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Milling Characteristics of Cutting-Type Rice Milling Machine - According to Cutting Roller Induced Guide Angles -

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Abstract

Purpose: The purpose of this study was to analyze the milling characteristics of white rice depending on the guide angles of the cutting roller's induced guide, as well as to verify optimum milling conditions for the cutting-type milling machine. **Methods:** Brown rice, which was produced in Cheongju-si, Chungcheongbuk-do, Republic of Korea, in 2014, was used as the experimental material. The milling characteristics of white rice were measured under six different guide angle levels of the cutting roller, which were none, 0°, 5°, 10°, 15°, and 20°. The quantity of brown rice for each experiment was 500 kg, and the milling characteristics were measured according to the whiteness, rice temperature, cracked rice ratio, broken rice ratio, and energy consumption. **Results:** The whiteness of white rice maintained a uniform level, indicating at range of 38±0.5, regardless of the cutting roller guide angles under all conditions. The rice temperature rise during milling was found to be rather low, at 13.9°C and 13.6°C at 10° and 15° guide angles, respectively. The cracked rice ratio after milling was 18.67%-19.47%, and the broken rice ratio was 0.68% at a 10° guide angle, which is the lowest in comparison to other guide angles. Energy consumption was lower when the guide was used compared to that with-out the use of the guide. The energy consumption tended to increase as the cutting roller guide angle increased. **Conclusions:** From the above results, we conclude that the cutting roller guide angles of 0° and 10° are suitable for producing high quality rice during milling with a cutting-type milling machine.

Keywords: Broken rice ratio, Cutting roller guide angle, Cutting type milling machine, Energy consumption, Milling machine

Introduction

In the domestic rice market in the Republic of Korea, rice consumption has been decreasing every year. The area for rice cultivation was approximately 930,000 hectares in 2014, reduced by 50,000 hectares compared to the 980,000 hectares in 2010 (Park, 2015; KOSIS, 2015). Furthermore, the government's rice policy has shifted to focus on the production of high-quality rice in response to the opening of the rice market under the World Trade Organization (WTO) system, since 2002 (Lee et al., 2013). Accordingly, the recently promoted project to revitalize high-quality rice distribution is aimed at strengthening competitiveness through safe, high-quality rice production focuse on the domestic Rice Processing Complex (RPC) and cost reduction by means of scaling and brand power expansion.

At the present, based on the processing capacity of 2.5 ton/h of the milling systems of rice processing plants, an electrical power specification of 22 kW is required for the abrasive-type rice milling machine, 37.5 kW for the friction-type milling machine, and 22 kW for the rice polisher. Therefore, a new rice milling technology is necessary to reduce power consumption and production costs per unit. However, domestic and foreign research studies on rice-polishing machines have been conducted

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only on existing equipment, such as milling distribution performance evaluations of abrasive-type and friction-type milling machines (Kawamura, 1990; Kim et al., 2009) and the functional rice maker (Lim et al., 2014; Yan and Chung, 2004).

As a cutting-type rice milling machine using its cutting power removes the aleurone layer at a low pressure, it can produce high-quality white rice because the rice temperature rise is low, as is the ratio of broken rice during processing.

Meanwhile, in the case of the cutting-type rice milling machine, very little research has been conducted on cutting edge durability, as the durability problem has been solved by recent rapid development in domestic laser processing technology and the metal heat treatment technique; however, interest in the cutting-type milling machine has been increasing.

Therefore, this study aims to analyze the milling characteristics according to the induced guide angles of the cutting roller and verify optimum induced guide conditions to develop a cutting-type milling machine that can minimize the existing milling process.

Materials and Methods

Sample

Brown rice, which was previously produced in Cheongju-si, Chungcheongbuk-do, Republic of Korea, in 2014, was used as the experimental material, and the initial average moisture content was 15.5%, w.b. (expressed in % hereafter). Furthermore, the average whiteness value was 19.85.

The ambient temperature during the test was 29~31°C, and the brown rice was stored in a cold warehouse at 15°C to minimize quality changes.

Experimental device

Figure 1 provides a schematic of the cutting type milling machine used in the experiment.

As shown in Figure 1, the dimensions of the machine are 12551625772 mm (LHW). The main components of the milling machine are the cutting roller (②), metallic mesh (③) for milling the brown rice, and screw (④) for forcibly transferring raw material to the milling chamber. Moreover, it includes an air suction inlet (①) for rice bran suction, and a main shaft air inlet (⑥) for blowing air into the hollow main shaft.

Experimental method

The rice milling characteristics were measured at six different cutting roller guide angles: none, 0, 5, 10, 15, and 20°. The guide angles of the cutting roller were introduced in two lines, at 180° intervals.

The cutting roller diameter and length were Φ150 mm and 570 mm, respectively. In addition, the experiment was performed with three cutting roller vents and at a blast velocity of 35 m/s. The main shaft speed was 1,000 rpm, and the brown rice quantity for one experimental

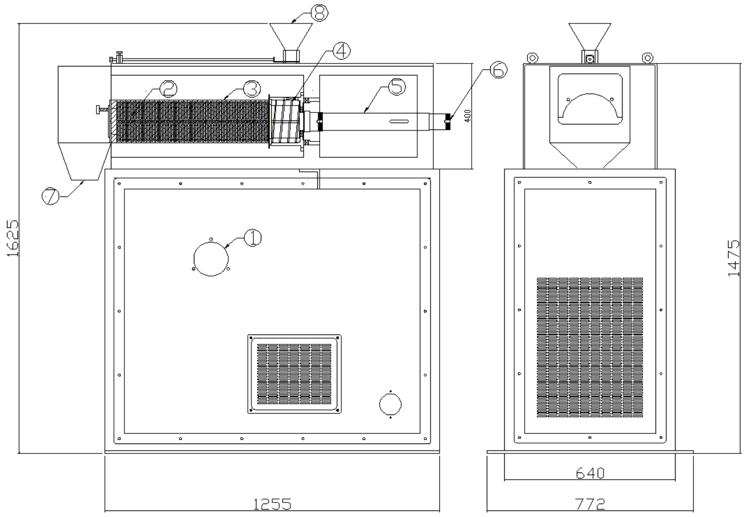

Figure 1. Schematic diagram of a cutting type milling machine. ① air suction inlet, ② cutting roller, ③ metallic mesh, ④ screw, ⑤ main shaft, ⑥ main shaft air inlet, ⑦ milled rice outlet, ⑧ brown rice inlet.

test was 500 kg. The milling rate was designated as 2 ton/h, the whiteness was 38±0.5 and milled rice recovery based on brown rice was 90.5±0.5%. Following the milling process, the whiteness, rice temperature, and milling characteristics were measured under different experimental conditions.

Measured parameters

Whiteness

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

Rice temperature

The milled and brown rice temperatures were measured before and after milling, using a digital thermometer (TES-1300, TES, Taiwan). The brown rice temperature before milling was measured by inserting the thermometer into the brown rice inlet of the milling machine, while the temperature of the milled rice was measured as the maximum temperature by inserting the thermometer into the milled rice outlet.

Cracked rice ratio

The cracked rice ratio is the ratio of cracked rice before and after milling. To calculate the cracked rice ratio, 50 grains of rice were used in each experiment and measured five times using a cracked rice scanner (RC-50, Kett, Japan).

Broken rice ratio

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

Energy consumption

The energy consumption of the cutting-type milling machine was measured during milling, with 500 kg of brown rice, using an integrated power meter (CW240, YOKOGAWA, Japan), and the measured value was subsequently converted and expressed as the energy consumption for producing 1 ton of milled rice.

Statistical analysis

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

Results and Discussion

Whiteness

Figure 2 illustrates the whiteness of the white rice after milling at different cutting roller guide angles of the cutting-type milling machine.

As indicated in Figure 2, the rice whiteness after milling was 38.08 when the guide was not used. The whiteness after milling was 38.05, 38.25, 38.15, 38.04, and 38.33 guide angles of 0°, 5°, 10°, 15°, and 20°, respectively.

These results demonstrate that rice whiteness was maintained at a uniform level within the range of 38±0.5, irrespective of the cutting roller guide angle, under all experimental conditions.

Rice temperature

Figure 3 displays the white rice temperature rise after milling at different cutting roller guide angles. The desirable rice temperature rise range was 12-15°C after milling. If the rice temperature is too high during processing, cracked rice and water loss increase, resulting in reduced quality (Park, 1999; Park and Han, 2002).

As shown in Figure 3, the rice temperature rise after milling was 13.8°C when the guide was not used. The white rice temperature rise after milling was 15.4°C, 16.7°C, 13.9°C, 13.6°C, and 14.6°C at guide angles of 0°, 5°, 10°C, 15°C, and 20°, respectively. These results imply that

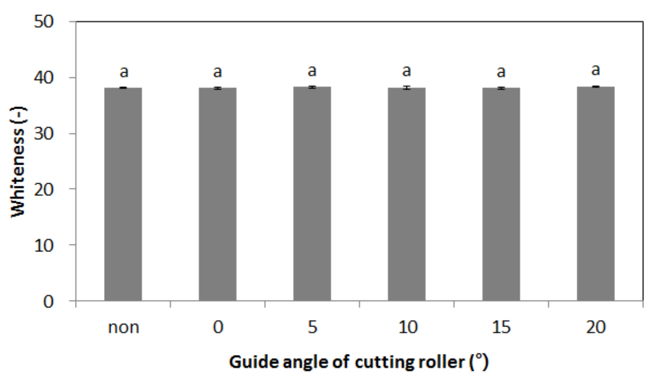

Figure 2. Rice whiteness at different cutting roller guide angles, where values are mean ± SD. Means (a) above the bars are significantly different according to Duncan's multiple range test (P<0.5).

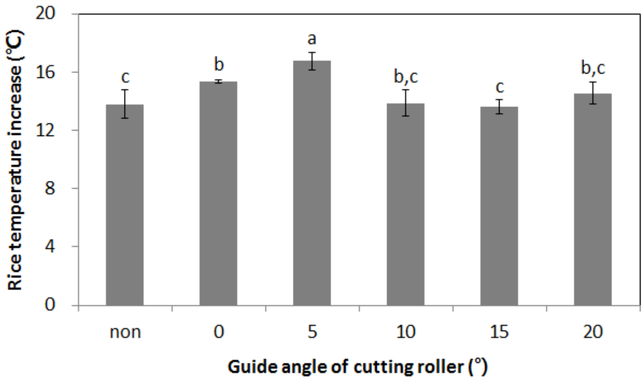

Figure 3. Rice temperature increase after milling at different guide angles, where values are mean ± SD. Means with different letters (a-c) above the bars are significantly different according to Duncan's multiple range test (P<0.5).

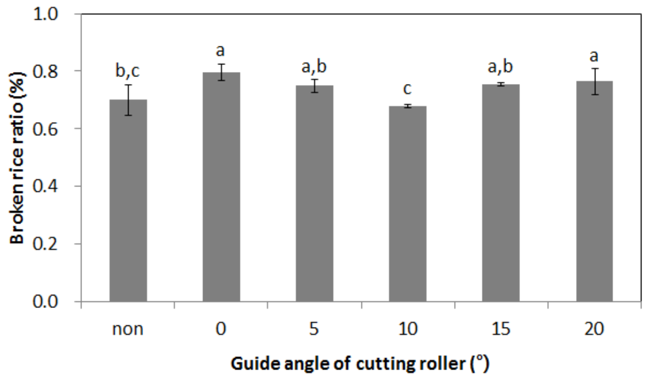

Figure 5. White rice broken rice ratio after milling at different cutting roller guide angles, where value are mean ± SD. Means with different letters (a-c) above the bars are significantly different according to Duncan's multiple range test (P<0.5).

the rice temperature with respect to the guide angles within the appropriate range.

The difference in the rice temperature rise after milling, depending on the guide angles, was determined to be significant.

Cracked rice ratio

Figure 4 displays the differences in the cracked rice ratio before and after milling at different cutting roller guide angles. The initial average cracked grain ratio before milling was 13.20%.

As shown in Figure 4, the cracked rice ratio was 18.93% when the guide was not used. The cracked rice ratios were 19.47%, 19.33%, 18.93%, 18.93%, and 18.67% cutting roller guide angles of 0°, 5°, 10°C, 15°C, and 20°, respectively. These values indicate that the cutting roller guide angle did not have statistically significant effect on the cracked rice ratio.

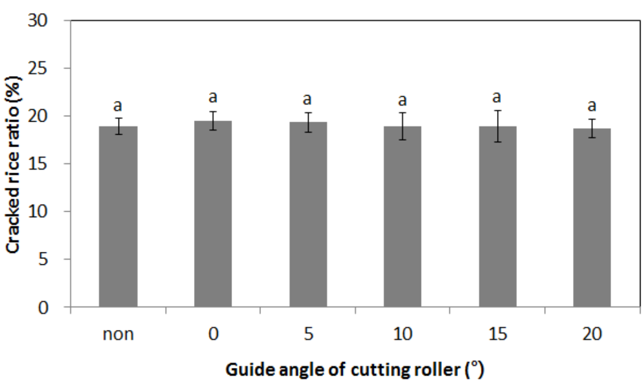

Figure 4. Cracked rice ratio before and after milling at different cutting roller guide angles, where value are mean ± SD. Means (a) above the bars are significantly different according to Duncan's multiple range test (P<0.5).

Broken rice ratio

Figure 5 displays the broken rice ratio at different cutting roller guide angles. The amount of broken rice during milling was found to be closely related to the milled rice temperature and moisture content (Kawamura, 1990). Furthermore, it was reported that if the rice temperature rise was too high, the broken rice ratio increased during milling, and moisture content decreased significantly (Park, 1999; Park and Han, 2002). Moreover, the current Korean rice rating standard specifies that a broken rice ratio of below 3% is the best grade, while that below 7% is high grade (MAFRA, 2011).

As shown in Figure 5, the broken rice ratio was 0.70% when the guide was not used. The broken rice ratios were 0.80%, 0.75%, 0.68%, 0.76%, and 0.76% at cutting roller guide angles of 0°, 5°, 10°C, 15°C, and 20°, respectively. These results demonstrate that the broken rice ratio was less than 1.0% under all experimental conditions.

The difference in cracked rice ratios before and after processing according to the cutting roller guide angles, was determined to be statistically significant, with a p-value of 0.004.

Energy consumption

Figure 6 illustrates the energy consumption for producing 1 ton of milled rice, according to the cutting roller guide angles.

As shown in Figure 6, it was found that the energy consumption for producing 1 ton of milled rice was lower when using the guide than that with no guide. Furthermore, energy consumption tended to increase with the guide angle.

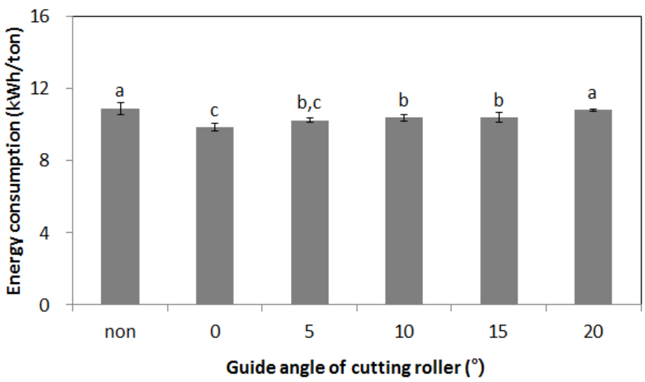

Figure 6. Energy consumption at different cutting roller guide angles, where value are mean ± SD. Means with different letters (a-c) above the bars are significantly different according to Duncan's multiple range test (P<0.5).

The energy consumption during milling was 10.88 kWh/ton when the guide was not used. The energy consumption amounts during milling were 9.84, 10.22, 10.38, 10.39, and 10.79 kWh/ton at cutting roller guide angles of 0°, 5°, 10°, 15°, and 20° respectively.

Conclusions

This study aimed to identify milling characteristics at different cutting roller guide angles in the production of high-quality white rice using the cutting-type milling machine, which can minimize the conventional milling process.

The results are summarized as follow.

The whiteness after milling remained at a uniform level within the range of 38±0.5, regardless of the cutting roller guide angles used, under all conditions. The rice temperature after milling was found to be low at 13.9°C and 13.6°C, cutting roller guide angles of 10° and 15°, respectively. The cracked rice ratio after milling showed no statistically significant difference with respect to the guide angles. The broken rice ratio after milling showed at range of 0.68-0.80% under all experimental conditions and the lowest value at a guide angle of 10°. The energy consumption during milling tended to increase with the cutting roller guide angle.

From these results, we conclude that cutting roller guide angles of 0° and 10° are suitable for producing high-quality rice during milling with the cutting-type milling machine.

Conflict of Interest

The authors have no conflicting financial or other interests.

Acknowledgments

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