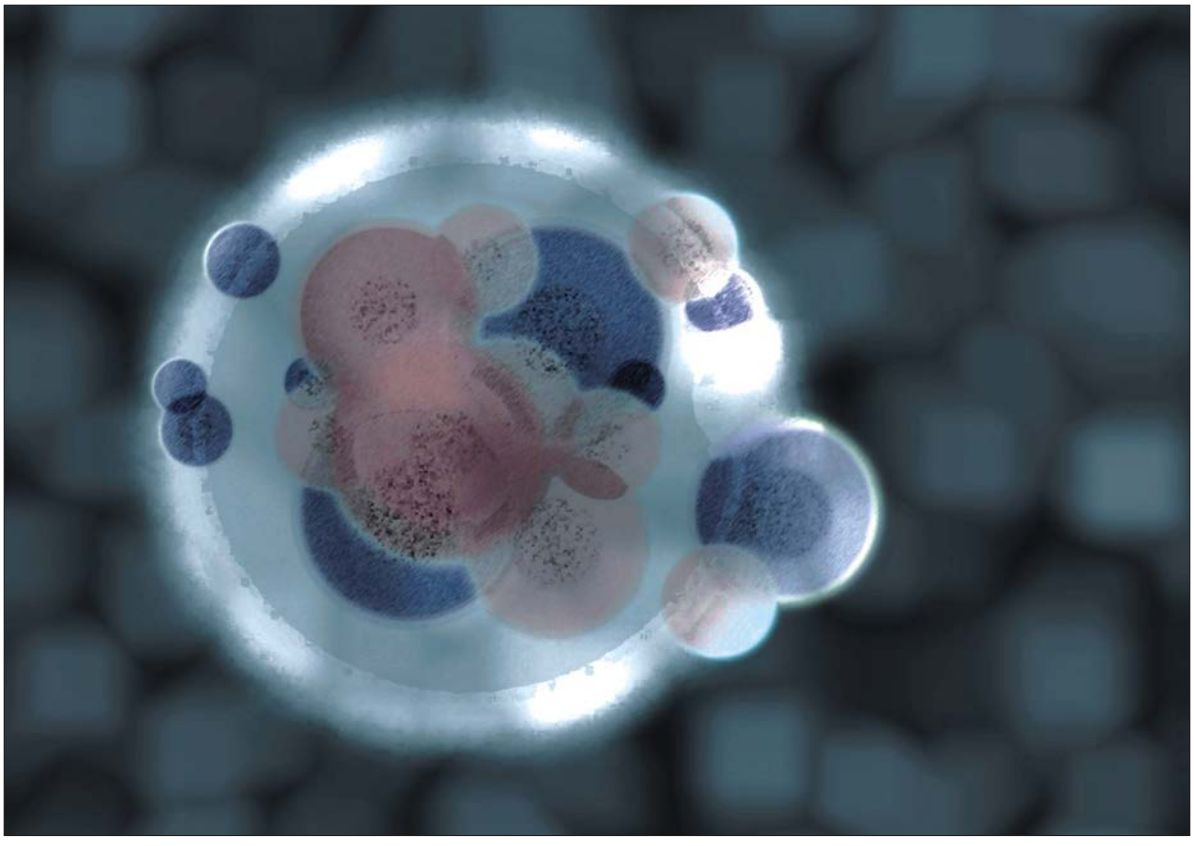

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Effective Parameters of Broken Rice During Paddy Hulling Using Rubber Roll Huller

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Abstract: One of the effective parameters on broken rice while hulling is the way in which the machinery like the paddy huller work. With regards to the nature of paddy hulling operation in the milling process some of the rice quality losses occur at this stage because the hulling operation is mechanical and consist of different stresses. Three varieties of Binam, Khazer and Alikazemi were used for the study. The levels of moisture content used in the tests were 9.5-11, 11-12.5 and 12.5-14% wet. The linear speed difference was chosen so that the linear speed of rollers was in the range of 200 to 275 m min^{-1}. The results showed that the main effects of all parameters studied were significant on the amount of rice breakage. The main effects such as linear speed differences of rollers m min^{-1} and variety were significant on the hulling index and the counter effects of linear speed differences of rollers and m.c. were also significant on the hulling index but did not have a significant effect on the amount of rice breakage. The highest hulling index for the three varieties considered occurred with a roller linear speed difference of 236.7 m min^{-1} and the least rice breakage occurred when the roller linear speed difference were 229.3 m min^{-1}. Under similar conditions the lowest rice breakage occurred with the Binam variety. The amount of rice breakage in the hulling process for the Alikazemi variety was significantly higher than the other two varieties. The highest broken rice in the hulling process for Alikazemi occurred at moisture content of 11-12.5% and for the other two varieties at 12.5-14%.

Key words: Rice breakage, rubber roll huller, linear speed, moisture content, variety

INTRODUCTION

Rice is the staple diet and main source of income of half the world population. After wheat, rice is the second major food source in Iran. Because of population increases, limited cultivated land and limits in water resources it is very important to decrease rice losses.

During the milling process (hulling and whitening) the paddy grain is under mechanical and heat stresses. Rice breakage at this stage is one of the main economic losses to the farmers. Some of quality losses occur during paddy hulling in the milling operation because it is a mechanical operation which causes stresses in the rice kernel. In the hulling operation compression and friction is used to produce brown or white rice with minimum grain breakage (Nishiyama, 1995).

The rubber roll huller has advantages over the hullers with other rollers and is used in most of the rice milling factories of Iran. In the hulling process, the paddy grain kernels are compressed and hulled between two rolls which are coated with rubber and move opposite directions with different speeds. In this huller the danger of grain breakage is less because of elasticity of the rubber coated rollers. However the cost of making this kind of rollers is higher and the costs of maintenance are also high because of wear of the rubber coatings due to friction (Garibaldi, 1981). Factors like rollers diameter, rotational speed and the distance between rollers affect paddy hulling rate. Garibaldi (1981) determined that the suitable ratio for rotational speed of the slow roller to the fast roller is 0.75 to 0.8 and the difference of linear speed between two rollers is 2 m sec^{-1}.

The most suitable distance between rollers in hulling operation for three varieties of Binam, Khazer and Sapidrood are 0.45 to 0.65 mm (Tavakoli *et al*., 2002). Khoshzamir *et al.* (1992) came to the conclusion that the best m.c. for Binam is 11-12% and for Khazer and Sepidrood 13- 14%, but the field studies show that in most rice milling factories the m.c. of paddy is reduced to less than 10% for milling process (Payman, 1999).

The results obtained by Stipe *et al.* (1971) showed that the quality of milled rice is low when paddy is shelled at high moisture level. Of the varietal characteristics of paddy, grain size and shape are considered the most

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stable properties of the variety (Juliano, 1985). Ancheta and Andales (1990) showed that varietal differences do not remain the same at different moisture content levels and that total milled and head rice responses to moisture content vary with varieties.

The aim of this study is to determine important factors that affect the operation of rubber roll hulling machine, in order to decrease the amount of rice breakage (decrease in quantity losses) in Iranian rice varieties.

MATERIALS AND METHODS

This study was conducted in 2003 at The University of Guilan In this study the effects of three factors on rice breakage in rubber roll hulling machines were studied; the difference of linear speed between rollers, rice variety and moisture content. The tests were carried out on three varieties of Alikazemi, Binam and Khazer, which are important varieties in Guilan province of Iran.

A laboratory rubber roll huller was used for the tests because a production size huller would require too large a quantity of rice and thus would be very expensive. In addition it would be easier to make adjustments to lab huller with the smaller rollers. The difference in linear speed of small roller was easily changed and also little amount of paddy grain is needed for the tests and the work quality of the machine has been evaluated before (Tavakoli *et al*., 2002).

Payman (1999) showed that most of the current hulling rollers in Iran were HC600 model and the difference in the linear speed between two rollers was 255 m min^{-1}. In order to determine the effects of hulling rollers linear speed differences on milling quality, four speed levels of 200.8, 229.3, 236.7 and 272.7 m min^{-1} are chosen. Therefore the changing of rotational speed in this study was chosen such that the differences in linear speed of rollers were between 200 to 275 m min^{-1} and was changed at four different levels. The rotational speed was changed by the size of the pulley at the end of the rollers.

Three moisture content levels of 9.5-11, 11-12.5 and 12.5-14% were used for the tests with regards to the m.c. levels used by other researchers and the existing condition in the laboratory. A laboratory batch dryer was used for drying the samples to the required m.c. level. For measuring m.c. of the samples a digital moisture measurement instrument GMK-303RS model was used. This instrument was electrical and had measuring resistance.

The distance between hulling rollers was 0.65 mm for all the tests based on the results obtained by Payman *et al*. (2000). For separating brown head rice from broken ones a vibrating sieve made by International Rice Research Institute was used. Each unit of test for carrying out the tests (Tavakoli *et al*., 2002; Payman *et al*., 2000) was 250 g. Therefore for hulling each variety at three moisture levels and 4 different levels of linear speed of rollers, 12 samples with overall weight of 3 kg were needed.

In this study the dependent variables were the mass of hull, percentage of broken brown rice, unhulled paddy, which were measured at hulling stage and hulling index the determining factor for quality hulling was calculated on the basis of above variables.

The formula below was used for measuring hulling index (Anonymous, 1981):

$$HI = 100\left(1 - \frac{W_2}{W_1}\right)\left(\frac{W_3}{W_1 - W_2 - W_4}\right)$$

Where HI is hulling index in %; W_1 is paddy fed in g; W_2 is unhulled paddy in g; W_3 is brown rice in g and W_4 is hull in g.

To manage the time required for the tests, the tests were carried out in split plots in randomized complete block design. The rotational speed of hulling rolls was the main factor in this study and the variety and m.c. was the first and second minor factors respectively. With regards to high workload of operation three repetitions were carried out. In analysis of variance of the data, comparing averages and calculating other required indices the MSTATC and for the graphs the Excel soft wears were used.

RESULTS AND DISCUSSION

The results of analysis of variance of measuring factors in hulling process are shown in Table 1. The results show that the main effects of all considered variables on the amount of broken rice are significant. The double counter effects are significant in all cases but one and the triple effects of variables are not significant.

Table 1: Results of analysis of variance of measuring factors

		Means square	
Source of variables	df	Rice breakage	Hulling index
Roller (m min^{-1})	3	0.0001	0.151**
Error	6	0.0001	0.0001
Variety	2	0.275**	0.128**
Variety * Roller (m min^{-1})	6	0.0001**	0.008**
Error	16	0.0001	0.001
Moisture content	2	0.004**	0.001 ns
Moisture * Roller (m min^{-1})	6	0.0001 ns	0.004**
Moisture * Variety	4	0.003**	0.003*
Moisture * Variety * Roller	12	0.0001 ns	0.002 ns
Error	48	0.0001	0.001
Coefficient of variance (CV)		10.7%	4.7%

*, ** = respectively significant, ns = non significant

The main factors of hulling rollers linear speed differences (revolution) and variety on hulling index is significant but the effect of m.c. on hulling index is not significant. The results from Duncan test show that the lowest hulling index is obtained at linear speed differences of 272.2 m min^{-1} (Fig. 1). When the linear speed differences of hulling roller is 272.2 m min^{-1}, because of high rotational speed of rollers the time the paddy are in contact with rollers is less and the time necessary for hulling paddy is not enough and the paddy are discharged towards exit instead of being hulled. The proof is the amount of unhulled paddy at four levels of rollers linear speed difference (Fig. 2).

As can be seen the most unhulled paddy is obtained at linear speed difference of 272.2 m min^{-1} and the least unhulled paddy is obtained at linear speed difference of 236.7 m min^{-1}. Increasing the linear speed differences of roller up to 236.7 m min^{-1}, the amount of unhulled paddy is decreased, but at high difference speed between rollers the amount of unhulled paddy is increased significantly.

The results of Duncan's multiple range tests show that the amount of breakage at linear speed differences of 229.3 m min^{-1} is significant and lower compared with other three levels. The reason for the increase in breakage at linear speed difference of 200.8 m min^{-1} is the period of time the paddy is in contact with rollers. There is more time for paddy to be in contact with rollers at low speed and even after being hulled the paddy are under pressure between two rollers therefore the damages are increased.

The Khazer variety is from improved varieties and the two other varieties are from local varieties. Although the measurement of coefficient of dynamic friction of these varieties are not available, but by looking at the surface of these paddy it can be seen that the percentage of roughness and unevenness of Alikazemi and Binam paddy surface are more than Khazer variety. This can be due to high coefficient of friction for the two varieties of Alikazemi and Binam compared with the Khazer variety. The results show that the effect of variety on hulling index is significant (Table 1). It can be said that decreasing moisture will decrease the adhesion force between paddy hull and the brown rice. When the paddy m.c. is low compared to when it is high, the paddy hull can be separated easier from brown rice by the force of hands.

The research results of Juma Omar and Yamashita (1987) show that by increasing m.c. of paddy from 12 to 16% (on wet basis), the amount of unhulled paddy and broken rice increase significantly. These amounts of increase are more significant at 14% m.c. level than other two m.c. levels. Therefore hulling index is more at 12% m.c. In order to give a more definite answer about the effect of m.c. on hulling index, more tests at more m.c. levels have to be carried out.

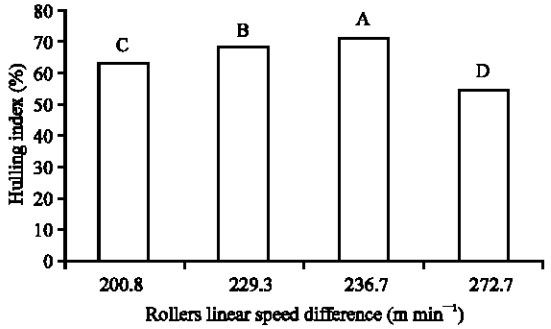

Fig.1: Effect of rollers linear speed difference on the hulling index

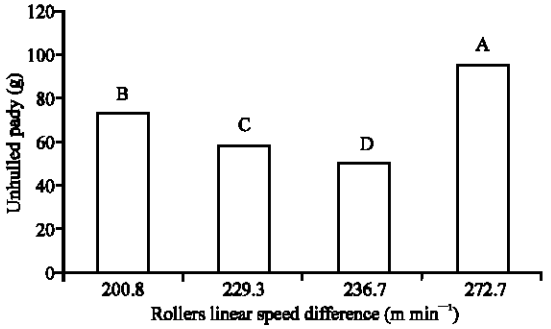

Fig. 2: Effect of rollers linear speed difference on the amount of unhulled paddy

Based on the information from analysis of variance Table 1, the counter effect of linear speed differences of rollers (revolution) and variety on hulling index and breakage were significant. Table 2 shows the results of comparison of the above counter effect on considered factors in Duncan's method. The changing trends of hulling index with increase in linear speed difference of rollers are the same for all the three varieties. In all four levels of linear speed difference of rollers, the hulling index of Alikazemi variety was significantly less than the other two varieties and this is due to the high breakage for this variety.

The hulling index of Binam and Khazer varieties at linear speed difference of 200.8 and 229.3 m min^{-1} are not significantly different from each other, but at higher linear speed difference the hulling index of Binam variety is significantly higher than Khazer variety. For all the three varieties the lowest hulling index occurred at linear speed difference of 272.7 m min^{-1}. This means that hulling process is not correctly carried out and it is due to high linear speed difference of rollers and the period paddy are in contact with rollers is decreased.

The consideration of the above counter effect on broken rice shows that by increasing the linear speed difference more than 229.3 m min^{-1} the broken rice in Alikazemi variety is increased significantly (Table 2).

Table 2: Results of Duncan's multiple range test for counter effect of rollers linear speed difference and variety on considered factors

Linear speed difference (m min^{-1})	272.7			236.7			229.3			200.8		
Variety	Khazar	Binam	Alikazemi	Khazar	Binam	Alikazemi	Khazar	Binam	Alikazemi	Khazar	Binam	Alikazemi
Hullin index	I	H	J	B	A	GH	CD	BC	FG	DE	EF	H
(%)	54	59	48	73	78	59	69	72	63	67	64	58
Rice breakage	DE	E	A	D	DE	B	D	E	C	D	E	C
(%)	5	4	21	6	5	20	6	4	19	6	4	19

Table 3: Results of Duncan's multiple range test for counter effect of rollers linear speed difference and moisture content on considered factors

Linear speed difference (m min^{-1})	272.7			236.7			229.3			200.8		
Moisture content (%)	12.5-14	11-12.5	9.5-11	12.5-14	11-12.5	9.5-11	12.5-14	11-12.5	9.5-11	12.5-14	11-12.5	9.5-11
Hulling index (%)	E	E	F	AB	ABC	A	BC	BC	ABC	D	D	C
	54	55	51	70	69	72	68	67	69	62	62	66
Rice breakage (%)	C	A	C	C	A	C	C	C	C	C	B	C
	10	12	9.6	9.8	1.8	9	9.4	10	9	10	11	9

Table 4: Results of Duncan's multiple range test for counter effect of variety and moisture content on considered factors

Variety	Khazar			Binam			Alikazemi		
Moisture content (%)	12.5-14	11-12.5	9.5-11	12.5-14	11-12.5	9.5-11	12.5-14	11-12.5	9.5-11
Hulling index (%)	C	BC	AB	AB	A	A	D	E	DE
	64	66	67	68	69	69	59	55	57
Rice breakage (%)	C	C	D	D	E	E	B	D	B
	6	6	5	5	4	4	18	23	18

The amount of broken rice at linear speed difference of less than 236.7 m min^{-1} for Binam and Khazer variety are significantly different and for Binam variety is less than Khazer variety, but broken rice for Binam and Khazer varieties in consequence of changes of linear speed difference of rollers are not significantly different.

The Alikazemi variety is sensitive to factors affecting losses and initial analysis show that the initial crack in Alikazemi is more than the other two varieties; the other reason for this is the long ness of the grain. In hulling process breakage of Khazer variety is more than Binam. The Khazer variety is longer than Binam variety and this causes it to break more at hulling process. The studies show that long grain varieties are more sensitive to breakage and crack than short grain and their percentage of breakage is more when the conditions are the same for both long and short grain varieties (Wiset *et al*., 2001). Juliano, (1985) also showed that of the varietal characteristics of paddy, grain size and shape are considered the most stable properties of the variety.

As shown in Table 3 the trend of changes of hulling index because of increase in linear speed difference of rollers for the three m.c. levels are the same. The least hulling index for the three m.c. levels is at the linear speed difference of 272.7 m min^{-1}. At linear speed difference of 229.3 and 236.7 m min^{-1} there is not a significant difference in hulling index for the considered m.c. levels, but at linear speed difference of 200.8 m min^{-1}, the hulling index at the m.c. of 9.5-11% show a significant difference with other two levels and is also higher.

The analysis of variance tests shows that the counter effect of variety and m.c on hulling index and breakage are significant (Table 1). The results of Duncan's multiple range test for this counter effect is shown in Table 4. The results show that the hulling index of the two Binam and Khazer varieties at all three m.c. levels is significantly more than the Alikazemi variety and this is due to high breakage of the Alikazemi variety. The most hulling index for Khazer variety is seen at m.c. of 9.5-11%. The analysis of the counter effect of variety and m.c. on broken rice shows that for Binam and Khazer varieties the broken rice at two m.c. levels of 9.5-11 and 11- 12.5% are significantly less than at m.c. of 12.5-14%. For these two varieties an increase in m.c. at the predetermined m.c levels will increase breakage, but for Alikazemi variety the most broken rice occurs at 11-12.5% m.c. (Fig. 3). Ancheta and Andales (1990) showed that total milled and head rice responses to moisture content vary with varieties. Stipe *et al*. (1971) also showed that the quality of milled rice is low when paddy is shelled at high moisture level.

In this study hulling stage were only assessed but for promoting new varieties it is necessary to evaluate the whole paddy hulling process (whitening and hulling). The tests in this research was carried out at laboratory scale (lab rubber roll huller) and in order to verify the results of this study it is necessary to do the tests at actual scale in rice milling factories (production scale hullers) and some research should be carried out on the physical properties of Iranian rice varieties.

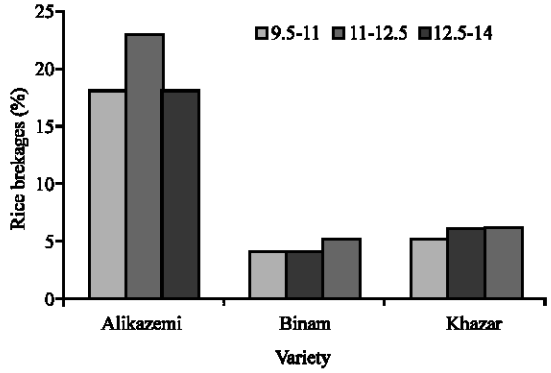

Fig. 3: Counter effect of variety and moisture content on the amount of rice breakage when hulling (Duncan's multiple range test)

The objective of this study was to determine important factors that affect the operation of rubber roll hulling machine in order to reduce rice breakage and based on this the significant findings of the research are as follows:

- The amount of rice breakage increases if the linear speed of rollers is high or low.
- The most suitable hulling index and least rice breakage occur at roller linear speed of 236.7 m min^{-1}.
- The Binam variety has less rice breakage than khazer and Alikazemi varieties and that is because Binam is a medium grain and the other two are long grain varieties.
- Increasing m.c. (at the predetermined m.c. levels) at hulling stage decreases hulling index and increases rice breakage.

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