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Effect of final paddy moisture content on breaking force and milling properties of rice varieties

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ABSTRACT

The effect of dried grain final moisture content on breaking force and milling properties of paddy and brown rice were studied. Results revealed that the breaking force decreased significantly ($P<0.01$) from 146.66 to 113.51 N, 150.49 to 101.93 N and 150.31 to 113.86 N for Hashemi, Kadous and Khazar, respectively, as the moisture content increased from 6 to 12 %(w.b.). In case of brown rice, the similar trend were observed such that at the same moisture range, the breaking force decreased from 93.18 to 79.32 N, 93.4 to 82.06 N and 104.4 to 83.64 N for Hashemi, Kadous and Khazar, respectively. The maximum and minimum head rice yield (HRY) of 80.13 and 73.76 % were obtained at moisture content of 6 and 12 % respectively. There was an incremental trend in the values of head brown rice yield (HBRY) and milling recovery with decreasing dried final moisture content.

Introduction

Rice is consumed as staple food grain by almost half of the world population in form of milled rice kernels. Milling, an important processing step of rough rice (paddy), is usually done to produce white and polished grain. A commercial rice milling system is a multi-stages process where the paddy is first subjected to dehusking and then to the removal of brownish outer layer, knows as whitening (Yadav and Jindal, 2008).

One of the major problems of rice industry is breakage of kernels during milling. As a cooking quality of broken rice is very poor, the market value with broken grain is much less than that for whole grains (Li et al., 1999). 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 (Iguaz et al., 2006). The breakage of rice in milling process is influenced by several factors. Besides rice variety, management of post-harvest operations and specially drying conditions, also affect the extent of kernel damage. Kernel breakage is closely related to fissure development in different stage of harvesting and post harvesting operations. Among factors affecting on the broken kernels during milling process, final moisture content of paddy is one of the important influencing parameters on the quantitative and qualitative of milling.

Many researches have been conducted to study on the breakage and milling quality of rice. Chaitep et al. (2008) investigated the compressive load of rough and brown rice with reference to a principal axis normal to the thickness of the grain at selected inclined angle range 0 to 70º in moisture content of 10-12%. The results showed the compressive load resistance of rice grain base on its characteristic of yield strength, of which can be expressed as relationships of the shear strength. Eshaghbeygi et al. (2009) studied on the effect of rice variety, drying temperature and kinetic energy level on mechanical resistance of brown rice kernel. Results show that no significant effect was observed at different drying temperature while the effect of rice variety and kinetic energy were significant at 1 % of probability. Nguyen and Kunze (1984) in a study of fissuring of rough rice in related to post drying treatment, determined the average breaking force was generally correlated that to the percentage of fissured kernels. Lu and Seibenmorgen (1995) studied the correlation of head rice yield to selected physical and mechanical properties of two long-grain rice varieties at moisture content range of 12 to 23 % and concluded that the average bending force had significant correlation with head rice yield. Afzalinia et al. (2002) evaluated the effect of paddy moisture content and different milling method on rice kernel breakage during milling process. They found that paddy moisture content had a significant effect on rice breakage of the whitener and the entire milling system, but moisture content had no significant effect on the rice breakage of the Sheller and polisher. Cao et al. (2004) reported that various moisture content of brown rice had affect on the physicochemical, mechanical and thermal properties.

In most of Iran mills, the milling practice of paddy is performed at various moisture content s. Thus, the objectives of this study were to investigate the effect of dried final moisture content of paddy on the breaking force and related milling properties and to determine the appropriate moisture content for different variety.

Methods and Materials

This study was conducted at the Department of Agricultural Engineering, Rice research Institute of Iran (RRII), Rasht, Iran. Three paddy varieties namely Hashemi, Kadous and Khazar were used as samples tests. The grains were cleaned manually to remove all foreign matters, broken and immature grains. The initial moisture content of grains was determined by oven drying at 103ºc for 48 h (Minaei et al., 2007) and was found to be, 14.5, 15.3 and 15.8 %, for Hashemi, Kadous and Khazar, respectively. In this experiment, the effect of four levels of dried paddy final moisture content of 6.0, 8.0, 10.0 and 12.0% (w.b.) on the breaking force and milling properties of the three paddy varieties. In order to attain the desired final moisture content below the initial content, the samples were placed in an electric

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oven with drying air temperature of 43ºC until desired moisture content of the samples were obtained.

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. The equivalent diameter Dp in mm of paddy grain was calculated through the following equation (Reddy and Chakraverty, 2004):

$$D_p = \left[4L\left(\frac{W+T}{4}\right)^2 \right]^{\frac{1}{3}} \qquad (1)$$

Where, L, W and T are length, width and thickness of the grain in mm, respectively.

Jain and Bal (1997) stated grain volume (V) and grain surface area (S) may be given by:

$$V = 0.25\left[\left(\frac{\pi}{6}\right) L (W+T)^2 \right] \qquad (2)$$

$$S = \frac{\pi B L^2}{(2L - B)} \qquad (3)$$

Where

$$B = \sqrt{WT} \qquad (4)$$

Breaking force (Hardness) of the dried paddy and brown rice kernels was measured using a texture analyzer (Lutron FG5020, Taiwan) with a 20 kgf (196 N) load cell using single compression. A 5 mm diameter stainless steel probe was used to compress a single grain (Mohapatra and Bal, 2007). The test was repeated for 20 times from the same sample lot, for all the three varieties. The maximum force indicated by the force gauge was taken as the maximum compressive force/hardness.

In order to study the milling properties of the tested varieties, four samples of 150 g were randomly chosen from the dried paddy sample lot. A laboratory husker (SATAKE ENGINEERING CO., LTD, Japan) was used to husk the paddy samples. Then, the samples were whitened using a laboratory friction type rice whitener (McGill Miller, USA). After husking and whitening, four samples of brown and milled rice were picked out from out let of the husker and whitener machine. A rotary indent separator (SATAKE, TRG 058, Japan) was used for separating head and broken kernels. A kernel having equal to or more than 75% intact was considered as whole kernel (Farouk and Islam, 1995). The head brown rice yield (HBRY) and head rice yield (HRY) was calculated by the following equation:

$$HBRY = \frac{W_1}{W_2} \times 100 \qquad (5)$$

Where HBRY is head brown rice yield in % and W1 and W2 are the weight of head brown rice and total brown rice in g, respectively.

$$HRY = \frac{W_3}{W_4} \qquad (6)$$

Where HRY is head rice yield in % and W3 and W4 are the weight of head milled rice and total milled rice in g, respectively.

The experiments were conducted in a factorial statistical design. Considering combination of the evaluated factors, 12 treatments were evaluated in the form of completely randomized design (CRD). At each treatment, the experiments were replicated four times and then the mean values were reported. The experimental data were analyzed using analysis of variance (ANOVA) and the means were separated at the 5% probability level applying Duncan's multiple range tests in SAS software (1990) program and figures were plotted using Microsoft Excel 2003 software.

Results and Discussion

Physical properties of the paddy varieties

The mean and standard deviations of 50 measurements of the axial dimensions and equivalent diameter of the tested varieties at moisture content of 12 % (w.b.) are given in Table 1. It can be seen that the highest length of 11.27 mm was measured for Kadous and the highest width of 2.41 mm was recorded for Khazar variety while the maximum thickness of 1.9 mm was measured for Kadous and Khazar varieties. Hashemi variety registered the lowest length (10.07 mm) and thickness (1.87 mm). The equivalent diameter for paddy of Hashemi, Kadous and Khazar were 3.57, 3.68 and 3.6 mm, respectively.

Breaking force

Effect of dried final moisture content on the breaking force of paddy and brown rice are presented in Figure 1 and 2. As shown in the figures, in all the tested varieties, breaking force decreased significantly (P<0.01) as the paddy moisture content increased. The breaking force of paddy decreased from 146.66 to 113.51 N, 150.49 to 101.93 N and 150.31 to 113.86 N for Hashemi, Kadous and Khazar, respectively, as the moisture content increased from 6 to 12 % (Figure 1). Similar trend was observed for brown rice, so that it decreased from 93.18 to 79.32 N, 93.4 to 82.06 N and 104.4 to 83.64 N at the same range of evaluated moisture content (Figure 2). It can be seen that at each level of moisture content, the breaking force of brown rice was lower than that of paddy. This may be due to that the presence of the hull which protects the grain against the compressive loading, leading to higher breaking force.

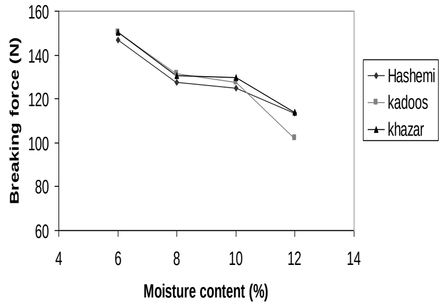

Figure 1: Effect of moisture content on breaking force of paddy for three varieties

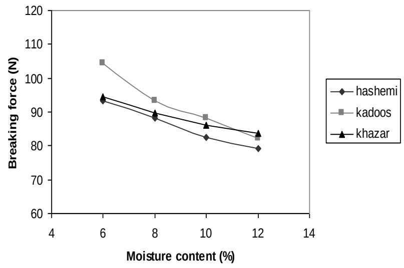

Figure 2: Effect of moisture content on breaking force of brown rice for three varieties

The highest and the lowest breaking force of paddy grain was recorded for Kadous variety at the moisture content of 6 and 12 %, respectively. In case of brown rice, the highest breaking force of 104.4 N was obtained for Kadous variety and the lowest value of 79.32 N was measured for Hashemi variety. The varietal difference in breaking force of brown rice also reported by Mohapatra and Bal (2007). Results of their study showed that the value of measured breaking force for Pusa Basmati, Swarna and ADT37 was 72.4, 45.6 and 81.8 N, respectively. Increasing breaking force with decreasing grain moisture content may be due to that main part of rice kernel consists of starch. Starch granules have semi-crystalline structure (Enevoldsen et al., 2007; Perez and Imberty, 1996). At lower moisture content crystalline zone become greater, resulting more resistance of kernel to breakage.

Similar trends have been reported by Bhandari et al. (2007) for brown rice at the moisture content range of 10 to 17 %, Qin and Seibenmorgen (2005) for paddy at the moisture content range of 13.4 to 26 %, Afzaliniya et al. (2004) and S h e r m a et al. (1992) studied the impact of damage on rough rice at the moisture content of 8 to 12 % and 10.7 to 11.5 %, respectively and reported that the highest percentage of unfissured brown rice obtained at the lower moisture content. Lu and Siebenmorgen (1995) studied the maximum compressive force (N) to crush rough, brown and white rice of Lemont variety and reported that with increasing moisture content from 13.4 to 22.7 %, the maximum value of compressive force was increased from 174.4 to 183.4 N, 54.2 to 63 N and 41.5 to 59.2 N for rough, brown and white rice, respectively.

Milling properties

Effects of dried paddy final moisture content on the head brown rice yield (HBRY) and head rice yield (HRY) are presented in Figure 3 and 4. For each type of variety, HBRY and HRY decreased significantly (P<0.01) with increasing moisture content. The highest HBRY values of 95.79, 90.34 and 90.49 % were recorded at the moisture content of 6 % and those of 94.5, 89.87 and 87.34 % at moisture content of 12 % for Khazar, Hashemi and Kadous varieties, respectively. Similarly, the maximum HRY of 74.07, 77.4 and 89.47 % were obtained at moisture content of 6 % and the lowest values of 60.21, 74.63 and 86.43 % at moisture content of 12 % for Khazar, Hashemi and Kadous varieties, respectively.

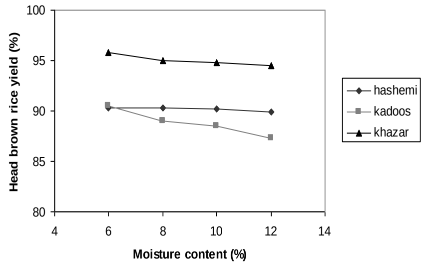

Figure 3: Effect of grain moisture content on head brown rice yield of three varieties

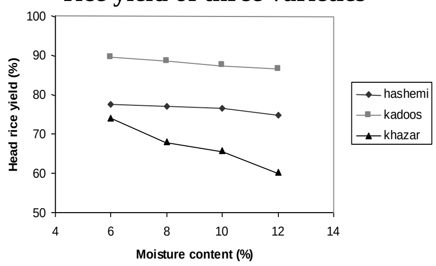

Figure 4. Effect of grain moisture content on head rice yield of three varieties

It can be seen that from the figures, the highest HBRY and HRY was achieved at the lowest paddy moisture content. This could be attributed to that at lower moisture content, the hardness of grains increased, leading to more resistance against compressive loading.

Results indicated that the maximum breaking force of 150.49 N was measured for Kadous variety (Figure 1) however maximum HBRY of 95.79% was obtained for Khazar variety, possibly due to that there are other parameters influencing on the HBRY. During the husking process, in addition to compressive force, the grain are exerted under frictional and bending force which can affected the breakage of the grain in husking. Sun and Siebenmorgen (1993) reported that the Head rice yield was increased as thickness (T) of the grain increased from range of T<1.83 mm to range of 1.88<T<1.93 mm in three tested varieties namely Newbonnet, Mille and Lemount. In this experiment, Hashemi variety had lowest average of thickness compared to Khazar variety, however Hashemi variety had greater HRY at all the moisture content range (Figure 4).

Effect of dried final moisture content on the milling recovery is shown in Figure 5. The milling recovery of Khazar, Hashemi and Kadous varieties decreased from 67.11 to 65.83 %, 60.22 to 58.99 % and 60.82 to 45.45 %, respectively as the moisture content increased from 6 to 12 %.

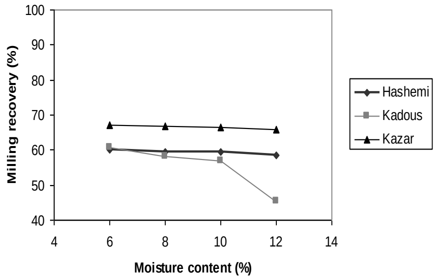

Figure 5. Effect of grain moisture content on milling recovery of three varieties

Conclusions

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

1. The breaking force of paddy and brown rice significantly affected by dried final moisture content, So that the breaking force increased as the moisture content decreased from 12 to 6 %.

2. The milling quality of the paddy not only affected by the hardness of the grain, but also depends on the grain moisture content during milling.

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Table1. Some physical properties of paddy varieties oh Hashemi, Kadous and Khazar

	Hashemi	**Kadous**	**Khazar**
Length (mm)	10.07 (± 0.48)	11.27 (± 0.61)	10.1 (± 0.59)
Width (mm)	2.38 (± 0.18)	2.31 (± 0.13)	2.41 (± 0.13)
Thickness (mm)	1.87 (± 0.11)	1.9 (± 0.14)	1.9 (± 0.09)
Equivalent diameter (mm)	3.57 (± 0.12)	3.68 (± 0.14)	3.6 (± 0.13)
Volume (mm^3)	23.87 (± 2.53)	26.2 (± 3.01)	24.55 (± 2.65)
Surface area (mm^2)	37.24 (± 2.43)	40.85 (± 3.32)	37.91 (± 2.91)
L/W	4.25 (± 0.37)	4.9 (± 0.37)	4.21 (± 0.33)
L×W (mm^2)	23.98 (± 2.07)	26.01 (± 2.07)	24.3 (± 1.97)
1000 grain mass (g)	25.77 (± 0.28)	25.71 (± 0.19)	23.26 (± 0.3)

The values in parentheses are the standard deviation