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Effect of the size of perforated screen and blade-rotor clearance on the performance of Engleberg rice whitener

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An experiment was conducted to study the effects of two engineering factors on the performance of Engleberg rice whitener as the most common machine for rice milling in the North of Iran. Three levels of the size of perforated screen (No. 22, 24 and 26) and three levels of the blade-rotor clearance (8, 10 and 12 mm) were considered for the experiment. Breakage percent and whiteness of milled rice and output rate of the machine were measured for milling of long grain paddy variety of Hashemi. It was concluded that as the size of perforated screen increased, amount of rice breakage and whiteness decreased at first and then did not change significantly. Amount of rice breakage and whiteness decreased with increasing the blade-rotor clearance. The output rate increased significantly with increasing blade-rotor clearance but no the effect of the size of perforated screen was significant on the output rate. A clearance of 10 mm and perforated screen No. 26 was the best combination for milling of Hashemi variety using Engleberg rice whitener.

Key words: Paddy milling, rice breakage, rice whitener, Engleberg whitener.

INTRODUCTION

Following wheat, rice is the staple food in Iran and the life of many families are supported by producing this crop. In spite of many difficulties in production, a considerable portion of the crop is damaged and lost during the planting to processing operations. A large part of the losses occurs during milling. According to the latest report, production of white rice only in Guilan province of Iran was about 700000 tons in 2006. Thus if only 1% of rice breakage in milling operation is decreased, the breakage of 7000 tons of rice is prevented. For this reason, investigation of crop losses is very important (Anonymous, 2009). Figure 1 illustrates the elements of common milling system in Guilan province. Dried paddy is fed into paddy cleaner and output of this machine is fed to a rubber roll husker for husking operation. Output of the rubber roll husker is a mixture of brown rice (dehusked paddy) and some paddy. This mixture is transferred into the hopper of Engleberg rice whitener for milling operation (Firouzi and Alizadeh, 2005). During the rice milling process in Engleberg rice whitener, pressure and bending stresses are exerted on the rice kernels and because of excessive friction between machine elements and kernels, considerable thermal stresses are produced. Thus conditions are very suitable for breakage and cracking of rice kernels. Therefore investigations on the effects of machine factors on milling characteristics of white rice in this whitener are very important.

Rice research scientists have already identified many factors that affect milling quality. Kunze (1964) has grouped these factors into two major categories: the engineering and varietal factors. Engineering factors include harvesting, handling, drying, storage, transport and milling operations while varietal factors include physical and mechanical properties of grain. Farouk and Islam (1995) showed that the speed of mill rotor in abrasive whiteners is an important factor affecting milling loss. A rotor speed of 1500 rpm generally caused losses of up to

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50% more than that at 1300 rpm. Milling is accomplished by pressure in frictional type whiteners and shock in abrasive whiteners. The pressure in the milling chamber is about 300 - 500 g/cm² (Juma Omar and Yamashita, 1987). Yamashita and Goto (1974) showed that long grain IR-8 in a horizontal frictional type milling machine with inside pressure of 105.4 g/cm² gave a milling yield of 91.9 and 44% broken rice while the pressure of 178.2 g/cm² produced 85.6% milling recovery and 57.4% broken rice ratio.

These findings show that more pressure inside the milling chamber, results in lower milling recovery rate and more broken rice. Regarding the abrasive rolls, the mesh or grit size denotes the roughness of the roll and each grit has different cutting effects. The Japanese Millers Association using short grain Japonica variety showed that the grit No. 36 had the highest effect (Anonymous, 1974). Firouzi and Alizadeh (2005) indicated that the rotor speed of Engleberg rice whitener is an important factor that affects broken rice. They found that with increasing the speed of the rotor from 600 to 900 rpm, rice breakage decreased up to 800 rpm and remained unchanged with further rpm increase. Research of Ghavami et al. (2005) showed that percent broken rice increased with increasing rotor speed of Engleberg rice whitener and concluded that the cross sectional area of the machine outlet was the most important factor affecting rice grain breakage. Breakage percent of milled rice reduced with increasing outlet opening of whitener.

Investigation of Firouzi et al. (2004) on a jet pearler indicated that feed rate and outlet pressure are two important factors that affect grain breakage. By increasing the feed rate from 150 to 300 kg/h, kernel breakage decreased at first and then increased significantly. Also increasing the output pressure increased the breakage percent of milled rice. Heidariesoltanabadi and Hemmat (2007) evaluated the performance index of a modified blade-type paddy whitener equipped with a feeding screw. Results of their study indicated that the most appropriate performance index was achieved at 11 mm distance between blade and rotor. Subsequently, research of Varnamkhasti et al. (2007) on the modified blade-type whitener showed that rice breakage percentage increased with increase in output rate from 500 to 600 kg/h and the best economical performance was attained at 500 kg/h output rate. A review of the findings on Engleberg rice whitener as the common whitener in Iran indicates that the effects of many factors are still unknown. In this study, effects of the size of perforated screen and the clearance between blade and rotor on some milling characteristics of rice and machine performance were investigated.

**MATERIALS AND METHOD**

This investigation was conducted at the Rice Research Institute of Iran in Rasht. The experimental apparatus was an Engleberg device which is a blade-type rice whitener popular in the rice-production provinces of northern Iran. Paddy of Hashemi variety as the most common variety was selected for experiment. The size of perforated screen and blade-rotor clearance (Figure 2) were considered as two engineering factors of the Engleberg rice whitener. Usually three sizes of perforated screens (No. of 22, 24 and 26) are used in this machine. The thickness of perforations and their number along 100 mm of the length of perforated screens are the criteria for their classification (Figure 3). The blade-rotor clearance is the adjustable distance between blade and rotor along the material passage from the machine input to discharge point. A preliminary investigation indicated that the clearance setting between blade and rotor for Engleberg rice whitener in Guilan mills is about 10 mm decreasing this clearance to less than 8 mm causes excessive breakage in milled rice and increasing the clearance results in reduced whiteness of the milled rice. Thus the blade-rotor clearance was considered at three levels of 8, 10 and 12 mm. A factorial experiment based on randomized complete block design (RCBD) with two factors and three replications was used for the experiment. Factors were the size of perforated screens at three levels of 22, 24, 26 and the blade-rotor clearance at three levels of

![Figure 1.](image-url)
Paddy 200 mm deep was dried in a batch-type dryer at 35 - 40°C reducing moisture content to 8 - 9% w.b. (Khoshzamir, 1993; Sabori, 2002). Because of the interest in very dried rice in Iran and due to better cooking quality, this level of moisture content was selected for the experiment. Moreover, research of Firouzi and Alizadeh (2005) indicated that 8 - 9% w.b. moisture content causes lower breakage in milling with Engleberg rice whitener. After husking 30 kg of dried paddy with rubber roll husker, the mixture of paddy and brown rice was fed into the hopper of an Engleberg rice whitener in each experiment.

Two hundred grams of milled rice was collected into plastic bags for later measurements. The output rice was collected for 30 s in order to determine the output rate of the machine. Sample collected from each experiment was fed into the rotary sieve (SATAKE TRG058, Japan). This instrument separates broken and whole kernels. Grains with at least 75% of the kernel intact were considered as whole (Farouk and Islam, 1995). Because of incomplete separation of rice kernels by the apparatus, hand sorting completed the application. Breakage percent of milled rice was determined as follows:

\[
\text{Broken kernel (\%) = } \frac{W_1}{W}
\]

Where \( W_1 \) and \( W \) are the mass of broken and total milled rice, respectively.

The collected white rice samples in 30 s, were weighed to determine the output rate of the apparatus, then the output rate were calculated for an hour of apparatus operation. Whiteness of milled rice was determined by the appropriate instrument (kett-c-100, Japan). This apparatus determines the degree of whiteness by measurement of the time of light reflection. The obtained data were analyzed using MSTATC statistical software.

**RESULTS AND DISCUSSION**

According to the statistical analysis, effects of the size of perforated screen and blade-rotor clearance as well as that of their interaction on percent breakage and whiteness of rice were significant. The effect of the blade-rotor clearance was only significant on the output rate of the apparatus. Amount of rice breakage decreased with increasing blade-rotor clearance (Figure 4). Because of rotational direction of flutes on the machine rotor, paddy and brown rice in milling chamber have a spiral movement around the rotor and toward the outlet. Thus with increasing blade-rotor clearance, the passage of spiral movement of rice kernels becomes narrow and subsequently the pressure inside milling chamber increases. This pressure on kernels inside milling chamber increases grain breakage. The same trend has been reported by Khoshtagha et al. (2001) on a modified model of Engleberg rice whitener. Results of Heidariesoltanabadi and Hemmat (2007) showed that there was not significant difference between the percentage of broken brown rice at lower clearances (11 and 12 mm) but an significant decrease was developed at clearance of 13 mm with amount of 15.42% which is slightly lower than breakage percentage of 16.36% at

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**Figure 2.** Elements of Engleberg rice whitener (Wimberly, 1983).

**Figure 3.** Arrangement of the perforations on the surface of perforated screens. Width of perforations (t) is: 0.8, 1 and 1.2 mm for perforated screens No. 26, 24 and 22, respectively. The numbers of perforations for 100 mm of the length of perforated screens are: 26, 24 and 22 for perforated screens No. 26, 24 and 22 respectively.

**Figure 4.** Effect of blade-rotor clearance on rice breakage in Engleberg rice whitener. Different letters show significant differences between their values at confidence level of 99%.
According to Figure 5, increasing the size of perforated screen from 26 to 22 causes an increase in rice breakage. Also there was no significant difference between the means of broken rice at the perforated screen Numbers of 24 and 22. Friction between the grains and the steel parts of the apparatus (particularly the perforated screen) causes the husk and bran to be scraped off (Wimberly, 1983).

Thus the size of perforated screen can affect the frictional characteristics and scraping of slender kernels over and into perforations. This can result in different breakage percentage in the different screens. Figure 6, illustrates that with increasing clearance between blade and rotor, the degree of whiteness of milled rice decreases. This result can be related to more flow ability of kernels in milling chamber and consequently decreasing the pressure on the materials in the mill housing. Thus, lower pressure results in lower whiteness. Firouzi et al. (2004) indicated that whiteness of output rice increased with increasing milling pressure by increasing output pressure in a rice jet pearler.

According to Figure 7, the highest degree of whiteness was obtained at perforated screen No. 22. This may be related to more scraping of rice kernels on larger perforations of this screen and consequently more bran removal from rice kernels. The difference between the effect of perforated screens No. 24 and 26 on rice whiteness was not significant. Figure 8, shows that the
Table 1. Correlation coefficients for studied variables in milling with Engleberg rice whitener.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Breakage</th>
<th>Whiteness</th>
<th>Output rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakage</td>
<td>1</td>
<td>+0.827**</td>
<td>-0.804**</td>
</tr>
<tr>
<td>Whiteness</td>
<td></td>
<td>1</td>
<td>-0.884**</td>
</tr>
<tr>
<td>Output rate</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

** Significant at p<0.01.

Table 2. Statistical comparisons of the studied variables for all treatments in milling with Engleberg rice whitener.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Breakage percent</th>
<th>Whiteness</th>
<th>Output rate (kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 P1</td>
<td>31.82*</td>
<td>59.27*</td>
<td>310*</td>
</tr>
<tr>
<td>C1 P3</td>
<td>23.76*</td>
<td>55.07*</td>
<td>275*</td>
</tr>
<tr>
<td>C1 P2</td>
<td>22.87*</td>
<td>54.80*</td>
<td>264*</td>
</tr>
<tr>
<td>C2 P1</td>
<td>22.30*</td>
<td>46.83*</td>
<td>251*</td>
</tr>
<tr>
<td>C2 P2</td>
<td>22.21*</td>
<td>43.50*</td>
<td>235*</td>
</tr>
<tr>
<td>C2 P3</td>
<td>19.82*</td>
<td>40.60*</td>
<td>235*</td>
</tr>
<tr>
<td>C3 P1</td>
<td>18.77*</td>
<td>38.03*</td>
<td>192*</td>
</tr>
<tr>
<td>C3 P2</td>
<td>18.51*</td>
<td>36.33*</td>
<td>162*</td>
</tr>
<tr>
<td>C3 P3</td>
<td>17.27*</td>
<td>35.70*</td>
<td>134*</td>
</tr>
</tbody>
</table>

C1, C2, C3: different levels of blade-rotor clearance: 8, 10, 12 mm, respectively. P1, P2, P3: three levels of the size of perforated screen. Numbers: 22, 24, 26 respectively.

* All data are means of three replications.

** Means in each column, followed by different letters are significantly different (p< 0.05)

effect of blade-rotor clearance on the output rate of milled rice was significant. This result can be attributed to more free flowing of rice kernels in the milling chamber because of more space for rotational movement around the rotor. Thus, the highest output rate in the largest clearance treatments can be logical. The effect of the size of perforated screen on output rate was not significant. Table 1, shows the correlation between variables. The correlation between breakage and whiteness of output rice was significantly positive ($R^2 = 0.827$). Increasing the pressure in the milling chamber increases the internal friction and stresses in the whitening chamber. Thus, increasing rice whiteness as well as breakage with increasing chamber pressure is logical. This means that the relationship between the two variables can be positive. The correlations between output rate and each of the other dependent variables, rice breakage and whiteness, are significantly negative at α=1% ($R^2 = 0.804$ and $R^2 = 0.884$ respectively). Since increasing the output rate decreases the time of milling, therefore, less friction is produced in the milling chamber. This means that the relation between the output rate and each of the two dependent variables can be negative.

Table 2, shows the comparison of the dependent variables for different treatments. Results clearly indicated that milled rice whiteness and output rate of the machine decreased with decreasing rice breakage. Treatments C2P3, C3P1, C3P2 and C3P3 have the least breakage percents among all treatments. They are not different significantly, but the output rate and rice whiteness of treatment C2P3 (clearance 10 mm and perforated screen No. 26) are greater than the others; Hence, this combination may be the best configuration for milling of Hashemi paddy variety in Engleberg rice whitener.

Conclusions

The following conclusions were drawn from the results of this research:

1. The size of perforated screen and the blade-rotor clearance are two important factors on the performance of Engleberg rice whiteners.
2. Breakage of rice kernels decreased with decreasing screen perforation size from No. 22 to No. 24 and it remained unchanged from 24 to 26. The breakage percent increased with decreasing blade-rotor clearance at the range of 8 -10 mm.
3. Whiteness of rice milled in Engleberg rice whitener increased with decreasing blade-rotor clearance while output rate of the machine varied inversely.
4. The correlation between breakage and whiteness of milled rice was significantly positive ($R^2=0.827$) but the correlation between the breakage and output rate was
significantly negative ($R^2=0.804$). The correlation between whiteness and output rate was significantly negative too ($R^2=0.884$).

5. A clearance of 10 mm and perforated screen No. 26 was the best combination for milling of Hashemi variety using Engleberg rice whitener.

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