

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

S. Firouzi, M.R. Alizadeh and S. Minaei

Abstract—A 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) and three levels of paddy moisture content (8-9, 10-11 and 12-13% w.b.). Two common paddy varieties namely, Binam and Khazar, 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, 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 and moisture content of 8-9% was the most appropriate combination for paddy husking of Binam and Khazar varieties in rubber roll husker.

Keywords—husking index, moisture content, paddy, rubber roll husker.

I. INTRODUCTION

RICE is a staple food in Iran and numerous farm families are supported by producing this crop. In spite of all the efforts in production, part of the crop is damaged and forms losses during the operations from planting to processing. According to the latest report, Annual production of white rice only in Guilan province of Iran is about 700000 tons [1]. Thus, if only 1% of rice breakage in milling operation is decreased, breakage of 7000 tons of rice will be prevented. For this reason, investigation of kernel damage and loss is very important.

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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 Iran, 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. 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. Some mechanical and varietal parameters affecting the performance of this machine need to be evaluated by researchers.

Rice researchers have already identified many factors that affect milling quality. Kunze has grouped these factors into two major categories: engineering and varietal factors. Engineering factors include harvesting, handling, drying, storage, transport and milling operations while varietal factors include physical and mechanical properties of grains [2]. Some factors like roller diameter, rotational speed and the clearance between rollers affect husking rate [3]. Garibaldi stated that the suitable 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 [3]. The most suitable clearance between rollers for three varieties of Binam, Khazar and Sepidroud was determined to be 0.45 - 0.65 mm in a laboratory husker [4]. An experiment was carried out by Shitanda *et al.* to analyze the Performance of experimental impeller and rubber roller huskers using three different varieties of paddy. Rubber roll husker had high husking energy efficiency compared to the impeller husker. Optimal husking ratio in terms of husking energy efficiency was also found to be optimal in terms of system cracked ratio and broken ratio for all tested paddy varieties [5]. Another experiment was conducted by Omar and Yamashita 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. Moisture content of 14% gave lower broken rice ratio among the three moisture levels of 12%, 14% and 16%. 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 [6].

A review of reports on rubber roller paddy huskers indicates that many originate from laboratory experiments. Thus, investigation on the industrial huskers is a need. In this regard, the effect of rollers differential speed as an important engineering factor in rubber roll husker and the effects of two grain factors including variety and moisture level were studied on the performance of commercial rubber roll husker in this research.

II. MATERIALS AND METHODS

Experiments were carried out at the Rice Research Institute of Iran in Rasht. The experimental apparatus was a rubber roll paddy husker which is the most common machine for paddy husking in mills of northern Iran. The effects of rollers differential speed, paddy variety, and moisture content were studied on broken brown rice and husking index.

Length, width and thickness of 100 paddy kernels were measured using a digital micrometer. Some shape factors such as sphericity and slenderness ratio were determined using related equations (Table 1).

A factorial trial based on randomized complete block design (RCBD) with three factors and three replications was used for the experiment. Factors were the differential speed of rubber rollers at six levels of 1.5, 2.2, 2.9, 3.6, 4.3, 5 m/s, paddy moisture content at three levels of 8-9, 10-11, 12-13% (w.b.) and two varieties namely Binam and Khazer as the common paddy varieties in northern Iran.

Twenty-centimeter deep layer Paddy was dried in a batch type dryer at air temperature of 35-40 °C up to the desired levels of moisture content [7]-[8]. The moisture content of dried paddy was determined by a grain moisture meter (Model GMK-303R5 – Korea). As the total number of treatments was 108 (6 levels of speed difference × 3 levels of moisture content × 2 paddy varieties × 3 replication) thus, we needed 108 packages of dried paddy. Each package contained 20 kg of paddy at one of three levels of desired moisture contents (8-9, 10-11, 12-13% (w.b.)).

Since a belt and pulley mechanism is used for power transmission in the rubber roll paddy husker, the following equation was used to determine the diameters of the driver and driven pulleys for obtaining the desired roller speed:

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

In this equation, N_1 and N_2 are the rotational speeds (rpm) while D_1 and D_2 are the diameters of driver and driven pulleys, respectively. Diameter of driver and driven pulleys were calculated based on a given electromotor rotational speed and peripheral speed of the rollers by means of the equation 2 below:

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

Where:

S= roller peripheral speed (m/s)

D= roller diameter (m)

N= rotational speed (rpm)

Twelve pulleys were fabricated for changing rotational speed of rollers. Six pulleys were used for drive shafts and six pulleys for driven shafts.

Paddy of each package was fed into the hopper of the husker based on the experimental design. 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).

Broken and head brown rice were separated by a rotary sieve (SATAKE TRG058, Japan). A kernel equaling or longer than 75% of the intact grain was considered as whole kernel [9]. Because of incomplete kernel separation in the instrument, hand sorting completed the operation. The percentage of hulled broken paddy was determined as below:

$$\text{Broken kernel (\%)} = \frac{W_1}{W_2} \quad (3)$$

Where, W_1 and W_2 are the mass of broken and total brown rice, respectively.

Husking Index (HI) was used as the main criterion to describe the performance of the paddy husker. It was calculated using equation 4:

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

Where HI is Husking Index in %, W_1 is mass of paddy fed in g; W_2 is mass of unshelled paddy in g; W_3 is mass of head brown rice in g and W_4 is mass of paddy husk in g.

III. RESULTS AND DISCUSSION

Some physical properties of the two varieties of rice husked using the rubber roll husker are given in Table 1. This Table shows that Binam variety is a medium grain with a length of 8.46 mm and thickness of 2.944 mm, whereas khazar is a long grain with a length of 9.974 mm and thickness of 2.494 mm. Slenderness ratios of Khazar and Binam varieties were determined as 4.0 and 2.87, respectively. Thus, Khazar is classified as a “long grain” paddy and Binam is “medium grain” based on the standards of IRRI [10].

Statistical analysis showed that paddy variety, moisture content and differential speed of rollers significantly affected the amount of broken brown rice and the husking index.

The mean value of breakage percent for Khazar variety (16.01%) was significantly ($P < 0.01$) higher than that of the Binam variety (11.75%). Binam variety is a medium grain which is thicker than the long grain khazar variety, so it is more resistant to pressures needed for husking. Previous studies have also indicated that the long grain varieties are more sensitive to breakage and cracking than the shorter grain varieties [6]-[11]. This result is in agreement with those reported by Payman *et al.* on a laboratory paddy rubber roll husker [12].

TABLE I
GRAIN PROPERTIES OF THE STUDIED PADDY

Rice variety ¹	l	t	w	*s	sr	m
	(mm)	(mm)	(mm)			(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= $(lwt)^{1/3}/1$, [13]

The effects of paddy moisture content on percent broken brown rice are shown in Fig. 1 for the two paddy varieties. Amount of broken brown rice significantly increased with paddy moisture content increasing from 8-9 % to 12-13% (w.b.). The least breakage was observed at the 8-9% moisture level with mean value of 13% and the maximum breakage was observed at the 12-13% moisture level with an average of 14.61%. There was no significant difference between the means of broken brown rice at paddy moisture levels of 10-11% and 12-13%. This could be attributed to lower grain hardness at higher moisture content [11]. Three moisture levels of 12%, 14% and 16% were used in the research of Omar and Yamashita on laboratory rubber roll husker. Their results showed that the moisture level of 14% gave a lower broken rice ratio [6].

Percentage of broken brown rice significantly decreased from 18.83 to 9.97% as the differential speed of the rubber rolls increased from 1.5 to 5 m/s. This may be attributed to more rapid discharge of husked paddy from the husker outlet. Since rapid discharge of materials from the husker shortens the time needed for husking operation, hence grain exposure to husking pressures is shorter which results in less breakage.

The mean value of husking index of the Khazar variety (64.71%) was significantly lower than that of the Binam variety (69.2%). It can be related to direct dependence of the husking index on the mass of head brown rice and since breakage of Khazar variety was greater than that of Binam, thus husking index for this variety is less than Binam.

Results showed that husking index decreased as paddy moisture content increased. The maximum husking index was observed at moisture level of 8-9% with a mean value of 71.64% (Fig. 1). Minimum husking index was observed at the 12-13% moisture level. The husking index directly depends on the mass of head brown rice, and because the head brown rice decreased with increasing grain moisture content, the husking index decreased with increasing moisture level. The obtained result agrees with that reported by Payman *et al.* under laboratory conditions [12].

According to Fig. 2, the husking index increased initially and then started to decrease in line with increase of rollers differential speed, such that the maximum amount was obtained at differential speed of 2.9 m/s. At low differential speeds (1.5 & 2.2 m/s), the cutting action of friction forces between grains husk and the surface of rubber rollers are low which resulted in low husking ratio and then low husking index. Besides, the high value of grain breakage at low

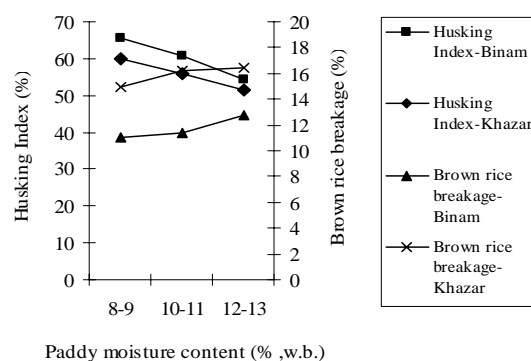


Fig. 1 Effect of paddy variety and moisture content on husking index and brown rice breakage in hulling with rubber roll husker

differential speeds intensified decreasing husking index simultaneously (Fig. 2). At higher differential speeds (4.3 to 5 m/s), materials discharge faster from machine outlet, thus, less stresses are exerted on kernels. Therefore, grain breakage and husking ratio were less. It seems that the decrease in husking ratio was lower than that of breakage percent resulting in the decrease in husking index. Thus the best speed difference was observed at one of the middle levels of the studied range (2.9 m/s).

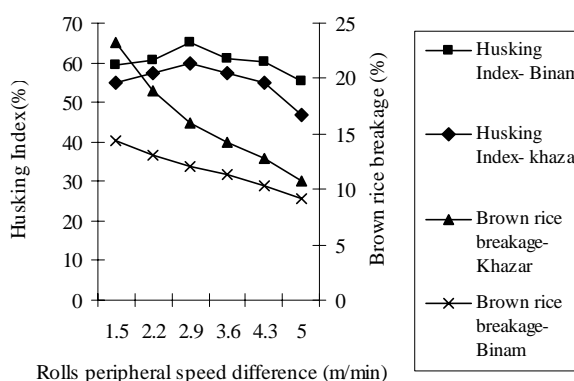


Fig. 2 Effect of paddy variety and rollers differential speed on husking index and brown rice breakage

The interaction effect of rollers differential peripheral speed and paddy moisture level on the dependent variables is shown in Fig. 3. This Fig. shows that the most suitable husking index was obtained at the lowest level of paddy moisture content and roller differential speed of 2.9 m/s. Since the husking index directly shows the qualitative performance of husker, the combination of differential peripheral speed of 2.9 m/s and paddy moisture level of 8-9% is most suitable for husking paddy varieties of Binam and Khazar with the rubber roll husker.

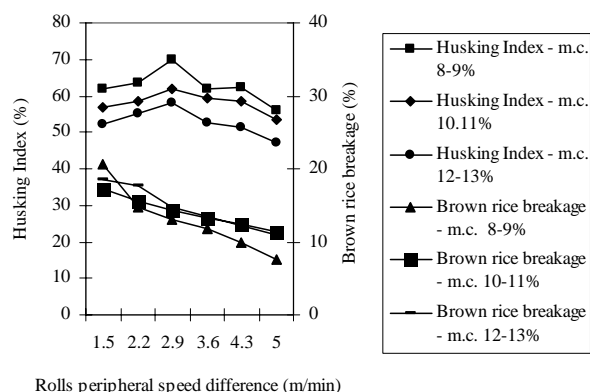


Fig. 3 Effect of paddy moisture content (%w.b.) on percent breakage and husking index at various levels of rollers differential speed

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REFERENCES

- [1] Anonymous. *Annual Report of Rice production in Guilan Province*. Guilan organization of Agriculture, Rasht, Iran, 2008, pp. 1-10.
- [2] O. R. Kunze. "Environmental conditions and physical properties with produce fissures in rice," Ph. D. Dissertation, Michigan State University, USA, 1964.
- [3] F. Garibaldi. Rice milling equipment operation and maintenance. *FAO Agric. Services Bull.* Rome, No. 22, M-17, ISBN 92-5-101095-1. 1981.
- [4] T. Tavakoli, M. H. Payman, M. Alizadeh, M. H. Khoshtaghaza. "Effect of moisture content and linear speed on paddy dehulling quality," *Proceeding of the International conference on Agricultural Engineering*, BUDAPEST, 2002, PP. 168-169.
- [5] D. Shitanda, Y. Nishiyama, S. Koide. "Performance analysis of impeller and rubber roll husker using different varieties of rice," *the CIGR Journal of Scientific Research and Development*. Manuscript FP 01 001. 2008, 3: 1-19.
- [6] J. S. Omar and R. Yamashita. Rice Drying, Husking and Milling- Part II Husking. *Agricultural Mechanization in Asia, Africa and Latin America*. 1987, 18: 43-46.
- [7] A. Khoshzamid. Determination the best degree of heat for drying and milling of paddy. *Final Report of Research, Iranian Rice Research Institute*. Rasht, Iran, 1993, PP. 20.
- [8] S. Sabori. Determination appropriate height of paddy in drying with bed type driers. *Final Report of research, Iranian Rice Research Institute*. 2002, PP. 1-22.
- [9] S. M. Farouk and M. N. Islam. "Effect of parboiling and milling parameters on breakage of rice grains," *Agricultural Mechanization in Asia, Africa and Latin America*. 1995, 26: 33-38.
- [10] Anonymous, . 1996. "Standard Evaluation System for Rice". IRRI, INGER, 4th Edition, July 1996.
- [11] S. Firouzi and M. R. Alizadeh. "Investigation on rice breakage in milling with common Engleberg rice whitener in the north of Iran," *Journal of Agricultural Sciences, Islamic Azad University*. 2005, 11: 117-128.
- [12] M. H. Payman, I. Bagheri, M. R. Alizadeh, R. Roohi. "Effective parameters of broken rice during paddy hulling using rubber roll huller," *Journal of Biological Sciences*, 2006, 7: 45-71.
- [13] N. Mohsenin, Physical properties of plant and animal materials, 2nd ed. New York, EE. UU Gordon and Breach Publishers, 1986.