Study on the Geometrical Properties of Brown Rice on Shape Factors

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Abstract

Purpose: This study was conducted to investigate the optimal sorting factors in establishing an efficient sorting technology for brown rice. **Methods:** The brown rice varieties used in this study were Il Pum, Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An. These were classified into whole grain, unriped grain, and green dead rice. The shape factors were analyzed based on length, width and thickness of the grains. **Results:** The results revealed that the maximum length among whole grain, unriped grain, and green dead rice was observed in Dae An variety while Chu Cheong variety showed the minimum. Further more, Il Pum brown rice showed the maximum width while Dong Jin variety showed the minimum. In the case of thickness, the maximum was observed in Un Gwang variety and that of the minimum among Nam Pyeong variety for both whole grain and unriped grain. **Conclusions:** The length and width can be used as determinants in sorting factors of whole grain and green dead rice, and the thickness can be considered as optimum sorting factor of whole grain and unriped grain.

Keywords: Brown rice, Shape factors, Sorting factors, Length, Width, Thickness

Introduction

Breeding and selection of rice varieties are very important, steps in nice cultivation of suitable lands, because variety contribute to the productivity by 60 ~ 70% (Yoon et al., 2005). Especially, after cultivation of Tong Il-type rice in 1970s, the rice industry became very stable with rice production reaching self-sufficiency status in Korea. Later however, a interest shifted from Tong Il rice to Japonica rice and the breeding aim also turned increasing production into improving quality with consumer demands for high quality rice in 1980 ~ 1990s. As a result of the improvement of rice variety and development of culture techniques, Korean rice production reached 5263 kilotons in the 1999s. However, rice imports according to MMA (Minimum Market Access) increased in the following years given: 2005s-22.5 kilotons →

2006s-24.6 kilotons →2007s-26.6 kilotons → 2008s-28.7 kilotons → 2009s-79.8 kilotons →2010s-98.1 kilotons → 2011-104.2 kilotons) and rice consumption per head (2002s: 87 kg → 2004s: 82 kg → 2006s: 78.8 kg → 2007s: 76.9 kg→ 2009s: 74.0 kg→ 2010s: 72.8 kg→ 2011s: 71.2 kg) decreased by 1.5 kg yearly. thus rice stock lead to an excess of 144 kilotons (Choung et al., 2008). In order to improve the quality of rice, the rice industry began efforts to diversify and develop functionality further. Therefore, there is need for production of high quality rice with the comsumer demand and change in international market (Han et al., 2001). In addition, many studies of rice have been carried out, such as, breeding of new rice varieties, growth characteristics (Lee, 2010), pest resistance (Kawata et al., 1992; Bughio and Wilkins, 2004), milling characteristics (Kim et al., 2009), and sensory characteristics (Park et al., 2011).

On the other hand, the quality and production of rice are closely related to variety and grown environment, harvesting, drying, storage and milling (Kim et al., 2001).

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With changes in dietary patterns and improved living standards, various varieties of the rice including Il Pum, Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An, which have good taste and high productivity, are widely cultivated in Korea.

However, in the initial RPC (Rice Processing Complex) step of rice processing, it may lead the energy loss and the degradation of rice quality resulting from the difference of rice shape and characteristics of the new rice varieties. Thus, in the future, it is necessary to develop the RPC processing model, which is able to save energy and production of high quality rice.

Subsequent to this, basic data for sorting rice according to the rice shape factor were required. However, limited attention has been given to the study of the geometric characteristics of brown rice.

In consideration of these issues, the present study was conducted to optimize the sorting factors and the geometrical properties of brown rice, and establish the efficient sorting technology.

Materials and Methods

Materials

The brown rice varieties used in this study were Il Pum,

Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An. They were harvested in 2009. The initial moisture content of the brown rice were 21.3% (w.b) (Il Pum), 22.0% (Chu Cheong), 19.4% (Dong Jin), 18.3% (Un Gwang), 19.0% (Nam Pyeong), and 19.0% (Dae An), respectively. The rough rice was dried at a rate of 1% decrease in moisture content, and until the final moisture content reached 13% using a hot air dryer. The dried rough rice was then processed into brown rice for the experiment. There is no information about the number of samples. Are the length, width and thickness the average values? Mention about it.

Experimental methods

The rough rice was hulled by a rice husker (FCEK, Yamamoto, Japan) according to their moisture content, and then classified as whole grain, unriped grain, and green dead rice using a 1.75 mm sieve separator. The number of grain samples were over the 1,000 kernels. The length and width of brown rice were measured by a grain discriminator (RN-500, Kett, Korea), and the thickness of brown rice was measured by a thickness gauge (G, PEACOCK, Japan) as shown in Figure 1. The measured data of length, width and thickness of brown rice calculated the average values.

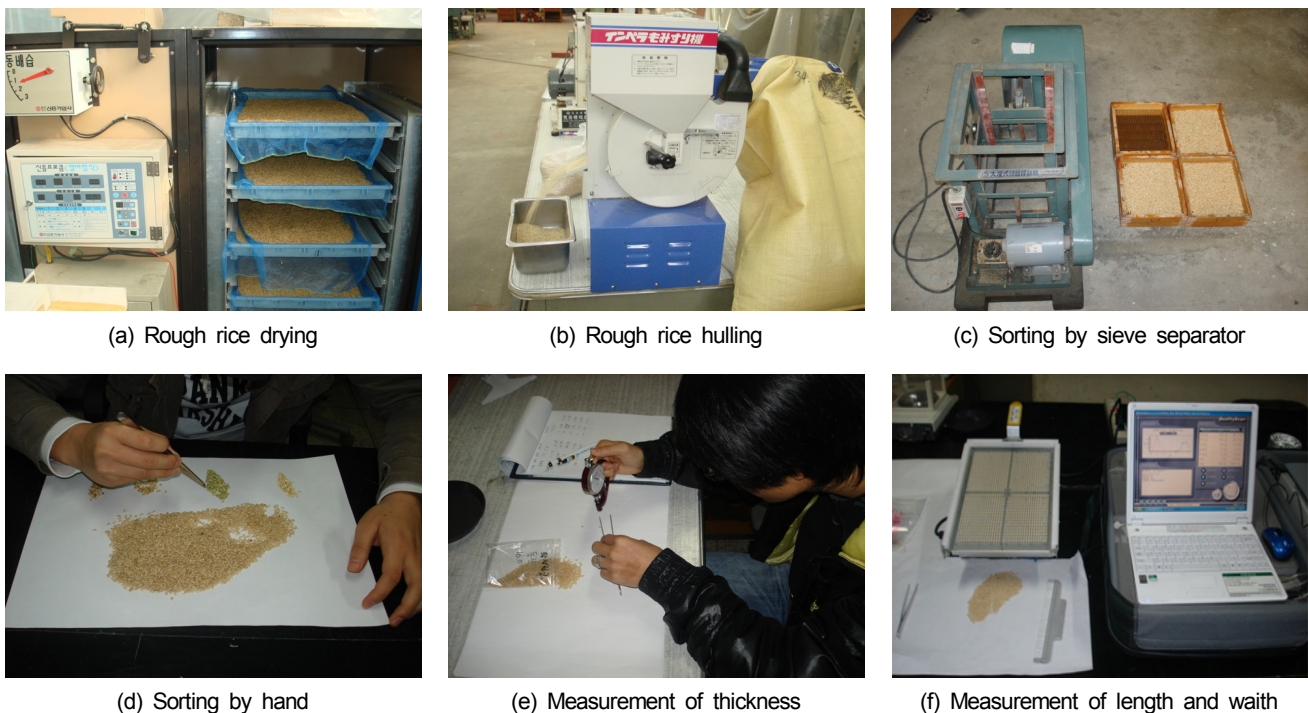The moisture content of brown rice was measured

(a) Rough rice drying   (b) Rough rice hulling   (c) Sorting by sieve separator
(d) Sorting by hand   (e) Measurement of thickness   (f) Measurement of length and waith

Figure 1. Sorting process and measurement of the geometrical properties.

with the air-oven method. 10±0.5 grams of each sample was taken and dried in an experimental dryer (WFO-600ND, TokyoRi-kakai, Japan) at a temperature of 135℃ for 24 hours. Moisture content (M_{135}, %) was determined from the ratio of the weight changes before and after drying. Then, the moisture content (M_{135}, %) was changed into 105℃ standard moisture content using the following Eq. (1) (Yon et al., 2001):

$$M_{105} = 100 - 1.012(100 - M_{135}) \qquad (1)$$

The correction of brown rice according to moisture content

The difference in the initial and final moisture content on the brown rice varieties occurred during drying process. Therefore, in order to compare the length, width, and thickness by brown rice varieties, the correction equation was made using moisture content. The change in the shape factors were evaluated by correction moisture content changes at 18, 17, 16, 15, 14 and 13%.

Results and discussion

The changes of length according to moisture content and varieties

Whole grain

The changes of the length with moisture content are shown in Figure 2. In all kinds of brown rice varieties, there was decrease in the length with decreasing moisture content, and in the case of Il Pum, Chu Cheong, Dong Jin, and Nam Pyeong, the length decreased by a small margin after 15% moisture content. The Dae An rice showed the highest grain length followed by Un Gwang and Dong Jin, while the shortest variety was observed in Chu Cheong.

The correction value of the length of whole grain is shown in Table 1. At 18% moisture, the correction value of the length for Il Pum, Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An variety were 5.026, 4.944, 5.172, 5.225, 5.026 and 5.320 mm, respectively. These correspondingly decreased by 0.120, 0.123, 0.124, 0.123, 0.106 and 0.120 mm at 13% moisture content. The smallest change in length was observed in Nam Pyeong variety. Dae An variety, which had the longest grain length was 0.379, 0.378, 0.377 mm longer than the shortest grain (Chu Cheong variety) at the correction moisture content of 14, 15, and 16%.
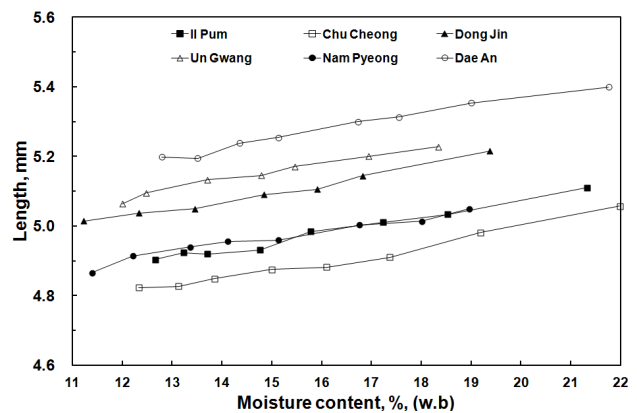

Figure 2. The variation in the length of whole grain according to moisture content and varieties.

Table 1. The correction of the length for whole grain according to moisture content and varieties			
Cultivars	Il Pum	Chu Cheong	Dong Jin
Correction equation	Y=0.0239X+4.5962	Y=0.0245X+4.5025	Y=0.0247X+4.7278
Coefficient of determination (R^2)	0.982	0.974	0.981
Correction value (mm) 16%	4.979	4.895	5.123
Correction value (mm) 15%	4.955	4.870	5.098
Correction value (mm) 14%	4.931	4.846	5.074
Cultivars	Un Gwang	Nam Pyeong	Dae An
Correction equation	Y=0.0245X+4.7278	Y=0.0211X+4.7841	Y=0.0239X+4.8899
Coefficient of determination (R^2)	0.975	0.958	0.982
Correction value (mm) 16%	5.176	4.984	5.272
Correction value (mm) 15%	5.152	4.963	5.248
Correction value (mm) 14%	5.127	4.942	5.225

Unriped grain

The variation in length according to moisture content of unriped grain is shown in Figure 3. As shown in Figure 3, Dae An variety showed the longest grain length, while no considerable difference between Dong Jin and Un Gwang variety length is shown. All unriped grain showed the same change trend in length of whole grain.

The correction value in the length of unriped grain is shown in Table 2. As shown in the table 2, the correction value for length in Il Pum, Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An variety were 4.869, 4.833, 5.057, 5.070, 4927, and 5.245 mm, respectively, at the 18% moisture content. These correspondingly decreased by 0.109, 0.106, 0.129, 0.120, 0.106, and 0.101 mm at 13% moisture content. Dong Jin variety showed the largest change in length. Dae An variety, likewise had the longest grain length, and it was at 0.373, 0.415 and 0.377

mm longer than the shortest grain (Chu Cheong variety) at correction moisture content of 14, 15, and 16%, respectively.

Green dead rice

The variation of the length of green dead rice according to moisture content is shown in Figure 4. The length of Green dead rice decreased in a linear trend for Dong Jin and Un Gwang variety. In the case of Il Pum, Chu Cheong, and Nam Pyeong variety, the length decreased by a small margin after 15% moisture content was reached. In addition, the Chu Cheong variety showed the shortest grain length compared to the other varieties. Green dead rice of Dae An variety could not be measured, because it did not exist in the testing materials of Dae An variety.

The correction value for length of green dead rice is shown in Table 3. At 18% moisture content, the correction
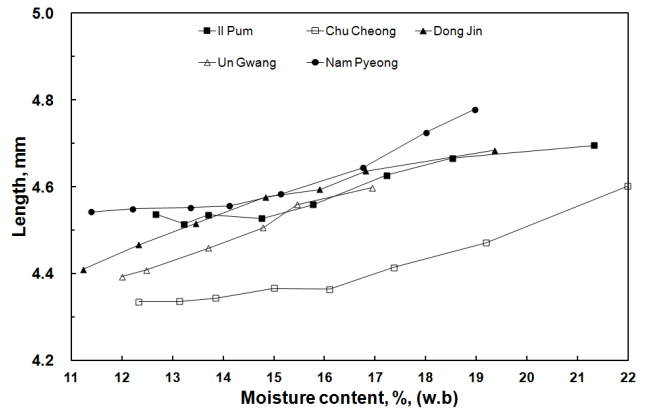

Figure 3. The variation in the length of unriped grain according to moisture content and varieties.

Figure 4. The variation in the length of dead green rice according to moisture content and varieties.

Table 2. The correction of the length of unriped grain according to moisture content and varieties

Cultivars		Il Pum	Chu Cheong	Dong Jin
Correction equation		Y=0.0218X+4.477	Y=0.0211X+4.4532	Y=0.0258X+4.5921
Coefficient of determination (R^2)		0.975	0.917	0.972
Correction value (mm)	16%	4.826	4.791	5.005
	15%	4.804	4.770	4.979
	14%	4.782	4.749	4.953

Cultivars		Un Gwang	Nam Pyeong	Dae An
Correction equation		Y=0.024X+4.6381	Y=0.0211X+4.5474	Y=0.0202X+4.8815
Coefficient of determination (R^2)		0.973	0.971	0.936
Correction value (mm)	16%	5.022	4.885	5.205
	15%	4.998	4.864	5.185
	14%	4.974	4.843	5.164

Table 3. The correction of the length of green dead rice according to moisture content and varieties

Cultivars		Il Pum	Chu Cheong	Dong Jin
Correction equation		Y=0.0225X+4.2252	Y=0.0294X+3.9239	Y=0.0340X+4.0498
Coefficient of determination (R^2)		0.913	0.934	0.967
Correction value (mm)	16%	4.585	4.394	4.594
	15%	4.563	4.365	4.560
	14%	4.540	4.336	4.526

Cultivars		Un Gwang	Nam Pyeong	Dae An
Correction equation		Y=0.0436X+3.866	Y=0.0355X+4.0763	-
Coefficient of determination (R^2)		0.987	0.912	-
Correction value (mm)	16%	4.564	4.644	-
	15%	4.520	4.609	-
	14%	4.476	4.573	-

Table 4. The correction of the width of whole grain according to moisture content and varieties

Cultivars		Il Pum	Chu Cheong	Dong Jin
Correction equation		Y=0.0218X+4.477	Y=0.0211X+4.4532	Y=0.0258X+4.5921
Coefficient of determination (R^2)		0.975	0.917	0.972
Correction value (mm)	16%	4.826	4.791	5.005
	15%	4.804	4.770	4.979
	14%	4.782	4.749	4.953

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Coefficient of determination (R^2)		0.973	0.971	0.936
Correction value (mm)	16%	5.022	4.885	5.205
	15%	4.998	4.864	5.185
	14%	4.974	4.843	5.164

value for length of Il Pum, Chu Cheong, Dong Jin, Un Gwang, and Nam Pyeong were 4.630, 4.453, 4.662, 4.65 and 4.715 mm, respectively. These correspondingly decreased by 0.112, 0.147, 0.170, 0.218 and 0.177 mm at 13% moisture content. The largest change in length was observed among green dead rice of Un Gwang variety.

The changes of width according to moisture content and varieties

Whole grain

The changes of the width of whole grain according to moisture content is shown in Figure 5. The maximum and minimum width were observed in Il Pum and Dong Jin variety, respectively. The width linearly decreased with moisture content.

The correction value for width of whole grain rice is
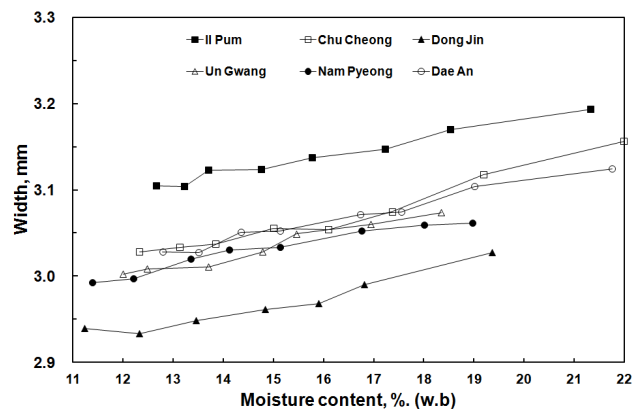
Figure 5. The variation in the width of whole grain according to moisture content and varieties.

shown in Table 4. As shown in the table 4, the correction value for width of Il Pum, Chu Cheong, Dong Jin, Un

Gwang, Nam Pyeong, and Dae An variety were 3.159, 3.096, 3.003, 3.071, 3.059 and 3.096 mm, respectively, at 18% moisture content. These values correspondingly decreased by 0.052, 0.068, 0.057, 0.060, 0.048 and 0.057 mm, respectively, at 13% moisture content. The width of Chu Cheong variety decreased by the largest margin. Furthermore, Il Pum variety with the largest grain registered 0.161, 0.159, 0.158 mm higher than that of the lowest Dong Jin at correction moisture content of 14, 15 and 16%, respectively.

Unriped grain

Figure 6 shows the variation in the width of unriped grain according to moisture content. The Il Pum and Dong Jin variety showed the maximum and minimum width, respectively. The unriped grain showed the same change trend in width as shown in the whole grain that decreased
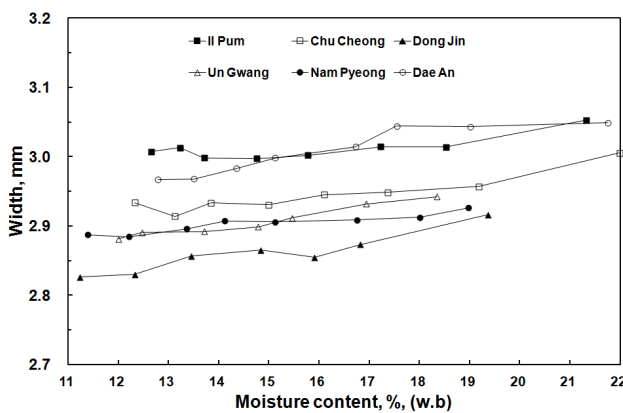
linearly with moisture content.

Table 5 shows the correction value of the width of unriped grain. At 18% moisture content, the correction value for the width of Pum, Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An variety were 3.022, 2.960, 2.892, 2.937, 2.919 and 3.022 mm respectively, and decreased by 0.035, 0.045, 0.051, 0.048, 0.024, and 0.051 mm at 13% moisture content respectively. The smallest change in width of unriped grain was shown in Nam Pyeong variety.

Green dead rice

The variation in the width of Green dead rice according to moisture content is shown in Figure 7. The maximum and minimum width were observed from Il Pum and Dong Jin variety, respectively.
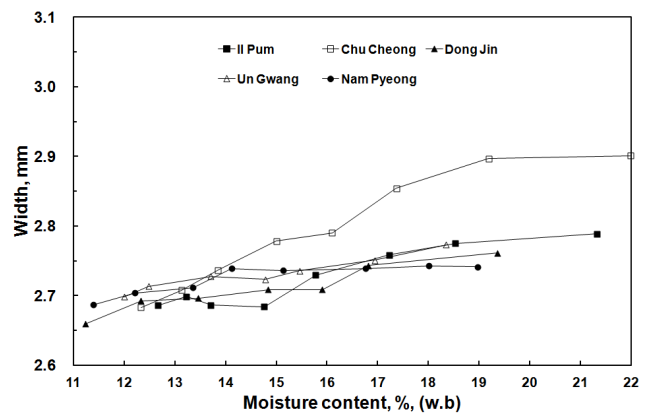
Table 6 shows the correction value in the width of

Figure 6. The variation in the width of unriped grain according to moisture content and varieties.

Figure 7. The variation in the width of dead green rice according to moisture content and varieties.

Table 5. The correction of the width of unriped according to moisture content and varieties

Cultivars		Il Pum	Chu Cheong	Dong Jin
Correction equation		Y=0.0218X+4.477	Y=0.0211X+4.4532	Y=0.0258X+4.5921
Coefficient of determination (R^2)		0.975	0.917	0.972
Correction value (mm)	16%	4.826	4.791	5.005
	15%	4.804	4.770	4.979
	14%	4.782	4.749	4.953

Cultivars		Un Gwang	Nam Pyeong	Dae An
Correction equation		Y=0.024X+4.6381	Y=0.0211X+4.5474	Y=0.0202X+4.8815
Coefficient of determination (R^2)		0.973	0.971	0.936
Correction value (mm)	16%	5.022	4.885	5.205
	15%	4.998	4.864	5.185
	14%	4.974	4.843	5.164

Table 6. The correction of the width of Green dead rice according to moisture content and varieties

Cultivars		Il Pum	Chu Cheong	Dong Jin
Correction equation		Y=0.0225X+4.2252	Y=0.0294X+3.9239	Y=0.0340X+4.0498
Coefficient of determination (R^2)		0.913	0.934	0.967
Correction value (mm)	16%	4.585	4.394	4.594
	15%	4.563	4.365	4.560
	14%	4.540	4.336	4.526

Cultivars		Un Gwang	Nam Pyeong	Dae An
Correction equation		Y=0.0436X+3.866	Y=0.0355X+4.0763	-
Coefficient of determination (R^2)		0.987	0.912	-
Correction value (mm)	16%	4.564	4.644	-
	15%	4.520	4.609	-
	14%	4.476	4.573	-

Table 7. The correction of the thickness of whole grain according to moisture content and varieties

| Cultivars		Il Pum	Chu Cheong	Dong Jin
Correction equation		Y=0.0120X+1.9767	Y=0.0182X+1.8162	Y=0.0120X+1.9032
Coefficient of determination (R^2)		0.841	0.927	0.989
Correction value (mm)	16%	2.169	2.107	2.095
	15%	2.157	2.089	2.083
	14%	2.145	2.071	2.071

Cultivars		Un Gwang	Nam Pyeong	Dae An
Correction equation		Y=0.0103X+2.0197	Y=0.0117X+1.8864	Y=0.0092X+1.9572
Coefficient of determination (R^2)		0.948	0.961	0.985
Correction value (mm)	16%	2.185	2.074	2.104
	15%	2.174	2.062	2.095
	14%	2.164	2.050	2.086

green dead rice. As seen in table 6, the correction value of the width for Il Pum, Chu Cheong, Dong Jin, Un Gwang, and Nam Pyeong variety were 2.784, 2.715, 2.621, 2.618, 2.644 and 3.096 mm, respectively, at the moisture content of 18%. These correspondingly decreased by 0.112, 0.147, 0.170, 0.218 and 0.177 mm at 13% moisture content. The largest change in width of green dead rice was shown in Un Gwang variety.

The changes of thickness according to moisture content and varieties

Whole grain

Figure 8 shows the variation in the thickness of whole grain according to moisture content and brown rice varieties. As shown in the Figure 8, Un Gwang variety observed the thickest while Nam Pyeong variety observed the thinnest in the testing materials.
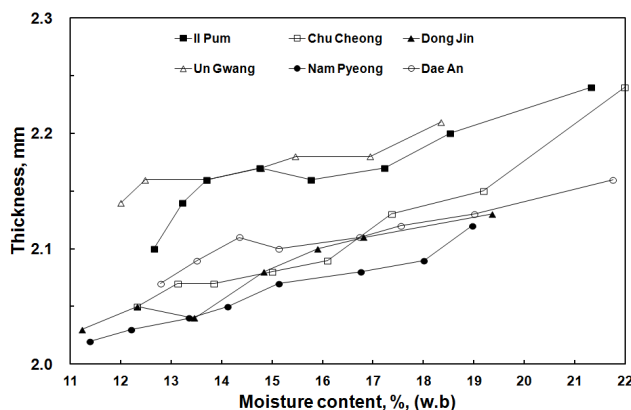
Figure 8. The variation in the thickness of whole grain according to moisture content and varieties.

In order to compare the changes of thickness of the different kinds of brown rice, the correction value for thickness of whole grain is shown in Table 7. The largest

decrement in thickness was observed in Chu Cheong variety. The correction value of the thickness for Il Pum, Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An varieties were 2.193, 2.144, 2.119, 2.205, 2.097 and 2.123 mm, respectively, at moisture content of 18%, and decreased by 0.060, 0.091, 0.060, 0.052, 0.059 and 0.046 mm at 13% moisture content. The thickness of the Un Gwang variety was 0.114, 0.112, 0.111 mm thicker than the thinnest Nam Pyeong variety at the correction moisture content of 14, 15 and 16%, respectively.

Unriped grain

The variation in the thickness of unriped grain according to moisture content is shown in Figure 9. The Un Gwang and Nam Pyeong variety showed the maximum and minimum width, respectively.
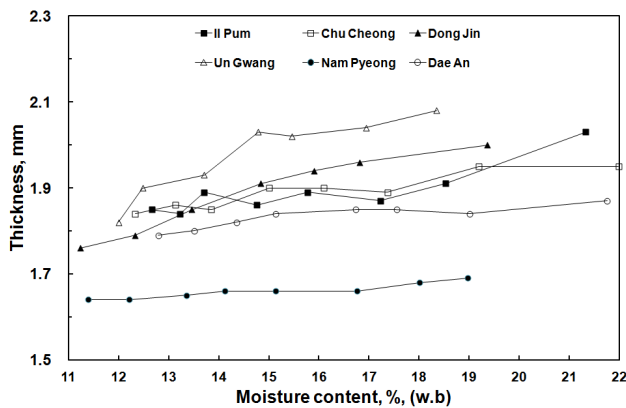
Table 8 shows the correction value in the thickness of

unriped grain. The minimum and maximum decrement in thickness were observed from Nam Pyeong and Dae An variety, respectively. At 18% moisture content, the correction value for thickness of Il Pum, Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An variety were 1.935, 1.913, 1.984, 2.104, 1.679, 1.844 mm, respectively and correspondingly decreased by 0.099, 0.061, 0.051, 0.152, 0.030, and 0.038 mm at 13% moisture content. Un Gwang variety had the thickest grain at 0.266, 0.305 and 0.346 mm thicker than the thinnest Nam Pyeong variety at the correction moisture content of 14, 15 and 16%, respectively.

Green dead rice

Figure 10 shows the variation in the thickness of green dead rice according to moisture content and brown rice varieties. The maximum and minimum thickness were
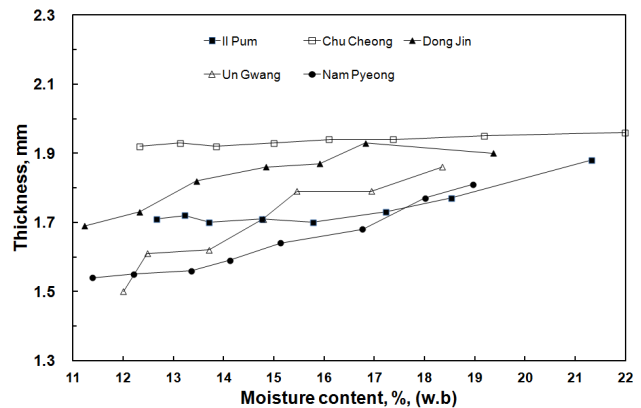

Figure 9. The variation in the thickness of unriped grain according to moisture content and varieties.

Figure 10. The variation in the thickness of green dead rice according to moisture content and varieties.

Table 8. The correction of the thickness of unriped grain according to moisture content and varieties			
Cultivars	Il Pum	Chu Cheong	Dong Jin
Correction equation	Y=0.0198X+1.579	Y=0.0122X+1.6937	Y=0.0304X+1.4369
Coefficient of determination (R^2)	0.909	0.842	0.944
Correction value (mm) — 16%	1.896	1.889	1.923
Correction value (mm) — 15%	1.876	1.877	1.893
Correction value (mm) — 14%	1.856	1.865	1.863
Cultivars	Un Gwang	Nam Pyeong	Dae An
Correction equation	Y=0.0458X+1.2794	Y=0.0060X+1.571	Y=0.0076X+1.7075
Coefficient of determination (R^2)	0.737	0.963	0.757
Correction value (mm) — 16%	2.012	1.667	1.829
Correction value (mm) — 15%	1.966	1.661	1.822
Correction value (mm) — 14%	1.921	1.655	1.814

Table 9. The correction of the thickness of green dead rice according to moisture content and varieties			
Cultivars	Il Pum	Chu Cheong	Dong Jin
Correction equation	Y=0.0235X+1.3509	Y=0.0038X+1.8769	Y=0.0409X+1.2396
Coefficient of determination (R^2)	0.879	0.890	0.962
Correction value (mm) — 16%	1.727	1.938	1.894
Correction value (mm) — 15%	1.703	1.934	1.853
Correction value (mm) — 14%	1.680	1.930	1.812

Cultivars	Un Gwang	Nam Pyeong	Dae An
Correction equation	Y=0.0524X+0.9234	Y=0.0371X+1.0845	-
Coefficient of determination (R^2)	0.906	0.950	-
Correction value (mm) — 16%	1.762	1.678	-
Correction value (mm) — 15%	1.709	1.641	-
Correction value (mm) — 14%	1.657	1.604	-

observed by Chu Cheong and Nam Pyeong variety, and Chu Cheong variety showed the largest decrement in thickness.

The correction value of the thickness of green dead rice is shown in Table 9. As shown in Table 9, the correction value for the thickness of Il Pum, Chu Cheong, Dong Jin, Un Gwang and Nam Pyeong variety were 1.774, 1.945, 1.976, 1.876 and 1.752 mm, respectively at 18% moisture content. These correspondingly decreased by 0.118, 0.019, 0.205, 0.262 and 0.186 mm at moisture content of 13%. Chu Cheong variety showed the thickest at 0.326, 0.293 and 0.260 mm thicker than the thinnest Nam Pyeong variety at the correction moisture content of 14, 15 and 16%, respectively.

Conclusions

This study was conducted to optimize the sorting factors and establish an efficient sorting technology for brown rice. After hulling of the main paddy variaties cultivated in Korea, the geometrical properties were studied, determine the optimal sorting factors. The brown rice varieties used in this study were Il Pum, Chu Cheong, Dong Jin, Un Gwang, Nam Pyeong, and Dae An. These were classified into whole grain, unriped grain, and green dead rice. The shape factors were analyzed based on length, width and thickness of the grains. Conclusions of the study are as follows:

(1) The maximum and minimum length in whole grain, unriped grain and green dead rice were observed Dae An and Chu Cheong variety. Especially, in the case of whole grain and unriped grain, Dae An variety, which had the longest grains were 0.379 and 0.373, 0.378 and 0.415, 0.377 and 0.377 mm longer than the shortest Chu Cheong variety at correction moisture content of 14, 15 and 16%, respectively.

(2) The Il Pum variety showed the maximum width while Dong Jin variety showed the minimum width.

(3) In the case of thickness, the maximum and minimum thickness were observed in Un Gwang and Nam Pyeong variety for the whole grain and unriped grain, respectively. The whole grain thickness of Un Gwang variety was 0.114, 0.112, 0.111 mm thicker than the Nam Pyeong variety at the correction moisture content of 14, 15 and 16%, respectively. For the unriped grain, the Un Gwang variety was 0.266, 0.305 and 0.346 mm thicker than Nam Pyeong variety. In the case of green dead rice, Chu Cheong variety, which showed the thickest was 0.326, 0.293 and 0.260 mm thicker than the thinnest of Nam Pyeong variety at the correction moisture content of 14, 15 and 16%, respectively.

(4) For different of the brown rice varieties, the length and width of whole grain and unriped grain had 0.2～0.4 mm of difference from green dead rice. Therefore, the length and width can be used as sorting factors of whole grain and green dead rice.

(5) The length and width, which showed 0.1 mm differences are considered inappropriate as sorting factors for whole grain and unriped grain. However, in the thickness showed 0.2～0.4 mm difference

between whole grain and unriped grain, and therefore can be considered as optimum sorting factor of whole grain and unriped grin.

Conflict of Interest

Acknowledgement

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