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Effects of Main Shaft Velocity on Turbidity and Quality of White Rice in a Rice Processing System

Byeong-Hyo Cho[1§], Tae-Hwan Kang[2§], Jin-Ho Won[1], Shin-Hyeong Kang[1], Hee-Sook Lee[3], Chung-Su Han[1]*

[1]*Department of Biosystems Engineering, Chungbuk National University, Cheong-Ju, Korea*
[2]*Major in Bio-Industry Mechanical Engineering, Kongju National University, Kong-ju, Korea*
[3]*Department of Consumer Studies, Chungbuk National University, Cheong-Ju, Korea*

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Abstract

Purpose: The purpose of this study is to analyze turbidity and quality characteristics of white rice as a function of main shaft blast velocity and to verify the optimum processing conditions in the cutting type white rice processing system (CTWRPS). **Methods:** Sindongjin, one of the rice varieties, which used to be produced in Gimje-si, Jeollabuk-do, in 2015, was used as the experimental material. Turbidity and quality characteristics of white rice were measured at three different main shaft blast velocities: 25, 30, and 35 m/s. The amount of test material used for a single experiment was 20 kg, and after processing, whiteness was found to be 42.5±0.5, following which, turbidity and quality characteristics were measured. **Results:** Turbidity decreased with increase in the shaft blast velocity, and as a result, was lowest at 35 m/s of shaft blast velocity among all the other experiment velocities. The trend of cracked rice ratios was similar to the turbidity. Broken rice ratio turned out to be less than 2.0% in all the test conditions. In the first stage of processing, the processing pressure decreased as the main shaft blast velocity increased. Additionally, in the second stage of processing, the processing pressure was at its lowest value at the main shaft blast velocity of 35 m/s. Energy consumption, too, decreased as the main shaft blast velocity was increased. **Conclusions:** From the above results, it is concluded that the main shaft blast velocity of 35 m/s is best for reducing turbidity and producing high quality rice in a CTWRPS.

Keywords: Blast velocity, Broken rice ratio, Cracked rice ratio, Processing pressure, Turbidity

Introduction

As dietary consumption patterns change from a grain-centered diet to meat and vegetables, the domestic rice market has contracted significantly over the years. The annual consumption of rice in 2015 was 62.9 kg, which was lower by 15.9 kg compared to that in 2006 (KOSIS, 2016). Also, in order to survive competition with imported rice before the opening of the rice market under the WTO system that has been postponed for last 20 years, high-quality rice production is an important issue on RPC (rice processing complex). Most research has been conducted with the aim of saving costs, strengthening competitiveness through safe and high quality rice production, and expanding brand power (Kang et al., 2015).

Turbidity as a quality characteristic of white rice, refers to the turbidity observed during the rice washing process, and is affected by the residual rice bran on the white rice surface. In addition, complete removal of the rice bran, not only results in an excellent appearance quality, but also minimizes deterioration of the quality from fat acidification during the distribution process. In addition, the water left from washing the rice contains a large amount of organic matter, causing water pollution such as eutrophication, odor, and red tide when it flows into rivers (Won et al., 2016). Recently, this water from washing rice has garnered a lot of attention due to it being released in large quantities from an increasing number of

***Corresponding author:** Chung-Su Han
Tel: +82-43-261-2580; **Fax:** +82-43-271-4413
E-mail: hansu@cbnu.ac.kr

cafeterias and restaurants (Kang et al., 2016).

In Korea, studies to reduce turbidity of white rice have been carried out through the development of rice cleaning machine with water additive (Chang et al., 1999; Kwon et al., 2004), electrostatic method and small water additive method (Choi, 2004), etc. In addition, a dry type of rice polishing machine without using water was also studied (Choi et al., 2000). However, it was impractical because fine degree of rice was lower than a wet rice polishing machine.

On the other hand, the CTWRPS can produce high quality rice with low turbidity because the fine residual rice bran on the rice surface is not pressed by removing the rice bran layer at low pressures. However, research and development on CTWRPS is very limited in Korea and overseas.

Therefore, this study aims to find out proper processing conditions for white rice by analyzing the turbidity and quality characteristics as a function of the main shaft blast velocity in the CTWRPS.

Materials and Methods

Sample

Sindongjin, which used to be produced in Gimje-si, Jeollabuk-do, in 2015, was used as experimental material, and the initial average moisture content was 15.5%, w.b. (expressed in % hereafter). In addition, the average values of turbidity and whiteness was about 62 ppm and 41.3, respectively.

Experimental device

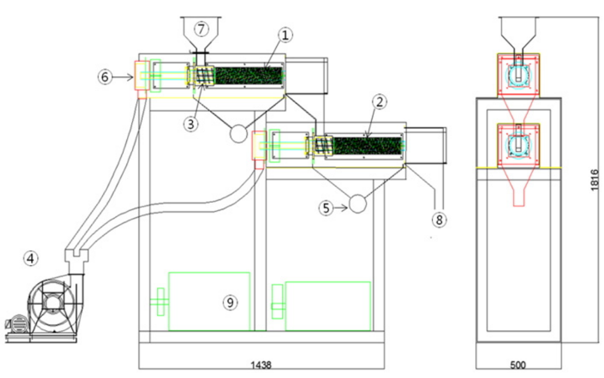

Figure 1. Schematic diagram of the CTWRPS. (1) Cutting roller, (2) Metallic mesh, (3) Screw, (4) Blast fan, (5) Air suction inlet, (6) Main shaft air inlet, (7) Rice inlet, (8) White rice outlet, (9) Motor.

Figure 1 shows the schematic diagram of the CTWRPS used in the experiment. As shown in Figure 1, the dimension of the device are 1438×1816×500 mm (L×H × W). Here, the rice kernels are passed through two stages in the processing chamber. The main components of this white rice processing system are the cutting roller (①), metallic mesh (②) for processing the white rice, and screw (③) for forcibly transferring the raw material to the processing chamber. The other components include the main shaft air inlet (⑥), blast fan (④) for blowing air to the hollow main shaft, and an air suction inlet (⑤) for rice bran suction.

Experimental method

Turbidity and quality characteristics of white rice were measured at three different main shaft blast velocities: 25, 30, and 35 m/s.

The diameter and length of the cutting roller were Φ 80×400 mm for the first stage and Φ76×400 mm for the second stage. In addition, the main shaft speed at the first and second stages was 1,000 and 1,100 rpm, respectively. The amount of test material used in a single experiment was 20 kg, and after processing, whiteness, turbidity and quality characteristics were measured at experimental conditions.

Measured parameters

Whiteness

Whiteness of the sample was measured with a whiteness meter(C300-3, Kett, Japan) in pentaplicate. The whiteness value of a standard white plate was 87.7.

Turbidity

Turbidity of white rice reduced after processing. A solution was made by putting 5 g white rice in 400 mL tap water (water temperature 20℃) in a beaker and then shaking for 30 seconds with amplitude (MAFRA, 2010). Turbidity of the water solution was measured three times by a water quality measuring instrument (90-FLT, TPS, U.S.A), and expressed as an average value (in ppm).

Cracked rice ratio

Cracked rice ratio is the ratio of cracked rice before and after processing. For calculating the cracked rice ratio, 50 grains of rice were used in each experiment and measured 5 times by using a cracked rice scanner (RC-50, Kett, Japan).

Broken rice ratio

Broken rice ratio is the weight of broken rice to that of non-broken rice. The broken rice ratio was measured 3 times and expressed as an average value. For selecting broken rice, 150 g of processed white rice was placed in a shaking table sorter (25M, Daeok, Japan) with sieve scale 1.7 mm and activated for 5 min.

Processing pressure

Pressure sensors (P3251, TECSIS, Germany) were installed at the inlet, center, and outlet of the processing chamber to measure processing pressure, which was measured by an indicator (IC-3000W, NEWINS, Korea). The processing pressure was expressed as the averages of the maximum values.

Energy Consumption

The energy consumption of the CTWRPS was measured by using an integrated power meter (CW240, YOKOGAWA, Japan), and the measured value was subsequently, converted and expressed in hour energy consumption.

Main shaft blast velocity

The main shaft blast velocity of the rice processing system was measured by inserting the sensor, an anemometer (9565A, TSI, U.S.A) at the center of the blast duct.

Statistical analysis

Statistical analysis was conducted by using one-way ANOVA in the SPSS statistical package (version 12.0K, SPSS Inc., USA) for Windows. The significance level of the statistical analysis was 5%.

Results and Discussion

Whiteness

Figure 2 shows the whiteness of white rice after the two-stage processing at different main shaft blast velocities of the CTWRPS.

As shown in Figure 2, the whiteness of white rice after processing was 42.5, 42.4, and 42.6 at main shaft blast velocity of 25, 30, and 35 m/s, respectively.

These results show that the whiteness of white rice is maintained at a uniform level in the range of 42.5±0.5, irrespective of the main shaft blast velocity under all the experimental conditions.

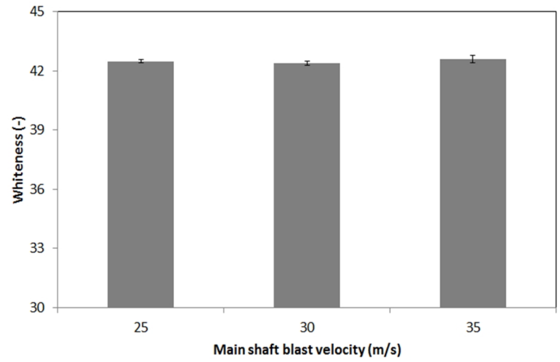

Figure 2. Whiteness of white rice at different main shaft blast velocities.

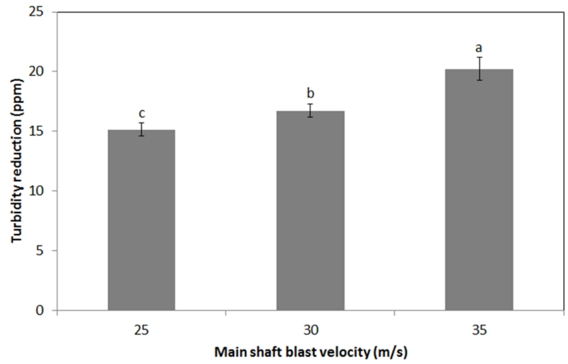

Figure 3. Turbidity reduction of white rice at different main shaft blast velocities.

Turbidity reduction

Figure 3 compares the turbidity reduction in white rice after processing, depending on the main shaft blast velocity at the first and second stages of the CTWRPS. It is seen that the turbidity reduction increased with increase in the main shaft blast velocity. The turbidity reduction was 15.08, 16.80, and 20.23 ppm at main shaft blast velocity of 25, 30, and 35 m/s, respectively. The turbidity reduction increased as the main shaft blast velocity increased because the residual rice bran removed by the cutting blade was more easily separated from the rice surface at higher shaft velocities.

Cracked rice ratio

The differences in cracked rice ratios before and after processing at different main shaft blast velocities are shown in Figure 4. The figure demonstrates that cracked rice occurrence reduces as the main shaft blast velocity is increased. As shown in Figure 4, the cracked rice ratio was 13.2 and 10.4% at the main shaft blast velocity of 25, and 30 m/s, respectively. In addition, the cracked rice ratio was 5.6% at the main shaft blast velocity of 35 m/s, showing low levels of cracked rice ratio by 46.15-57.58% compared to other experimental conditions. Based on the above results, it is considered that high quality white rice can be produced at main shaft blast velocity of 35 m/s; the processing pressure was decreased by strong blast blowing through the main shaft.

The difference in the cracked rice ratios before and after processing with varying main shaft blast velocity turned out to be significant at p-value of 0.002.

Broken rice ratio

Figure 5 shows the broken rice ratios at different main shaft blast velocities. As shown in Figure 5, the broken rice ratio was 0.99%, 1.34%, and 1.06% at main shaft blast velocity of 25, 30, and 35 m/s, respectively. The above result show that the broken rice ratio was less than 2.0% under all the test conditions.

The differences among the broken rice ratios with vartying main shaft blast velocities are not statistically different (p-value = 0.099).

Processing pressure

Figure 6 shows the processing pressure at different main shaft blast velocities. The processing pressure is shown separately for the first and second stage. As shown in Figure 6, in the first stage of processing, the processing pressure reduced as the main shaft blast velocity increased, and even in the second stage, it showed relatively low pressure at the main shaft blast velocity of 35 m/s than under other velocities.

The 1st and 2nd stage processing pressure was 134.26 and 47.59 g_f/cm^2, respectively, at 25 m/s and 110.13 and 54.72 g_f/cm^2, respectively, at 30 m/s. For the main shaft blast velocity of 35 m/s, the 1st and 2nd stage processing pressure was 106.73 and 42.83 g_f/cm^2, respectively, which was relatively lower when compared to the pressure values at other velocities.

The above results showed that, because white rice is discharged more smoothly by strong blast, the processing pressure is reduced.

Energy consumption

Figure 7 shows the energy consumption per hour

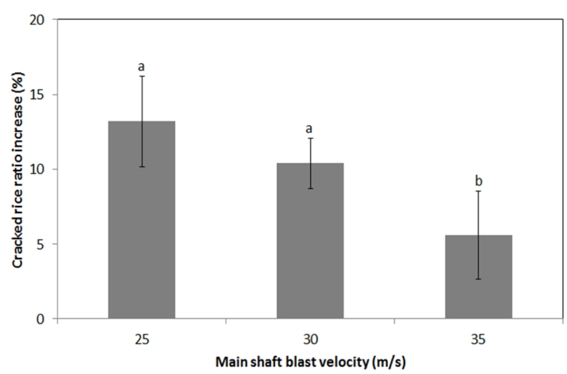

Figure 4. Cracked rice ratio before and after processing at different main shaft blast velocities.

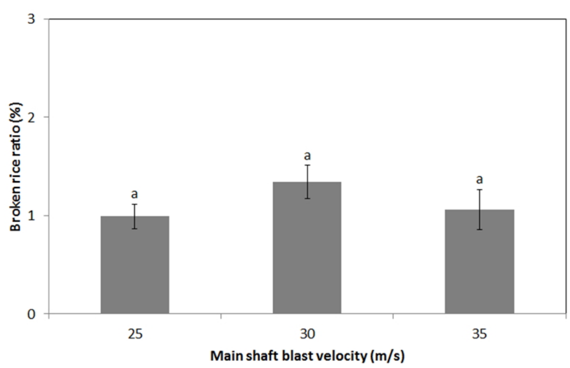

Figure 5. Broken rice ratio of white rice after processing at different main shaft blast velocities.

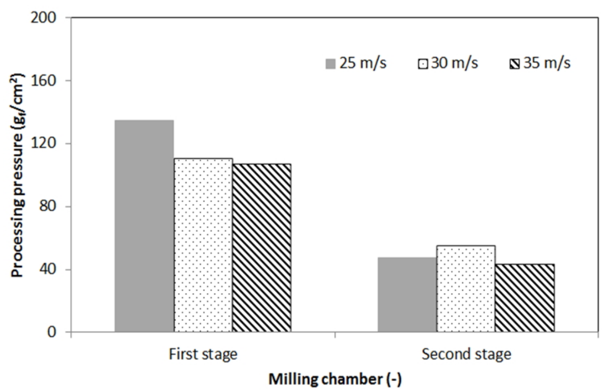

Figure 6. Processing pressures at different main shaft blast velocities.

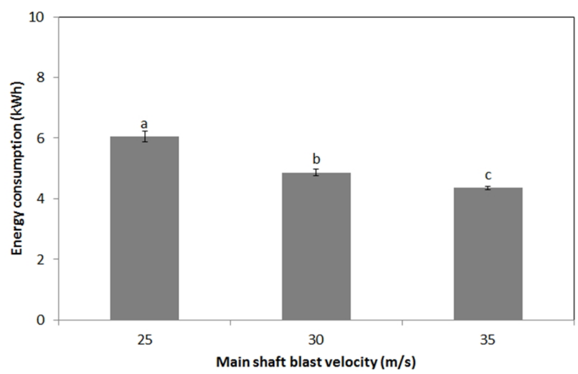

Figure 7. Energy consumption at different main shaft blast velocities.

depending on the main shaft blast velocity. The figure shows that the energy consumption decreases as the main shaft blast velocity is increased because the load was less when processed at high shaft velocity.

As shown in Figure 7, the energy consumption during processing was 6.05 and 4.86 kWh at the main shaft blast velocity of 25, and 30 m/s, respectively. In addition, the energy consumption was 4.35 kWh at the main shaft blast velocity of 35 m/s, leading to energy savings by 10.49-28.10% when compared to other test conditions.

Conclusions

The purpose of the present study was to analyze turbidity and quality characteristics of white rice and verify the optimum processing conditions in the CTWRPS. The CTWRPS is known to produce high quality white rice by reducing the turbidity during processing.

The main results are summarized as follows.

The amount of turbidity after processing reduced as the main shaft blast velocity was increased, and this reduction was higher for the main shaft blast velocity of 35 m/s, with turbidity being in the range of 3.43-5.15 ppm compared to conditions when shaft blast velocity was lower. The difference in cracked rice ratios before and after processing decreased with increase in the main shaft blast velocity, and the cracked rice occurrence exhibited the lowest level when the main shaft blast velocity was 35 m/s. Broken rice ratio turned out to be less than 2.0% in all the conditions; thus, it showed no significant differences at the three test conditions. In the 1st stage of processing, the processing pressure decreased with an increase in the main shaft blast velocity. In addition, in the second stage of processing, the processing pressure had the lowest value when the main shaft blast velocity was 35 m/s. Energy consumption during processing showed a decreasing trend as the main shaft blast velocity increased, and the energy consumption was reduced by 10.49-28.10% at the main shaft blast velocity of 35 m/s.

From the above results, it is concluded that the main shaft blast velocity of 35 m/s is suitable for reducing turbidity and producing high quality rice in a cutting type white rice processing system.

Conflict of Interest

The authors have no conflicting financial or other interests.

Acknowledgments

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