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Influence of moisture content and whitening method on degree of milling and head rice yield of three Iranian rice varieties

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Abstract

In spite of good aroma and flavor, common rice varieties in Isfahan province (central Iran) encounter high breakage losses during milling. In this research, head rice yield (HRY) and degree of milling (DOM) of three rice varieties namely, Sazandegi, Sorkheh and Nogaran (all Japonica, medium-grain and aromatic), whitened by abrasive and frictional rice millers were investigated. The experiments were conducted at moisture content (MC) levels of 8, 10, 12 and 14% (w.b.). The DOM was measured by two methods: mass degree of milling (DOM_M) and degree of milling measured by a milling meter (DOM_{MM}). The results showed that the effect of all three independent variables on HRY and DOMs were significant. Among varieties, Sorkheh and Sazandegi had the maximum values of HRY and DOM, respectively. In frictional rice miller, HRY decreased with an increase in MC. In contrary, both DOMs increased as MC increased. However, the effect of MC on HRY and DOM_{MM} was not significant for abrasive type. In frictional whitener, DOM_M increased as DOM_{MM} was increased. When milling by abrasive rice miller, DOM_{MM} value of 40 is optimum for Sorkheh variety. Moreover, for Sazandegi, Nogaran and Sorkheh the minimum DOM_{MM} values of 51, 47 and 55 are respectively recommended when using frictional rice miller. In terms of three dependent parameters, abrasive rice miller indicated better performance and consequently could be proposed for milling varieties under investigation.

Key words: Degree of milling; Head rice yield; Moisture content; Variety.

Abbreviation	
DOM_M	Mass degree of milling (%)
DOM_{MM}	Degree of milling obtained by milling meter (-)
HRY	Head rice yield (%)
m_b	Mass of brown rice before whitening (g)
m_r	Mass of rough rice (g)
m_s	Mass of sound rice (g)
m_w	Mass of whitened rice (g)
MC	Moisture content

Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops in the world and ranks as the second cereal grain after wheat. Statistics show that in the world markets, the fissured rice kernels in the offered product decrease its economical value, since broken kernels are typically worth half the value of sound kernels (Cnossen et al., 2003; Sibenmorgen and Qin, 2005). Rice fissuring depends on many factors including farm management, moisture at harvesting and processing time, drying method and devices that are used for its milling. The most of rice losses occur during milling operation. Moreover, the quality of rice is influenced by cultivars, conditions of climate, cultivation, post-harvesting, milling yield and cooking process (Champagne et al., 1990; Champagne et al., 1997). Two important factors in rice milling quality are head rice yield (HRY) and degree of milling (DOM). HRY is the weight percentage of rough or unprocessed rice that remains as sound kernels (equal or greater than ¾ intact kernels) after milling. DOM is defined as the extent to which the germ and bran layers of brown rice kernels are removed during the milling process (USDA, 1990). Whitening is one of the most important operations of rice milling process. Increase in whitening duration causes reduction in HRY and increase in DOM by non-linear relationships (Yadav ad Jindal, 2008). Previously, this operation was operated through brown rice rasing in Iran. Recently, the researchers have studied rice fissuring and the devices used for milling. Zareiforoush et al. (2010) evaluated the effect of screw auger rotational speed on paddy grain damages. The results revealed that as the screw rotational speed increased from 100 to 500 rpm, the mass percentage of broken grains and husked grains increased from 0.11 to 0.32%, and 0.23 to 0.44%, respectively. Alizadeh (2011) assessed the effect of paddy husked ratio on rice breakage and whiteness during milling process for three varieties (two long-grain varieties and one medium-grain variety). It was reported that the broken brown rice (mass ratio of the broken brown rice kernels, i.e. those smaller than 0.75 sound brown rice, to the total brown rice) increased significantly for three varieties as the husked ratio (in versus of husk removing ratio from brown rice) increased from 0.6 to 0.9. In contrary, rice

Table 1. Milling characteristics affected by rice miller, variety and moisture content (MC).

Experimental factor	HRY[*] (%)	DOM_M (%)	DOM_{MM} -
Rice miller			
Abrasive	64.7 ^{a} ± 2.7 [**]	12.3 ^{a} ± 1	54.90 ^{a} ± 5.8
Frictional	63.3 ^{b} ± 6.3	9.4 ^{b} ± 1	48.60 ^{b} ± 3.6
Variety			
Sazandegi	62.1 ^{b} ± 2.2	11.1 ^{a} ± 2	54.10 ^{a} ± 5.1
Nogaran	61.7 ^{b} ± 2.2	11.2 ^{a} ± 2	51.73 ^{b} ± 5.2
Sorkheh	68.2 ^{a} ± 5.9	10.2 ^{b} ± 2	49.41 ^{c} ± 6.2
MC (%)			
8	65.5 ^{a} ± 3.1	10.3 ^{c} ± 3	51.93 ^{b} ± 7.2
10	65.4 ^{ab} ± 3.5	10.6 ^{bc} ± 3	50.68 ^{b} ± 6.9
12	64.3 ^{b} ± 3.5	11.2 ^{ab} ± 2	50.80 ^{b} ± 4.8
14	60.7 ^{c} ± 6.9	11.3 ^{a}± 2	53.60 ^{a} ± 3.2

[*] HRY, DOM_M and DOM_{MM} stand for head rice yield, mass degree of milling and degree of milling read from the milling meter device. [**] For each experimental factor, the means followed by the common lower case letter in the columns do not differ statistically at 5% probability level according to Duncan's multiple-range test. Table values represent mean ± one standard deviation.

whiteness (degree of milling obtained by a milling meter (DOM_{MM})) decreased by increasing husked ratio. In Iran, abrasive and frictional rice millers are used in milling operation, which work based on two different methods for removing the bran. Afzalinia et al. (2002) studied different rice whitening methods and reported that blade rice miller type (one kind of frictional rice miller) resulted in much greater losses in comparison with abrasive rice miller. Hedayatipur et al. (2005) investigated the effect of moisture content on rice breakage percentage in frictional and abrasive rice millers. Contrary to the frictional type, they observed that in abrasive rice miller, the moisture contents less than 10% (w.b.) caused increasing breakage percentage. In another research, Yan et al. (2005) showed that in a vertical abrasive rice miller the effect of rice miller shaft speed and moisture content on DOM were significant. DOM increased as the speed of the shaft and moisture content increased. Mohapatra and Bal (2007) reported that at 12–16% DOM the grain is stripped of all the bran, making it white. These high values inevitably are led to high energy consumption and loss of much endospermic material. The optimum range of DOM in order to obtain the maximum cooking quality and minimum specific energy was reported to be 10-13% for the tested varieties. In spite of good aroma and flavor, common rice varieties in Isfahan province (central Iran) have high breakage losses during milling process. The objective of this study was to study the milling characteristics (HRY and DOM) of three common rice varieties in two rice miller types at different moisture contents. Moreover, as determining mass degree of milling (DOM_M) is time and cost-intensive, its correlation with degree of milling measured by a milling meter (DOM_{MM}) is investigated.

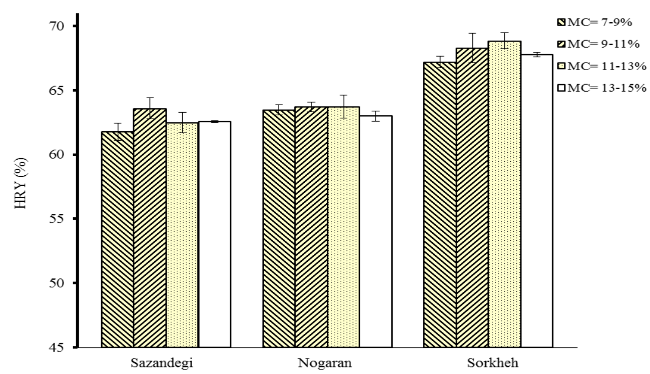

Fig 1. Variations in HRY with moisture content for each variety in abrasive rice miller. The means followed by the common lowercase letter do not differ statistically at 5% probability level according to Duncan's multiple-range test. The error bars represent ± one standard error of the mean.

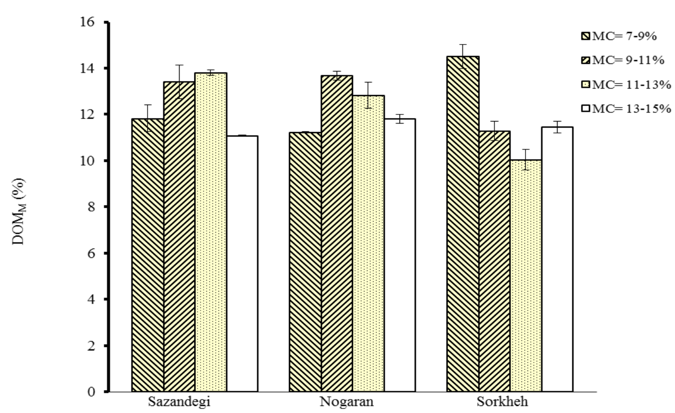

Fig 2. Variations in DOM_M with moisture content for each variety in abrasive rice miller. The means followed by the common lowercase letter do not differ statistically at 5% probability level according to Duncan's multiple-range test. The error bars represent ± one standard error of the mean.

Results and Discussion

The analysis of variance (ANOVA) showed that all factors had a significant effect on HRY and both DOMs ($P < 0.01$). As shown in Table 1, abrasive rice miller significantly caused fewer losses in comparison with frictional type. This finding is in line with the results presented by Afzalinia et al. (2002). However, the difference between HRY values for abrasive (64.7%) and frictional (63.3%) rice millers is not considerable in practice (although, the difference is statistically significant). On the other hand, DOM_M and DOM_{MM} values (12.3% and 54.9) for abrasive rice miller are remarkably much greater than the corresponding values (9.4% and 48.6) for frictional rice miller. Therefore, considering three milling characteristics, the abrasive rice miller could be proposed for rice milling operation. Among varieties, Sorkheh had the highest HRY and the lowest DOM_M and DOM_{MM}. The differences in HRY and DOM_M values for Sazandegi and Nogaran, were not significant, but Sazandegi showed the highest DOM_{MM} among three varieties. These results could be due to inherent characteristics of the varieties. Sazandegi is a breeding line selected of Nogaran (a local rice population), whereas Sorkheh is another local population. The mass of 1000 kernels for Sazandegi, Nogaran and Sorkheh are 20.52, 20.60 and 21.64 g, respectively (Ghasemi Varnamkhasti *et al*. 2008). Also, the aspect ratio (the ratio of width to length defined by Maduako and Faborode (1990) for Sazandegi, Sorkheh and Nogaran are 0.28, 0.29 and 0.34, respectively (Ghasemi Varnamkhasti et al., 2008). As presented in Table 1, contrary to both DOMs, the values of HRY decreased statistically as MC increased. This result is confirmed by researchers who represented a relationship between rupture strength of brown rice and moisture content for 12 varieties at four MC levels (8, 10, 12 and 14% w.b.). So that, the rupture force of brown rice grain decreased by increasing the moisture content. They found a significant relationship between the rupture force and breakage percentage as well as the HRY. Fig. 1 indicates that for each variety milled by abrasive rice miller, the effect of MC on HRY values was not significant. Sorkheh variety had significantly the highest HRY values at all MCs as compared to other varieties. In contrary, significant differences were observed among the means of DOM_M for each variety (Fig. 2), and means of DOM_{MM} for Sorkheh variety (Fig. 3), as MC varied. However, two whiteness indices showed no distinct trend by increasing moisture content. Yan et al. (2005) showed an increase in DOM while moisture content decreased in a vertical abrasive rice miller. This could be due to differences in the rice miller types and varieties which were used in two studies. The results showed that when using abrasive rice miller, the optimum MC levels are 8% (w.b.) for Sorkheh, and 10% (w.b.) for Sazandegi and Nogaran. In frictional rice miller, the differences among the HRY values at different MC levels were significant (Fig. 4). The same finding was also observed for both DOMs indices (Figs. 5 and 6). It is observed that for all varieties milled by the frictional rice miller, as the MC increased from 8 to 14% (w.b.), the HRY values decreased and both DOMs values increased. These results are in accordance with Yan et al. (2005) and Alizadeh (2011) findings. For Sazandegi, Nogaran and Sorkheh the highest HRY obtained at MC levels of 10, 8 and 8-10% (w.b.), respectively. However, from energy consumption point of view (drying process; reducing MC from initial value to the mentioned levels), the higher level of MC (10%, w.b.) is proposed for Sorkheh. In terms of whiteness indices, the maximum values of DOM_M and DOM_{MM} obtained at 14% (w.b.) for Nogaran and Sorkheh and 12-14 and 10-14% (w.b.) for Sazandegi, respectively. Nevertheless, considering the energy consumption, the higher MC levels can practically be used for Sazandegi. Since determining DOM_M is time and cost-intensive, it can be measured by the other whiteness index provided that their correlation is specified. Therefore, the relationship between DOMs was investigated. The variation in DOM_M with respect to DOM_{MM} for three varieties is shown in Fig. 7 for abrasive rice miller and in Fig. 8 for frictional type. As shown, a linear relation was fitted to the data. It is observed that, the correlation between DOMs were stronger for frictional whitener. For abrasive rice miller (Fig. 7), excluding Sorkheh variety, the correlation was weak. This finding again confirms the aforementioned difference

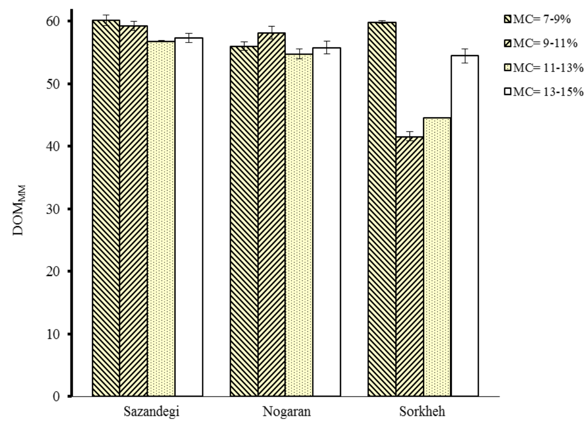

Fig 3. Variations in DOM_{MM} with moisture content for each variety in abrasive rice miller. The means followed by the common lowercase letter do not differ statistically at 5% probability level according to Duncan's multiple-range test. The error bars represent ± one standard error of the mean.

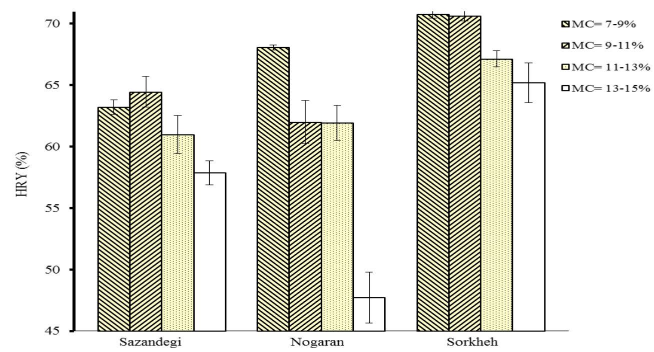

Fig 4. Variations in HRY with moisture content for each variety in frictional rice miller. The means followed by the common lower case letter do not differ statistically at 5% probability level according to Duncan's multiple-range test. The error bars represent ± one standard error of the mean.

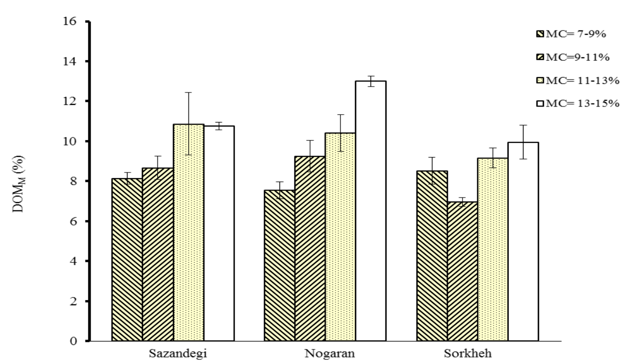

Fig 5. Variations in DOM_M with moisture content for each variety in frictional rice miller. The means followed by the common lower case letter do not differ statistically at 5% probability level according to Duncan's multiple-range test. The error bars represent ± one standard error of the mean.

among tested varieties. When whitening with frictional rice miller (Fig. 8.), DOM_M increased as DOM_{MM} was increased. In abrasive rice miller, the data for Sazandegi and Nogaran varieties have been concentrated in a circle. Therefore, it can be concluded that when whitening by abrasive rice miller, milling duration for Sazandegi and Nogaran varieties should be less than it for Sorkheh variety. The arrows in Figs. 7 and 8 shows the minimum values of DOM_{MM} for the varieties under investigation based on the minimum value (10%) of the optimum range of DOM_M reported by Mohapatra and Bal, (2007) who considered the marketability of rice and whitening energy consumption. Therefore, for Sorkheh variety when milling by abrasive rice miller DOM_{MM} value of 40 can be recommended. Also, when using frictional rice miller, for Sazandegi, Nogaran and Sorkheh the minimum values of DOM_{MM} are approximately 51, 47 and 55, respectively.

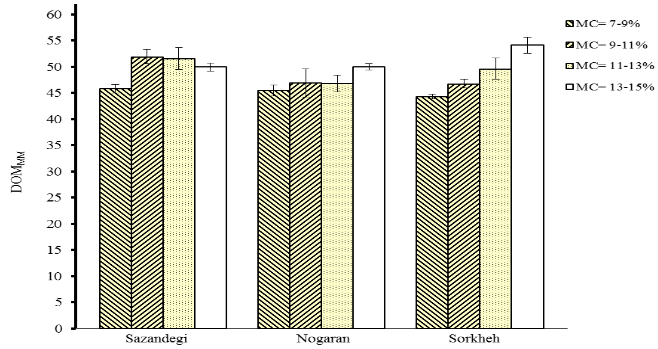

Fig 6. Variations in DOM_{MM} with moisture content for each variety in frictional rice miller. The means followed by the common lower case letter do not differ statistically at 5% probability level according to Duncan's multiple-range test. The error bars represent ± one standard error of the mean.

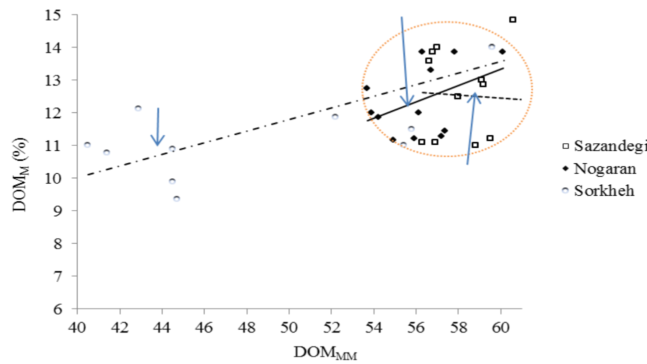

Fig 7. Relationship between DOM_M and DOM_{MM} for Nogaran, Sazandegi and Sorkheh varieties in abrasive rice miller.

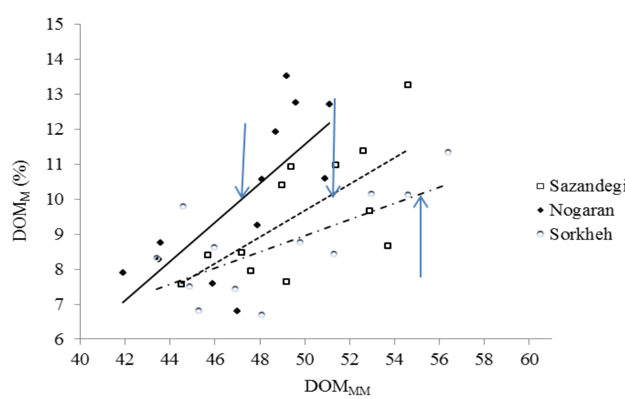

Fig 8. Relationship between DOM_M and DOM_{MM} for Nogaran, Sazandegi and Sorkheh varieties in frictional rice miller.

Material and methods

Samples preparation

To perform the experiments, 35 kg from each variety (Sorkheh, Sazandegi and Nogaran) which are were prepared from Isfahan Agricultural Science and Natural Resources Research Centre. All the verities are Japonica, medium-grain and aromatic type. The initial moisture content of the samples was measured based on standard method (ASAE 2001) and was 16.6, 15.9, and 17.2% (w.b.) for Sazandegi, Sorkheh and Nogaran, respectively. The samples were stored at about 4°C until conducting the experiments. A fixed bed laboratory dryer was used to achieve the desired moisture contents of 7-9, 9-11, 11-13 and 13-15% (w.b.). Henceforth, these levels are referred to as 8, 10, 12 and 14% (w.b.), respectively. Drying experiments were carried out at air temperature of 50 °C, air velocity 1 m s^{-1} and air relative humidity of about 40%.

Milling tests

After cleaning and weighing, the samples were husked by a laboratory roll paddy husker (Satake, THU model) and whitened by abrasive (Satake, TM05 model) and frictional (McGill No. 3 model) rice millers. Then, head rice yield (HRY) and degree of milling (DOM) were determined for each treatment. The HRY was calculated by the Eq. 1 as follows:

$$HRY = \frac{m_s}{m_r} \times 100$$

(1)

where, m_s is the mass of rice kernels (g) that are longer than 0.75 the sound rice kernel after milling, and m_r is the mass of rough rice (g) for each sample. The DOM is used as whiteness index in rice milling operation. In this study, DOM was determined by two methods: 1) mass degree of milling (DOM_M); the mass ratio of removal bran layer from brown rice to initial brown rice, calculated by Eq. 2, and 2) the degree of milling measured by a milling meter (DOM_{MM}). The milling meter was Kett, C. 300 model, which works based on the amount of reflected light from the whitened rice surface.

$$DOM_M = \frac{m_b - m_w}{m_b} \times 100$$

(2)

where, m_b and m_w are the mass of brown and whitened rice (g) for each treatment, respectively.

Data analysis

The effect of rice miller type, variety and moisture content on the HRY and both DOMs were studied using a factorial experiment in a completely randomized design with three replications. Treatment effects were analyzed using analysis of variance by the procedure of SAS (SAS Institute 1990). When the F-value was significant (P < 0.05), Duncan's multiple range test was used for means comparison of data at a probability level of 0.05.

Conclusions

Abrasive rice miller showed better performance in compared with frictional rice miller and therefore could be proposed for milling operation of Isfahan (central Iran) rice varieties. The results of this study confirm the inherent characteristics of the varieties under investigation. Based on the values of head rice yield (HRY) and degree of milling (DOM) indices, the milling duration for the varieties could be proposed in the order of Sorkheh, Nogaran and Sazandegi. The effect of MC on HRY was rice miller type-dependent. As this effect was not significant for abrasive rice miller, whereas for frictional rice miller, the differences among the HRY values at different MC levels were significant. The correlation between DOM_M and DOM_{MM} were stronger for frictional whitener. For this rice miller, DOM_M increased as DOM_{MM} was increased. When milling by abrasive rice miller, DOM_{MM} value of 40 is recommended for Sorkheh variety. Also, when using frictional rice miller, for Sazandegi, Nogaran and Sorkheh the minimum values of DOM_{MM} are approximately 51, 47 and 55, respectively.

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