rice (overall flavor)
(Kirara 397 produced in Kitamura in 2001).

Discussion

For many years, only a thickness grader has been used for sorting brown rice. To increase the percentage of sound whole kernels and to improve rice grade, the sieve slot width of a thickness grader has gradually become larger. In recent years, conventional standard sieve slot widths have been 2.00 mm for Kirara 397 and 1.95 mm for Hoshinoyume. However, even using the conventional standard sieve slot widths, it has been difficult to process no. 1 grade rice and sorting yields have been very low.

A color sorter has been used for many years to sort white rice (milled rice). A combination of a thickness grader with sieve slot width smaller than the conventional standard width and a color sorter could be used to increase sorting yield and percentage of sound whole kernels, as well as to improve grade of brown rice. However, the use of a sieve slot width of 0.2 mm smaller than the conventional standard width has resulted in low milling yield and low eating quality. The results of this study showed that the use of a combination of a thickness grader with sieve slot width 0.1 mm smaller than the conventional standard width and a color sorter is the best method for processing brown rice of high quality and high yield (see bold lettering in Table 3).

The new technique for fine sorting of brown rice by use of a combination of a thickness grader and a color sorter developed in this study has been in practical use in Hokkaido and spreading now in Japan. The amounts of Kirara 397 and Hoshinoyume produced in Hokkaido in 2006 were 263 kt and 173 kt, respectively. Calculations show that the use of the technique for fine sorting of brown rice would result in increases in rice production of 13 kt and 12 kt because of increases of sorting yield of each cultivar (4% and 6%) . The total amount of increase in rice farmers' income would be 12 million US$.

Conclusion

It was found that a greater sorting yield and processed rice of high quality can be obtained by reducing the width of the sieve slot of a thickness grader by 0.10 mm from the conventional standard slot width and then removing immature, damaged and discolored kernels by the combined use of a color sorter. By using the brown rice fine sorting technique developed in this study, rice farmers' income can be increased and high-quality rice can be supplied to consumers.