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Effect of Rollers Differential Speed and Paddy Moisture Content on Performance of Rubber Roll Husker

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Abstract

This study was carried out at the Rice Research Institute of Iran (RRII) to investigate the effect of rollers differential peripheral speed of commercial rubber roll husker and paddy moisture content on the husking index and percentage of broken rice. The experiment was conducted at six levels of rollers differential speed (1.5, 2.2, 2.9, 3.6, 4.3 and 5 m s^{-1}) and three levels of paddy moisture content (8-9, 10-11 and 12-13% w.b.). Two common paddy varieties, namely Binam and Khazer, were selected for this study. Results revealed that the effect of rollers differential speed and moisture content significantly ($P<0.01$) affected percentage of broken brown rice and paddy husking index. Average broken kernel percentage increased from 13 to 14.61% while husking index decreased from 71.64 to 61.81%, as paddy moisture content increased from 8-9 to 12-13%. It was observed that amount of broken rice decreased from 18.83 to 9.97%, when rollers differential speed varied from 1.5 to 5 m s^{-1}, while the husking index initially increased and then started to decrease. The mean value of husking index for Khazar variety (64.71%) was significantly lower than that for Binam variety (69.2%). It was concluded that rollers differential speed of 2.9 m s^{-1} and moisture content of 8-9% was the most appropriate combination for paddy husking of Binam and Khazar varieties in rubber roll husker.

Keyword: Paddy husker, Hulling index, Broken rice, Rollers speed.

INTRODUCTION

Within the worldwide-cultivated cereals, rice (*Oryza sativa* L.) stand out, constituting the basic food for large number of human beings, sustaining two-thirds of the world population [18]. In Asia, where 95% of the world's rice is produced and consumed, it contributes 40-80% of the calories of the people diet. Rice is a major crop in Iran, where rice production increased from 1.3 Mt in 1980 to 3.5 Mt in 2007 [5]. The main rice cultivated areas are located in the northern parts of the country, producing 75% of Iran's rice crop. Both local and improved varieties are cultivated in the rice growing regions of the country [2].

Milling, an important processing step of paddy (rough rice), is usually done to produce milled and polished grain. A typical rice milling system is a multi-stages process where the paddy is first subjected to dehusking by using a husker and then to removed of brownish outer layer, known as whitening [17]. One of the major problems of rice industry is breakage of kernels during milling. As cooking quality of broken rice is very poor, the market value with broken grain is much less than that for whole grains. The ultimate goal of the rice industry is to achieve maximum head rice yield (HRY) from the milling process. HRY is the current standard to assess commercial rice milling quality [9].

Among factors affecting the broken kernels during milling process, husking is one of the important influencing stages on the quantitative and qualitative losses of rice. During paddy husking by paddy huskers, some compressive stresses are exerted to rice kernels. Rubber roll husker is a common type used for paddy husking in many rice growing countries, because of its better husking performance and less broken rice compared to blade-type huskers. In principle, the rubber roll husker consists of two rubber rollers. One has a fixed position; the other is adjustable to obtain the desired clearance between the two rollers (Fig. 1). The rollers are driven mechanically and rotate in opposite directions, the adjustable roller normally running about 30 percent slower than the fixed one to create shearing effect. Both rollers have the same diameter.

Many researchers have already identified factors affecting performance of such milling machines as paddy husker and rice whiteners. Garibaldi (1981) reported that the appropriate ratio for rotational speed of the slow roller to the fast roller is 0.75 to 0.8 and the suitable peripheral speed difference between two rollers is 2 m s^{-1}. Tavakoli et al. (2002) reported that the most appropriate clearance between the rubber rollers for a laboratory husker for three varieties of Binam, Khazar and Sepidroud was ranged from 0.45 to 0.65 mm. Payman et al. (1999) determined the most suitable spacing between rubber rolls for increasing husking percentage and reducing rice breakage in the test huller. Alizadeh and Payman (2004) reported that use of blade-type whitener as a huller in milling process increased rice breakage in comparison with rubber roll husker. Shitanda et al. (2001) studied the Performance of experimental impeller and rubber roller huskers using three different varieties of paddy. Results of their study showed that Rubber roll husker had high husking energy efficiency compared to the impeller husker. Another experiment was conducted by Omar and Yamashita (1987) on laboratory rubber roller and impeller paddy husker. Results showed that the clearance ratio of 0.5 resulted in husking ratio higher than 80% and lower broken rice ratio than the other levels, thus it is the most suitable level for long grain paddy husking. The long grain variety of IR-8 gave somewhat more broken rice than that of Blue bonnet, and the husking efficiency was the highest with 0.5 mm clearance ratio.

Although many factors affecting performance of laboratory rubber roll husker have already been studied, however there is dearth information on commercial husking machine. Therefore, the objective of this study was to investigate the effect of such important parameters as rollers differential peripheral speed, paddy moisture content and type of variety on the broken brown rice and husking index of a commercial rubber roll husker used in rice mills.

MATERIALS AND METHODS

This study was carried out at the rice mill of Department of Agricultural Engineering, Rice Research Institute of Iran (RRII), Rasht, Iran. A commercial paddy husker (ISEKI HC 600, Japan) was used for the husking process. The schematic representation of the rubber roll husker used in the research is shown in Fig. 1.

In this experiment, the effect of six levels of rollers differential speed of 1.5, 2.2, 2.9, 3.6, 4.3, 5 m s^{-1}, three levels of paddy moisture content range of 8-9, 10-11, 12-13% (w.b.) and two varieties namely Binam (local variety), and Khazer (high-yielding variety) on the broken brown rice and husking index was investigated. The moisture content of paddy was measured by the means of a grain moisture meter (GMK-303 RS Model, Korea). In order to obtain the desired paddy moisture content, the samples were dried in a batch-type bed dryer (HASAN-MANSOR Manufacturing Co. Ltd., Iran) at a constant air temperature of about 43 ºC until the desired moisture content of the samples were obtained [10].

To determine the average size of the grain, 100 grains were randomly picked and their three axial dimensions namely, length L, width W and thickness T were measured with a caliper (Mitutoya caliper, Japan) reading to 0.01 mm. Some shape factors such as sphericity and slenderness ratio were determined using related equations.

In order to attain the desired rotational speed of the rollers, a belt and pulley mechanism was used for changing the rollers speed. For this, twelve pulleys were fabricated for varying rotational speed of the rollers. Six pulleys were used for drive shafts and six pulleys for driven shafts. The following equation was used to determine the diameters of the driver and driven pulleys for obtaining the desired roller speed:

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \qquad (1)$$

Where N_1 and N_2 are the rotational speeds of driver and driven pulleys (rpm) while D_1 and D_2 are the diameters of driver and driven pulleys (m), respectively. Diameter of driver and driven pulleys were calculated based on a given electromotor rotational speed and peripheral speed of the rollers by the following equation:

$$S = \frac{\pi \times D \times N}{60} \qquad (2)$$

Where, S is the roller peripheral speed (m s^{-1}), D is the roller diameter (m) and N is the rotational speed (rpm).

All the adjustments on the paddy husker and rice whitener were done before the major tests. At each test run, 20 kg paddy was fed into the hopper of the husker based on the experimental design. A total of 108 tests were recorded (6 levels of speed difference × 3 levels of moisture content × 2 paddy varieties × 3 replications). Unshelled paddy, brown rice and paddy husk were collected from the outlets of the paddy husker and then weighed using a 0.01 g precision digital scale (Sartorius CP 124 S, Germany).

To obtain the percentage of broken brown rice, three samples of 100 g were randomly chosen from the outlet of the husker machine. A rotary indent separator (TRG058 Model, SATAKE Test Rice Grader, Japan) was used for separating head and broken kernels. A kernel having equal to or more than 75% intact was considered as whole kernel [6]. The percentage of broken rice was calculated by the following equation:

$$\text{Broken kernel (\%)} = \frac{W_2}{W_1} \times 100 \qquad (1)$$

Where, W_1 is the mass of the sample of total milled rice (g) and W_2 is the mass of kernels with smaller than of 0.75 of intact milled rice (g).

Husking Index (HI) was used as the main criterion to describe the performance of the paddy husker. It was calculated using the following equation:

$$H = 100 \times \left(\frac{W_2}{W_1}\right)\left(\frac{W_3}{W_1 - W_2 - W_4}\right) \qquad (4)$$

Where HI is Husking Index (%), W_1 is mass of paddy fed (g); W_2 is mass of unshelled paddy (g); W_3 is mass of head brown rice (g) and W_4 is mass of paddy husk (g). The results gained were subjected to statistical analysis applying a factorial trial based on randomized complete block design (RCBD) with 36 treatments and three replications. Since the data of broken kernels were non accountable percentage amounts, so the transformation of Arc Sin $\sqrt{X}$ was used for normalization of them.

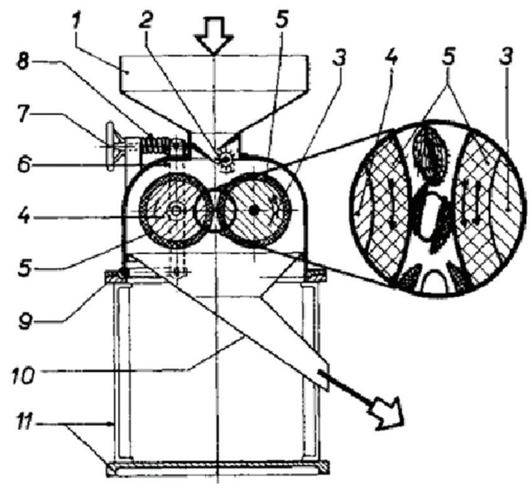

Fig. 1. Rubber rolls paddy husker and its construction (Aroullo et al. 1976). 1. Feed hopper, 2. Feed roller, 3. Fast roll, 4. Slow roll, 5.Rubber surface, 6.Roll adjusting arm, 7. Roll adjusting hand-wheel, 8.Compression spring, 9. Housing, 10. Outlet spout, 11. Base and frame

RESULTS AND DISCUSSION

Physical properties

Some physical properties of brown rice of the two tested varieties husked using the rubber roll husker is given in Table 1. It can be seen that Binam variety is shorter in length than Khazar variety, however the width and thickness of Binam is more than that of Khazar. Furthermore, the slenderness ratio of Binam (2.87) is lower than that of Khazar (4.00). Thus, based on the standards of IRRI [3], Khazar is classified as a "long-grain" paddy variety and Binam is "medium-grain". Previous studies have also indicated that the long grain varieties are more susceptible to breakage compared to shorter grain varieties during milling process [7, 11, 12, 16].

Broken brown rice

The results of analysis of variance (ANOVA) indicated that all of the three independent variables significantly (P<0.01) affected the broken brown rice (Table 2). The effect of paddy moisture content on the values of broken brown rice is illustrated in Fig. 2. It can be seen that for each type of variety, the broken brown rice significantly increased from 11.01 to 12.74% and from 14.89 to 16.45% for Binam and Khazar varieties, respectively with increasing paddy moisture content range from 8-9 to 12-13% (w.b.). This may be due to that at lower moisture content, the hardness of grains increased resulted in fewer broken brown rice [7].

Effect of rollers differential speed on the broken brown rice is presented in Fig. 3. As shown, there was a decreasing trend in the broken brown rice with increasing rollers differential speed for the tested varieties. The highest values of broken brown rice of 14.34 and 23.29% were obtained at the differential speed of 1.5 m s^{-1}, while the lowest values of 9.09 and 10.78 were measured at differential speed of 5 m s^{-1} for Binam and Khazar varieties, respectively.

Interaction effect of paddy moisture content and rollers differential speed on the broken brown rice is shown in Fig. 4. It can be seen that at each level of the evaluated moisture content, the broken brown rice decreased as the rollers differential speed increased. So that, the broken brown rice decreased from 20.62 to 7.57%, 17.24 to 11.29% and 18.59 to 10.96% for the paddy moisture content range of 8-9, 10-11 and 12-13%, respectively, as the rollers speed increased from 1.5 to 5.0 m s^{-1}. This could be attributed to that at higher rollers speed, the grains discharge faster from the machine outlet which resulted in less mechanical stresses exerted on kernels. There was no significant difference between the means of broken brown rice at paddy moisture levels of 10-11% and 12-13%.

Husking index

Effect of paddy moisture content on the husking index of the two tested varieties using rubber roll husker is presented in Fig. 5. A decreasing trend in husking index was observed with increasing moisture content. The husking index varied significantly (P<0.01) from 65.46 to 54.22% and 59.82 to 51.40%, for Binam and Khazar varieties, respectively as the moisture content increased from 8-9% to 12-13%. This could be related to that at higher moisture content, lower head brown rice was obtained (Fig. 4), thus, according to equation (4), the husking index which directly depends on the amount of head brown rice decreased. Further, at high paddy moisture content, there was a reduction in the husking rate (husked rice to paddy input ratio), caused to lower husking index. Similar results were reported by Payman et al. (2006) and Minaei et al. (2007) during paddy husking using a laboratory rubber roll husker.

Table 1. Grain properties of the studied paddy varieties

Rice variety	l (mm)	t (mm)	w (mm)	*s	sr	m (g)
Khazar	9.974	2.494	1.906	0.36	4	0.0375
Binam	8.46	2.944	1.924	0.43	2.87	0.0285

l: length, w: width, t: thickness, s: sphericity; sr: slenderness ratio; m**:** mass; * s: sphericity= (lwt)1/3 / l , (9).

Table 2. Results of analysis of variance (ANOVA) for broken brown rice and husking index of the tested varieties

Source of variations	df	M.S.	
		Broken brown rice	Husking index
Replication	2		
Variety	1	0.095*	544.233**
Error	2	0.004	4.089
Rollers differential speed	5	0.037**	397.019**
Variety × Differential speed	5	0.005**	33.021**
Error	20	0.0001	5.284
Moisture content	2	0.006**	875.845**
Variety × Moisture content	2	0.002*	19.85 ns
Differential speed × Moisture content	10	0.002**	79.174*
Differential speed × Variety × Moisture content	10	0.001**	49.974 ns
Error	48	0.0004	34.622
Total	107		

* significant at α =5%   ** significant at α =1%   ns non significant difference

Effect of rollers differential speed on the husking index is illustrated in Fig. 6. It can be seen that the maximum husking index for 65.00 and 59.97% was registered at the rollers speed of 2.9 m $s^{-1}$and the minimum of values of 55.23 and 46.72% at rollers speed of 5.0 m s^{-1} for Binam and Khazar varieties, respectively. This may be due to that at low rollers speeds (1.5 and 2.2 m s^{-1}), insufficient shearing action of friction forces exerts from the rubber rollers against husk of grains which resulted in low husking ratio. Besides, more grain breakage at low differential speeds intensified decreasing husking index simultaneously. It seems that at higher rollers speed, the decreasing rate of husking ratio was lower than that of broken brown rice, and according to equation 4, resulting the decrease in husking index. The mean value of husking index for Khazar variety (64.71%) was significantly less than that of Binam (69.2%). This could be attributed to more head brown rice yield of Binam (88.28%) compared to Khazar (84.13%).

Interaction effect of paddy moisture content and rollers speed on the husking index is presented in Fig. 7. The results revealed that at each level of rollers speed, there was an indirect relationship between the husking index and paddy moisture content. the husking index decreased from 62.00 to 56.00%, 56.77 to 53.62% and 52.22 to 47.09% for the paddy moisture content range of 8-9, 10-11 and 12-13%, respectively as the rollers speed increased from 1.5 to 5.0 m s^{-1}. This trend agrees with that reported by Payman et al. (2006) under laboratory conditions.

CONCLUSIONS

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

1. The head brown rice and husking index was decreased as the paddy moisture content range increased from 8-9% to 12-13%.

2. There was an indirect relation between broken brown rice and the rollers differential speed, i.e. higher broken brown rice was achieved at lower speeds. The maximum of husking index for Khazar (59.97%) and Binam (62.00%) was recorded at rollers speeds of 2.9 m s^{-1}.

3. It was concluded that rollers differential speed of 2.9 m $s^{-1}$and moisture content of 8-9% was the most appropriate combination for paddy husking of Binam and Khazar varieties in rubber roll husker.

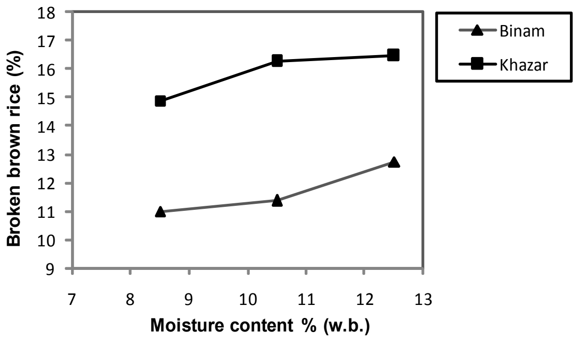

Fig. 2. Effect of paddy moisture content on brown rice breakage in hulling with rubber roll husker

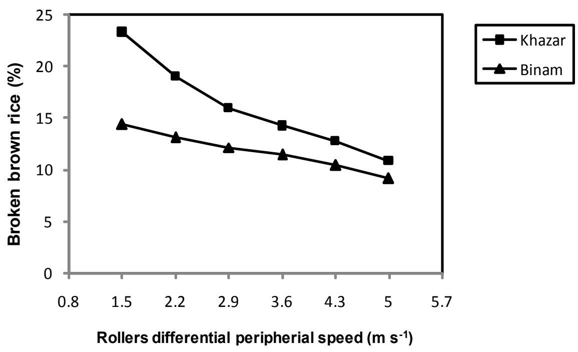

Fig. 3. Interaction Effect of paddy variety and rollers differential speed on brown rice breakage

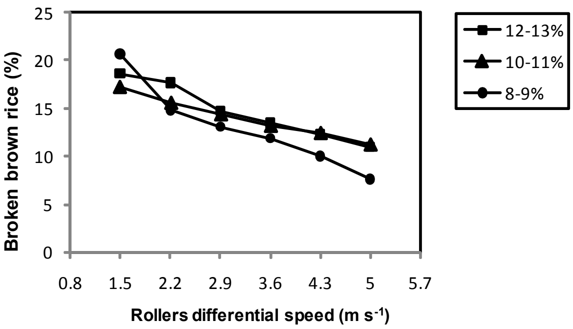

Fig. 4. Interaction Effect of paddy moisture content and rollers differential speed on brown rice breakage

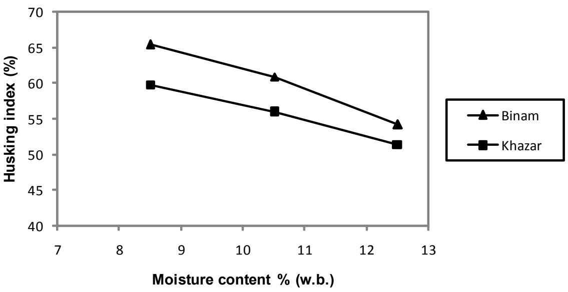

Fig. 5. Interaction Effect of paddy variety and moisture content on husking index

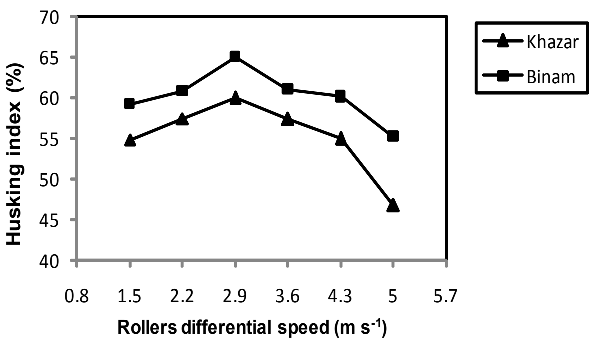

Fig 6. Interaction Effect of paddy variety and rollers differential speed on paddy husking index

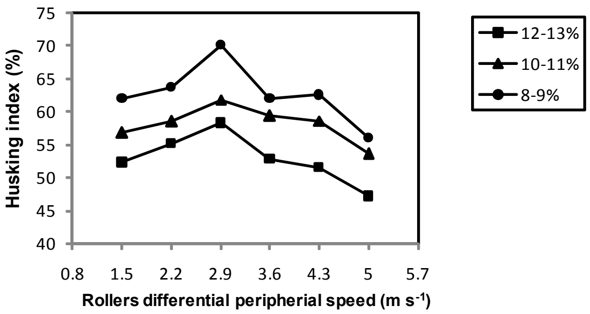

Fig 7. Interaction Effect of paddy moisture content and rollers differential speed on paddy husking index

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