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Development of a System for Fine Cleaning of Rough Rice for High-Quality Storage

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Abstract. *Bulk rough rice after drying consists of sound whole kernels, immature kernels, empty kernels, damaged kernels, hulled kernels and foreign materials such as straw, weed seed and dust. Fine cleaning of rough rice is an important step after drying to improve rough rice quality and to minimize quality deterioration of rough rice during storage.*

We developed a system for fine cleaning of rough rice. The system consists of a wind separator, gravity separator and indented cylinder separator. The wind separator removes straw, weed seed, dust and empty kernels by means of an air stream. The gravity separator discharges four streams of material: a mixture of sound whole kernels and hulled kernels; good rough rice product (mostly sound whole kernels); a mixture of sound whole kernels, damaged kernels and immature kernels, which is returned through the wind separator and gravity separator to achieve a complete separation; and a mixture of damaged kernels, immature kernels and empty kernels that is removed from the line. The indented cylinder separator removes hulled kernels from the mixture of sound whole kernels and

hulled kernels discharged from the gravity separator. The sound whole kernels separated by the indented cylinder separator are mixed with the good rough rice product from the gravity separator.

The fine cleaning system developed in this study enables separation and removal of immature kernels, empty kernels, damaged kernels and hulled kernels and therefore improvement in rough rice quality. The fine cleaning system has been in practical use in Japan.

Keywords. rough rice, fine cleaning, storage, wind separator, gravity separator, indented cylinder separator

Introduction

For hundreds of years, the common rice storage system in Japan has been a brown rice storage system, which is a system to store brown rice in a rice warehouse after drying and hulling. However, in terms of rice quality preservation, rough rice storage is better than brown rice storage. Therefore, country elevators (rice grain elevators) to store rough rice in silos after drying have increased in recent decades in Japan.

Bulk rough rice after drying consists of sound whole kernels, immature kernels, empty kernels, damaged kernels, hulled kernels (i.e., brown rice hulled during harvesting and drying, and deteriorated grain) and foreign materials such as straw, weed seed and dust. Fine cleaning of rough rice is an important step after drying to improve rough rice quality and to minimize quality deterioration of rough rice during long-term bulk storage in a grain silo. However, there has been no appropriate system for fine cleaning of rough rice for high-quality storage. The objectives of this study were to determine separating characteristics of several separators that may be used for a rough rice cleaning system and to develop a fine cleaning system of rough rice.

Materials and Methods

The rice samples used in this study were Kirara397 and Hoshinoyume varieties, which are commercial Japonica non-waxy varieties and were produced in Hokkaido, Japan in 1996, 1997, 1998 and 1999.

Separating characteristics of rough rice were examined using several kinds of separators shown in Table 1, i.e., a wind separator, indented cylinder separator, thickness separator, paddy separator and gravity separator.

Table 1. Separators used in this study.

Separator	Make and model	Capacity (t/h)
Wind separator	Satake, AS-15A	15.0
	Yanmar, PAS-200	20.0
	Kongskilde, KF-12	12.0
Indented cylinder separator	Satake, LRG-102F	1.5
	Carter Day, Uni-Flow 3Hi	3.0
Thickness separator	Satake, WS-600A	5.0
Paddy separator	Satake, PS-800E	7.5
Gravity separator	Oliver, 4800A	10.0
	Harasima, MH-506	9.0

Each separator was adjusted properly for a rough rice cleaning experiment by a machine operator at a country elevator. Sampling of rough rice at 10-minute intervals and measurement of flow rate at 20-minute intervals were carried out over a period of three hours for each experiment. To examine the separating characteristics of the gravity separator in detail, the discharge gate of the separation deck end was divided into 14 sections and 14 rough rice samples were taken from each section at 10-minute intervals during the experiment. Composition analysis of the rough rice samples and a hulling test were done, and free fat acidity of hulled brown rice was determined by the rapid method of the American Association of Cereal Chemists (AACC, method 02-02).

Results and Discussion

Separating Characteristics of Each Separator

A wind separator removes straw, weed seed, dust and empty kernel, which are lighter than rough rice, by means of an air stream.

An indented cylinder separator removes hulled kernels based on the difference in size from rough rice. Hulled kernels are brown rice kernels hulled by mechanical and physical action during harvesting and drying. Hulled kernels should be removed before rough rice storage because of high free fat acidity (i.e., of low quality) and more increase in free fat acidity than sound whole kernels during storage.

A thickness separator is usually used for brown rice cleaning to remove thin kernels (chalky and immature brown rice). We tried to use a thickness separator to remove hulled kernels from rough rice. However, some hulled kernels remained in rough rice after separating and some rough rice was mixed in hulled kernels after separating. The performance of the thickness separator was therefore not sufficient for rough rice cleaning.

A paddy separator is usually used for separating rough rice from brown rice based on grain size after hulling. Hulled kernels (brown rice) were concentrated at one end of the discharge gate of the separation deck end of the paddy separator, but rough rice was not sorted into sound whole kernels, immature kernels and damaged kernels. A paddy separator can therefore be used for separation of hulled kernels but can not be used for classification of rough rice.

A gravity separator separates materials based on particle density. Figure 1 shows the percentage of each component in samples taken from 14 discharge gates of the separation deck end of a gravity separator. Hulled kernels were concentrated at the good product side of the separation deck end (discharge gate 1). Percentage of sound whole kernels was higher in the sample at the good product side. Percentages of immature kernels, empty kernels and damaged kernels were the highest in the sample taken from the waste side (discharge gate 14). Figure 2 shows percentage of hulling yields and sound brown rice yields of samples taken from 14 discharge gates of the separation deck end of the gravity separator. Hulling yield and sound brown rice yield of samples from the good product side were higher than those of waste side samples. Figure 3 shows free fat acidity of samples taken from 14 discharge gates of the separation deck end of the gravity separator. Free fat acidity dramatically increased along the discharge gate from the good product side to waste side. These results indicate that a gravity separator concentrates hulled kernels, classifies rough rice based on maturity, and removes low quality rice.

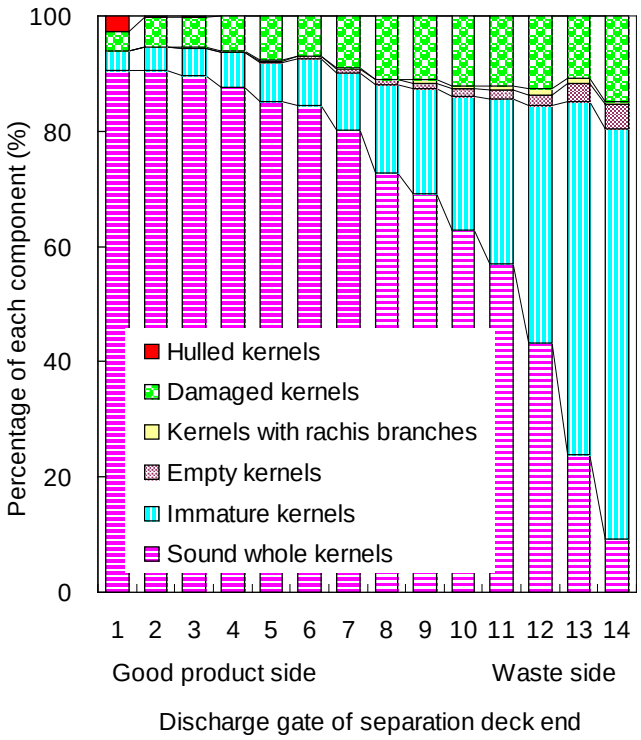

Figure 1. Percentage of each component in samples from 14 discharge gates of the separation deck end of a gravity separator.

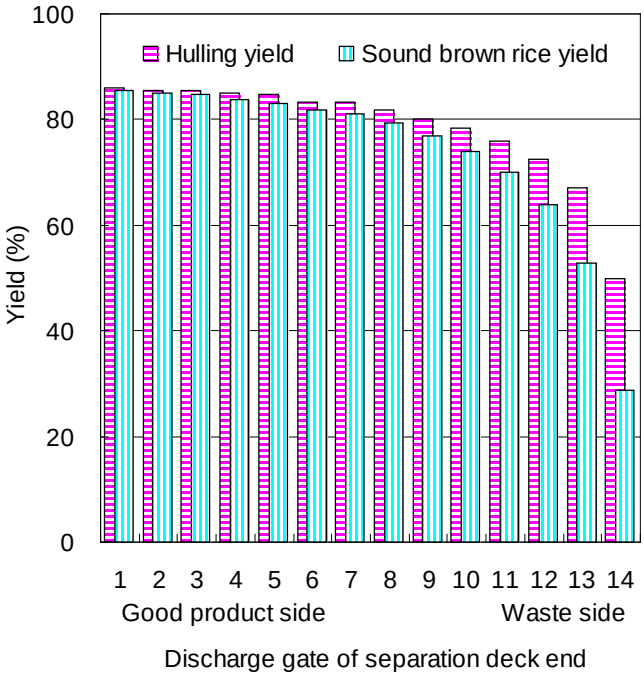

Figure 2. Hulling yields and sound brown rice yields of samples from 14 discharge gates of the separation deck end of a gravity separator.

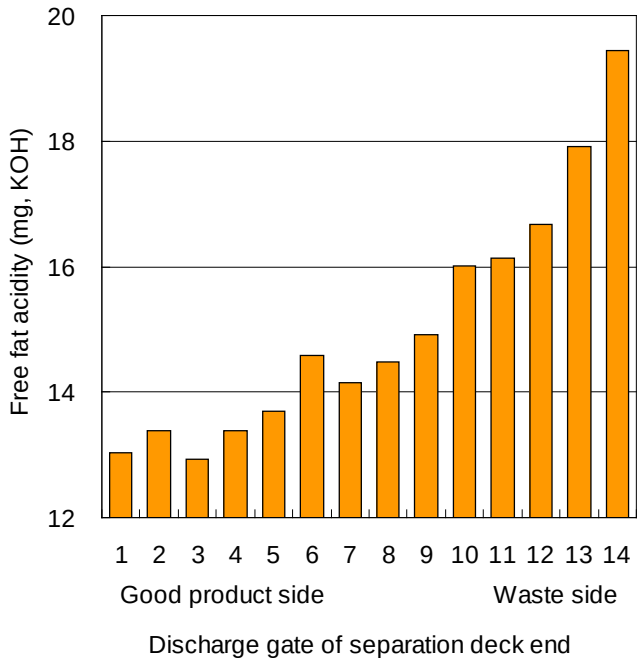

Figure 3. Free fat acidity of samples from 14 discharge gates of the separation deck end of a gravity separator.

Development of a Fine Cleaning System

We developed a system for fine cleaning of rough rice. A flowchart of the fine cleaning system is shown in Figure 4. The system consists of a wind separator (WS), gravity separator (GS) and indented cylinder separator (ICS). Raw rough rice is first fed into the wind separator. The wind separator removes straw, weed seed, dust and empty kernels. Rough rice that has passed through the wind separator is then fed into the gravity separator, which is the main feature of the fine cleaning system. The gravity separator discharges four streams of material: a discharge gate at the end of the good product side of the separation deck end discharges a mixture of sound whole kernels and hulled kernels that is of high density; a discharge gate in the middle of the separation deck end discharges good rough rice product (mostly sound whole kernels); a discharge gate close to the waste side of the separation deck end discharges a mixture of sound whole kernels, damaged kernels and immature kernels, which is returned through the wind separator and gravity separator to achieve a complete separation; and a discharge gate at the end of the waste side of the separation deck end discharges a mixture of damaged kernels, immature kernels and empty kernels that is of low density and removed from the line. The discharge gate at the end of the good product side for the mixture of sound whole kernels and hulled kernels is an original and unique gate of the rough rice fine cleaning system. The indented cylinder separator removes hulled kernels based on the difference in size from the mixture of sound whole kernels and hulled kernels discharged from the gravity separator. The sound whole kernels separated by the indented cylinder separator are mixed with the good rough rice product from the gravity separator. The good rough rice product after fine cleaning is loaded into a silo for long-term storage.

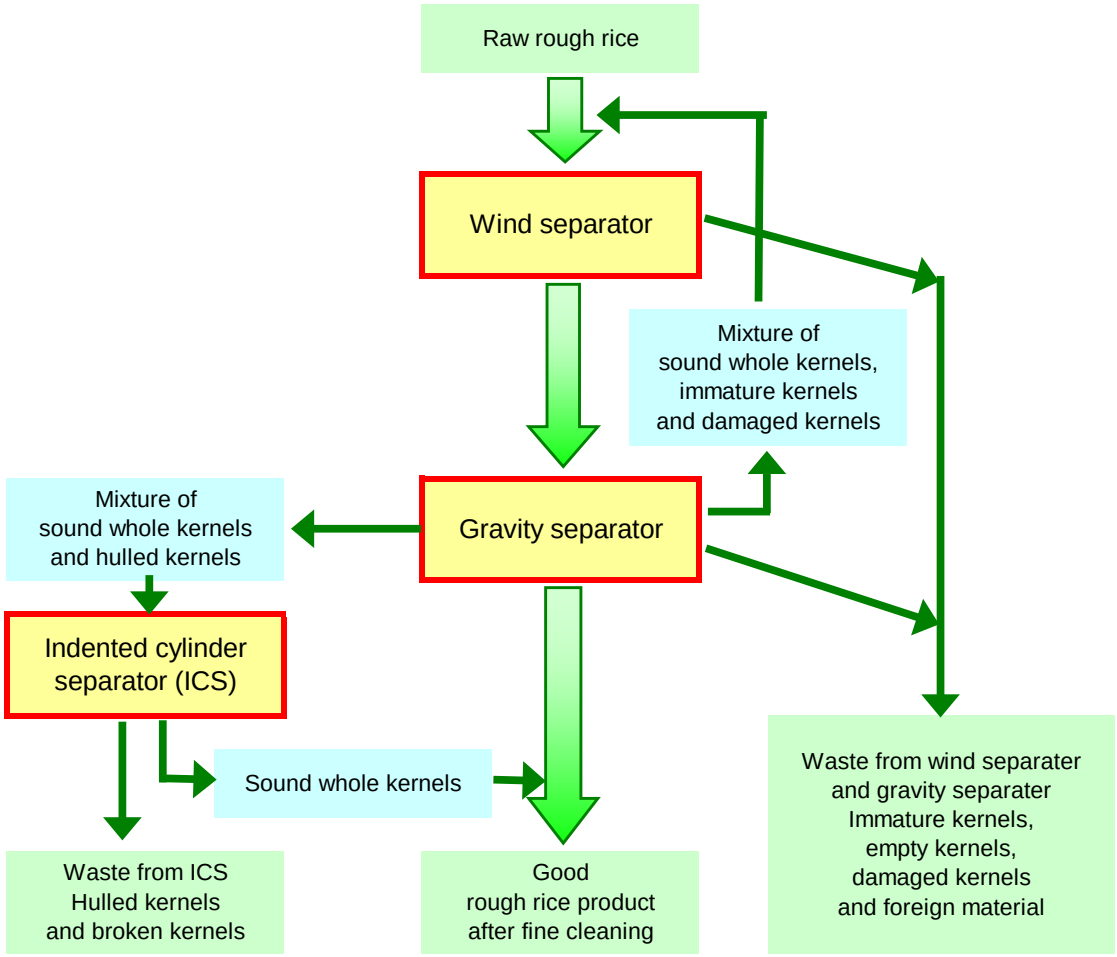

Figure 4. Flowchart of the system for fine cleaning of rough rice for high-quality storage.

Table 2 shows an example of performance of a fine cleaning system installed in a country elevator. Flow rate of raw rough rice was 14.3 t/h. Yield of good rough rice product was 95.4%. Sound whole kernel ratio increased from 79.3% to 86.8%, immature kernel ratio decreased from 10.7% to 7.9%, damaged kernel ratio decreased from 7.0% to 4.8% and hulled kernel ratio decreased from 0.6% to 0.4% after fine cleaning. Hulled kernels were concentrated to 77.5% in waste from indented cylinder separator. Immature kernels were concentrated to 75.5% in waste from wind separator and gravity separator. Sound whole kernels in waste from indented cylinder separator, and waste from wind separator and gravity separator were 0.5% and 2.2%, respectively. The fine cleaning system developed in this study enables separation and removal of immature kernels, empty kernels, damaged kernels and hulled kernels and thus improvement in rough rice quality and minimization of quality deterioration of rough rice during storage. The fine cleaning system has been in practical use in Japan.

Table 2. Performance of the fine cleaning system.

Material	Mass balance		Composition of material							
	Flow rate	Ratio	Sound whole kernels	Immature kernels	Empty kernels	Kernels with rachis branches	Damaged kernels	Hulled kernels	Broken kernels	Foreign material
	(t/h)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Raw rough rice	14.30	100.0	79.3	10.7	1.3	0.8	7.0	0.6	0.2	0.3
Good rough rice product after fine cleaning	13.64	95.4	86.8	7.9	0.0	0.1	4.8	0.4	0.0	0.0
Waste from ICS	0.08	0.6	0.5	0.2	0.0	0.0	0.1	77.5	21.6	0.1
Waste from wind separator and gravity separator	0.58	4.0	2.2	75.5	3.3	0.2	18.5	0.2	0.1	0.1

Two gravity separators are used in parallel in this system.

Conclusion

We developed a system for fine cleaning of rough rice. The system consists of a wind separator, gravity separator and indented cylinder separator. The fine cleaning system developed in this study enables separation and removal of immature kernels, empty kernels, damaged kernels and hulled kernels and thus improves rough rice quality and minimizes quality deterioration of rough rice during storage. The fine cleaning system has been in practical use in Japan.

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