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Investigating some Factors Affecting the Milling of Long-Grain, High-Yielding Rice Varieties Dried in a Fluidized Bed Dryer

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ABSTRACT

In this study the effect of air temperature, paddy final moisture and variety on degree of whiteness and breakage percentage in fluidized bed dryer were investigated. Three rice varieties (Tarom-domsiah, Hashemi, and Shiroodi); air temperature in four levels (40, 45, 50 and 55°C) and final moisture in three levels (8-10, 10-12, and 12-14%) were considered. Tests were conducted within the factorial design. The results indicated that the degree of whiteness of Shiroodi variety is more than other varieties in different temperatures. Only the degree of whiteness of Tarom-domsiah is increased with increasing the moisture. The average degree of whiteness in moisture 8-10 percent was less than other moistures. Hashemi variety in each temperature indicated the least rice breakage percentage. Breakage percentage of Tarom-domsiah and Shiroodi varieties had no significant difference in any moisture levels. While Breakage percentage of Hashemi variety in 12-14% moisture had a significant difference in its breakage percentage in the moisture of 8-10% and 10-12% and it showed more breakage percentage value.

INTRODUCTION

Rice is the main food of most people in Iran and the world that every year a wide range of lands are allocated for planting this valuable crop. Rice can be harvested in paddy form and its moisture is one of the key factors which should be considered in all the processes conducted on this product (Khodadadi *et al.*, 2013). One of the rice production steps is paddy drying which is a critical step from the aspect of losses since according to related studies the most important factor in grain loss is non-normative drying. Imposed tensions on rice and made breakage at this stage, have much effect on white rice quality. According to the economic significance of rice losses, investigating ways to reduce losses in post-harvest rice operations is very important, especially in the drying step before milling paddy into white rice(Khodadadi *et al.*, 2013). Applying mechanical dryers is a method which can be used for reducing rice moisture, especially in areas with high level of moisture. In these dryers, by using compulsory replacement of hot air, the rate of moisture reduction in the crops increases, but if the process is conducted in an uncontrolled way, it may cause an increase of losses in the stage of milling paddy into white rice and as a result economic value of rice is reduced. Because, in husking step and whitening, the product faces bending and friction forces and in order to prevent from breaking paddy, it must have enough bending and tensile resistance to minimize level of losses (Brooker *et al.*, 1992; Sahay and Singh, 1996).

Among new methods of drying, fluidized bed method is of a great significance. This method is mainly applied for drying granular materials. Uniformity of moisture distribution in the whole bed, high level of transferring heat and mass between hot air and particles, proper mixing, and easy transferring of particles are positive results of using fluid bed system for drying (Kunii and Levenspiel, 1991). One of the factors that affect rice milling or rice breakage quality is tensions which are created as a result of the moisture reduction. In a study, it was found that increasing temperature in the drying process is a super-influential factor to rise rice breakage percentage in the process of milling while the undesirable effects of it could be reduced to some extent by reducing dryer air evaporation capacity (Courtois *et al.*, 2001).

Rordprapat et al. (Rordprapat *et al.*, 2005) developed a mathematical model of paddy drying in super-hot steam fluidized bed dryer to predict the moisture level and temperature level. Empirical results indicated that for the same drying time, the rate of drying paddy with super-hot steam was less than paddies dried with hot air, Because of primary vapor density. Tirawanichakul et al., (Tirawanichakul *et al.*, 2009) investigated the effective moisture distribution level of long-grain rice during drying of fluidized bed in the temperature range of 40-150°C and concluded that effective distribution coefficients depend on drying temperature intensity compared to the content of initial moisture. Jittanit et al. (Jittanit *et al.*, 2010) investigated the energy consumption for drying rice in a big factory and results had indicated that drying in two stages can

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provide better quality; once drying with fluidized bed dryer in temperature 100-110°C and in the second step drying in room temperature by use of solar drying method.

By attention to the importance of rice in the world, high wastes in the drying step and cited researchers, it seems necessary to investigate the effect of dryer air temperature and paddy final moisture content in terms of the degree of whiteness and rice breakage percentage in a fluidized bed dryer. This research is investigated the amount of damage on rice and quality of paddy milling into white rice during drying by a fluidized bed dryer by the concept of degree of whiteness and rice breakage percentage indices, then offered the best drying conditions to obtain the best rice quality.

MATERIALS AND METHODS

In this research, a fluidized bed dryer was used which had been equipped with controlling temperature system and drying airspeed (Fig. 1).

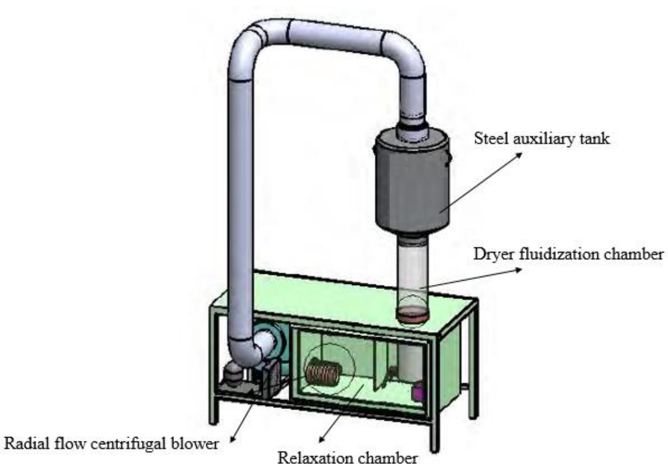

Fig 1. Fluid bed dryer (Malekjani *et al.*, 2011)

The device included radial flow centrifugal blower with three horsepower. Dryer fluidization chamber was a cylinder with 20 cm diameter and 60 cm height and its material is Plexiglass. In order to facilitate the fluidization of the seeds and to create a uniform fluidization, an auxiliary tank with a diameter three times more than the diameter of Plexiglass chamber was set up above it. In this research according to the area under cultivation and paddy performance in per unit area, also due to the significance of production of the area, *Tarom-domsiah* and *Hashemi* varieties which are among the long-grain varieties (Zamani and Alizadeh, 2007), and *Shiroodi* variety which is among the high-yielding varieties were used (Mohaddesi *et al.*, 2008).

High-yielding varieties are a group of crops created intentionally during the Green Revolution to increase global food production. (Rice Varieties at the Wayback Machine, IRRI Knowledge Bank). High-yielding varieties of rice are achieved from the confluence of two hybrid rice varieties that have various characteristics such as pests and diseases resistant to achieve high operation and production. Quality characteristics such as scent, smell, taste, people acceptance and proper digestion are less than local varieties but their production and performance is higher. Shiroodi variety that is one of the high-yielding Iranian rice varieties was introduced by Mohaddesi et al. (Mohaddesi *et al.*, 2008).

Long grain rice has a long, slender kernel, four to five times longer than its width. Cooked grains are separated, light and fluffy (Zamani and Alizadeh, 2007). Tarom-domsiah variety has a black spot on one end, which gives it the name, which is Persian meaning "black end". It is cultivated mainly in the Gilan province of Iran. Domsiah rice is related to Basmati rice. Domsiah is especially valued for its aroma, which is more expressed than other Basmati-type of rice. Hashemi variety is the most popular cultivar in northern Iran, which is cultivated in most rice fields of Guilan province. To the best of our knowledge, these cultivars have never been used to investigate their cultivability (Pazuki and Sohani, 2013).

The varieties were prepared from Iran rice research institute (IRRI) located in Rasht City. During transporting, we tried to avoid mechanical damages, moisture tensions and negative factors, which are effective factors in conducting tests. American Society of Agricultural Engineers Standard was used to determine initial moisture of rice (Standard, 2003), and initial moisture of paddy samples under study for varieties of *Tarom-domsiah*, *Hashemi* and *Shiroodi* were measured 19.38, 18 and 18 percent, respectively based on dry weight. During drying, samples were weighed by using a digital scale with an accuracy of ±0/1 %. 250-gram samples from three varieties of *Tarom-domsiah*, *Hashemi* and *Shiroodi* to a moisture level of 8-10, 10-12 and 12-14 percent were dried based on dry weight and in four temperatures of 40, 45, 50, and 55°C with three replications. Since in one hand temperature around 40 °C is used for drying paddy in common condition of fixed bed dryer. One of the advantages of fluidized bed dryers is using higher temperatures, Therefore to investigate temperature effect on drying time, in addition to the temperature of 40 °C, temperatures of 45, 50 and 55 °C were considered (KHOUSH *et al.*, 2007). Experiments were carried out according to the research of other researchers (Habibian *et al.*, 2006) and according to device dimensions with a constant input airspeed of 4 m/s. Husking operation of the samples was done by using lab huscker (SATAKE, THU, Japan).

To whiten the samples, a lab whitener (BALDOR, Germany) was used where each of the samples was put on the device for 45 seconds. Also for separating healthy rice from the broken one, a rotary sieve with trademark SATAKE trademark (made in Japan) was used. After milling, the value of brown rice, white rice, healthy white rice and broken white rice was gained and indices of the degree of whiteness and percent of broken rice were calculated.

The degree of whiteness can usually be expressed by using two indices of mass degree of whiteness and light degree of whiteness. The mass degree of whiteness is shown with a symbol of DOM_m. Light degree of whiteness is a level index of absorbing light by white rice grains which can be measured using white gauge device and can be shown with DOM_{mm} (Khodadadi *et al.*, 2014). In this research light degree of whiteness for treatment was measured. The light degree of whiteness was measured using white gauge instrument (KETT, C300). After calculating unbroken white rice and broken white rice, rice breakage percentage was calculated using formula 1 (Minaei *et al.*, 2005):

$$\text{Rice breakage percentage} = \frac{\text{weight of broken white rice}}{\text{weight of total white rice}} \times 100 \qquad (1)$$

To investigate the effect of various treatments on degree of whiteness and breaking percentage, some tests were done in four levels of entire air temperature (40, 45, 50, and 55 °C), three moisture levels (8-10, 10-12 and 12-14%) and three rice varieties (*Tarom-domsiah*, *Hashemi* and *Shiroudy*) and three replications within factorial design of three-factor 3×3×4.

Data analysis was done by a randomized complete design and three-factor variance decomposition using SPSS (PASW statistics 18) statistical software and charts were drawn through Microsoft Office Excel 2010.

RESULTS AND DISCUSSION

Effects of the treatments on the degree of whiteness

Table 1 presents the analysis of variance results regarding the effect of rice varieties (*Tarom-domsiah*, *Hashemi* and *Shiroudy*) in various temperatures (40, 45, 50 and 55 °C) and final moisture levels (8-10, 10-12 and 12-14 %) on the degree of whiteness.

As can be seen, main effects of variety, moisture, temperature and their interaction effects on the degree of whiteness are significant at 1 % level, but the interaction effect of temperature and moisture is significant at 5 % level. Since Interaction effects of variety on moisture, variety on temperature, temperature on moisture and the Interaction effect of the variety on moisture are all significant, we should try to compare the mean degrees of whiteness resulted from the combined treatments (Soltani, 2007). Therefore, in Figs. 2, 3 and 4 and, table 2, the comparisons resulted from the interactive effects are provided using LSD Test. Nasrnia et al. also concluded in their research that the variety and conditions of drying and their interaction effects were significant on whiteness matter (Nasrnia *et al.*, 2012).

Table 1. Results of variance analysis regarding the effect of rice variety, temperature, and final moisture on the degree of whiteness

Source	df	Sum of Squares	Mean Square	F
Variety	2	109.713	54.857	78.967**
Moisture	2	155.465	77.733	111.898**
Temperature	3	9.075	3.025	4.354**
Variety × Moisture	4	11.797	2.949	4.246**
Variety × Temperature	6	24.116	4.019	5.786**
Moisture × Temperature	6	10.898	1.816	2.615*
Variety × Moisture × Temperature	12	27.620	2.302	3.313**
Error	72	50.017	.695	
Total	108	116628.785		

** Significant at p = 0.01. * Significant at p = 0.05

As shown in Fig. 2 results of statistical analysis of the variety-temperature interaction effects showed no significant differences in degrees of whiteness of *Tarom-domsiah* and *Hashemi* varieties in various temperatures. Also, it can be observed that whiteness degree of *Shiroodi* variety in various temperatures has a significant difference with whiteness degree of two others varieties that are related to physical features and genetic features of this variety. Also, the reason can depend on easy separation of bran layer from brown rice of one variety compare to another variety (Minaei *et al.*, 2005).

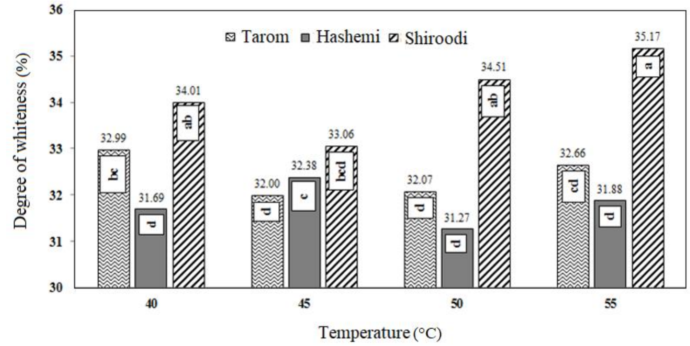

Fig 2. Chart of the degree of whiteness in various temperatures for varieties of *Tarom-domsiah*, *Hashemy* and *Shiroudi*

As shown Fig. 3, statistical analysis results of moisture interaction effects in temperature indicates that degree of whiteness in moisture of 8-10 percent in various temperatures, and degree of whiteness in moisture of 10-12 percent and 12-14 percent in various temperatures have no significant difference with each other and that temperature changes have no effect on whiteness degree of various temperatures. However, average degree of whiteness in the moisture of 8-10 percent is significantly less than degree of whiteness in the moisture of 10-12 and 12-1%. With increasing moisture, the degree of whiteness increases due to a significant reduction of the level of broken rice made during operation of whitening. It confirms the results of Peyman et al. (Peyman *et al.*, 2007); whiteness degree has a direct relation with moisture.

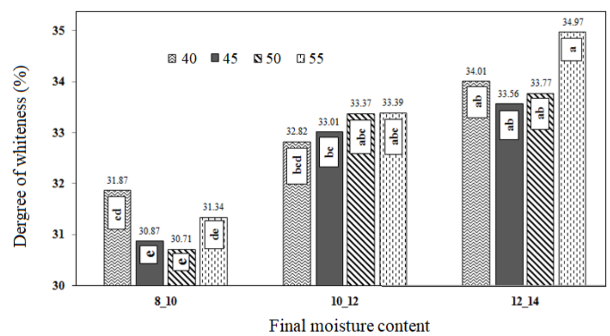

Fig 3. Chart of average degree of whiteness in various moisture for different temperatures

Based on Fig. 4 that is related to statistical analysis results of variety interaction effects in moisture, it can be observed that degree of whiteness of *Tarom* variety in various moisture has significant difference and increasing the moisture from 8-10 percent to 12-14 percent can increase the degree of whiteness. While for *Hashemi* and *Shiroodi* varieties, increasing the moisture only from 8-10 percent to 10-12 percent can increase the degree of whiteness and no significant difference in the degree of whiteness can be observed between moisture levels of 10-12 and 12-14 percent for both varieties.

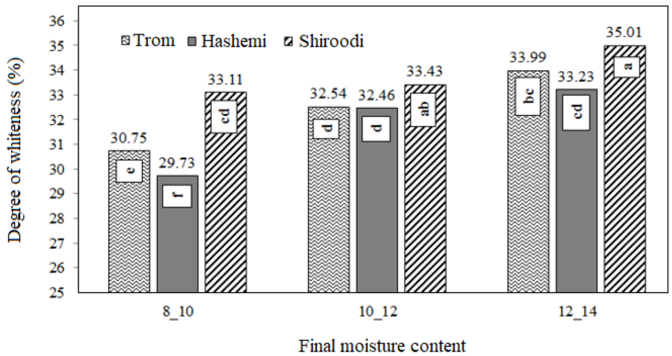

Fig 4. . Chart of degree of whiteness in different moisture level for varieties of *Tarom-domsiah*, *Hashemy* and *Shirudy*

Therefore, only when the variety is *Tarom-domsiah*, increasing the moisture can rise the whiteness degree. Based on this diagram in moisture of 8-10 and 12-14 percent, the degree of whiteness of *Hashemi* variety is less than two other varieties and the least whiteness degree for three varieties can be made in the moisture of 8-10 percent. Also, the degree of whiteness for all three varieties has a direct relation with moisture.

Statistical analysis results of both interaction effects of variety on moisture and temperature in Table 2, indicate that for *Tarom-domsiah* variety in moisture of 8-10 percent, degree of whiteness only in temperature of 40 °C has significant difference with other temperatures and with increasing the temperature from 40 °C to 45 °C, degree of whiteness can be reduced, but from temperature higher than 45 °C, temperature changes can't influence on whiteness level. In moisture of 10-12 percent and with temperature increasing, no significant changes can be observed in degree of whiteness. In moisture of 12-14 percent, the degree of whiteness has a significant difference only in temperature of 55 °C with degree of whiteness in other three temperatures and its level is more than other three temperatures. For *Hashemi* variety, we can observe a significant reduction only in moisture of 8-10% and temperature of 50 °C; while in other moisture, temperature changes can create no significant difference in degree of whiteness. No significant difference can be observed in degree of whiteness for *Shiroodi* variety in moisture of 8-10 and 10-12%, but in moisture of 12-14% degree of whiteness can increase with increasing the temperature from 45 °C to 55 °C. Therefore, for *Shiroodi* variety, increasing the temperature can increase whiteness degree only in moisture of 12-14 percent. In general, increasing moisture can increase the degree of whiteness for all the three varieties.

Table 2. Interaction effects of variety on moisture and temperature and LSD test of the degree of whiteness (average ±standard deviation)

Interaction effects			Degree of whiteness (%)
Variety	Moisture	Temperature	
Tarom	8-10	40	32.17±0.49^{ghij}
Tarom	8-10	45	30.00±0.10^{lm}
Tarom	8-10	50	30.43±0.45^{klm}
Tarom	8-10	55	0.40±0.62^{klm}
Tarom	10-12	40	32.33±0.38^{fghij}
Tarom	10-12	45	32.73±0.38^{efghi}
Tarom	10-12	50	32.70±0.10^{efghi}
Tarom	10-12	55	32.40±0.61^{fghi}
Tarom	12-14	40	34.47±0.2^{bcd}
Tarom	12-14	45	32.27±1.21^{cdefgh}
Tarom	12-14	50	33.07±0.47^{cdefghi}
Tarom	12-14	55	35.17±0.25^{b}
Hasemi	8-10	40	30.30±1.05 ^{klm}
Hasemi	8-10	45	30.83±0.85 ^{jklm}
Hasemi	8-10	50	27.93±0.76 ^{n}
Hasemi	8-10	55	29.83±0.25 ^{m}
Hasemi	10-12	40	31.45±0.25 ^{ijklm}
Hasemi	10-12	45	32.37±0.31 ^{fghij}
Hasemi	10-12	50	32.83±1.12 ^{defghi}
Hasemi	10-12	55	33.20±0.61 ^{cdefgh}
Hasemi	12-14	40	33.33±0.42 ^{cdefgh}
Hasemi	12-14	45	33.93±1.07 ^{bcdef}
Hasemi	12-14	50	33.03±0.55 ^{cdefghi}
Hasemi	12-14	55	32.60±0.53 ^{efghi}
Shiroodi	8-10	40	33.13±0.95 ^{cdefgh}
Shiroodi	8-10	45	31.77±0.76 ^{hijklm}
Shiroodi	8-10	50	33.75±0.95 ^{bcdefg}
Shiroodi	8-10	55	33.80±0.95 ^{bcdefg}
Shiroodi	10-12	40	34.67±1.86 ^{bc}
Shiroodi	10-12	45	33.93±1.52 ^{bcdef}
Shiroodi	10-12	50	34.57±0.77 ^{bc}
Shiroodi	10-12	55	34.57±1.10 ^{bc}
Shiroodi	12-14	40	34.23±1.21 ^{bcde}
Shiroodi	12-14	45	33.47±1.40 ^{cdefg}
Shiroodi	12-14	50	35.20±0.87 ^{b}
Shiroodi	12-14	55	37.13±0.67 ^{a}
	F		14.341**
	Sig.		0.000

Different letters in each column (a, b, c ...) indicate significant differences at the level of one percent.

The effects of the treatments on the breakage percentage

Table 3 represents the analysis of variance results for the effects of rice varieties, temperature and final moisture on rice breakage percentage. Based on the results, the main effects of variety, moisture and temperature and their interaction effects (except the interactive effect of temperature on moisture) on rice breakage percentage are all significant at an error level of 1%. Therefore, we should try to compare the mean breakage percentages resulted from the combined treatments (Soltani, 2007). After this and comparing the interaction effects using LSD test, results are provided in Fig. 4 and 6 and Table 4.

Table 3. Analysis of Variance regarding the effect of rice varieties, temperature, and final moisture on rice breakage percentage

Source	df	Sum of Squares	Mean Square	F
Variety	2	8029.223	4014.612	864.716**
Moisture	2	174.504	87.252	18.793**
Temperature	3	44.011	14.670	3.160**
Variety × Moisture	4	228.913	57.228	12.327**
Variety × Temperature	6	1330.076	221.679	47.748**
Moisture × Temperature	6	500.787	83.464	17.978^{ns}
Variety × Moisture × Temperature	12	628.113	52.343	11.274**
Error	72	334.274	4.643	
Total	108	121538.299		

** Significant at P = 0.01, * Significant at P = 0.05, ^{ns}: Not significant

According to Fig. 5 statistical analysis results of the variety-temperature interaction effects on rice breakage percentage of Tarom-domsiah variety showed no significant differences in various temperatures, indicating the importance of fluid bed dryer for drying the rice varieties with high temperature to reduce drying time and work losses. In temperatures of 40°C and 45°C, the rice breakage percentage for *Hashemi* variety was significantly lower than the temperature of 55 °C since increased temperature leads in heat tensions inside the seeds, underlying the breakage in the next stages. Sun et al. (Sun, 1995) and Hagh Khah and Maghsoodloo (Hagh Khah and Maghsoodloo, 2006) conducted similar research using a fixed bed dryer and obtained the similar results. Moreover, according to Fig. 4, *Hashemi* variety in every four temperatures has the least percentage level of rice breakage in all three varieties. *Tarom-domsiah* and *Hashemi* varieties at temperatures 55 °C and 45 °C have the least breakage level. While *Shiroodi* variety has the least breakage level at temperature 55 °C and the maximum level of breakage at temperature 55 °C.

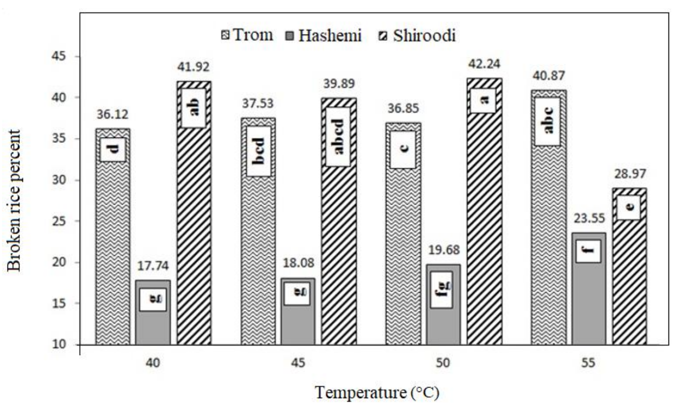

Fig 5. Chart of percentage level of rice breakage in various temperatures for various varieties

In Fig. 6 the results of statistical analysis of interaction effects of variety on moisture showed Tarom-domsiah and Shiroodi percentage of breakage was no differed significantly at any level of moisture and placed in a group. However, rice breakage percentage of *Hashemi* variety in the moisture of 12-14% had a significant difference compared to the moisture of 8-10% and 10-12%; with increased moisture from 10-12% to 12-14%, the breakage percentage of *Hashemi* variety increased since it is a long-grain rice with reduced resistance by increased moisture. This confirms other researchers' results (Bagheri *et al.*, 2011; Firouzi and Alizadeh, 2011). In all temperatures, breakage percentage of *Hashemi* variety was less than the other ones since physical and mechanical characteristics of various varieties are key parameters for rice breakage percentages in the drying process and rice milling operations. Out of these factors, hardness and the length/width ratio of rice have a significant effect on the level of rice breakage and *Hashemi* variety grains have higher resistance against breakage. Therefore, with the *Hashemi* variety and moisture increasing from 10-12% to 12-14%, it can be expected that increased moisture can lead to higher breakage levels.

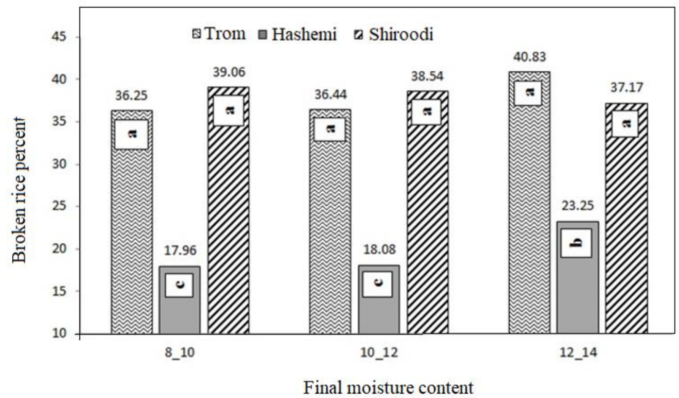

Fig 6. Chart of rice breakage percentage in various humidities for various varieties

According to Table 4, the statistical analysis of interaction effects of rice variety on moisture only showed the significant difference in the breakage of *Tarom-domsiah* variety in the moisture of 8-10% and 10-12% at 55 °C while the breakage in 45 °C had a significant difference with other temperatures in the moisture of 12-14%. In general, changes in temperature with different humidifies did not lead in the significant changes of the breakage percentage of *Tarom-domsiah* variety. Moreover, percent of breakage for *Hashemi* variety in moisture of 8-10 % and 10-12 % and temperatures of 55 °C had a significant difference with other temperatures; while breakages in the moisture of 12-14 % fall in the same group showing no significant differences. For *Shiroodi* variety in the moisture of 8-10 and 10-12 percent, the significant difference can be observed in temperatures of 50 °C and 55 °C and the breakage percent in 40 and 45 °C. The rice breakages are maximum and minimum in 50 °C and 55 °C, respectively. In moisture of 12-14%, rice breakage falls in the same group in 40 and 45°C while breakage of *Shiroodi* variety in temperature of 50 and 55 °C is significantly lower than 40 and 45 °C.

Table 4. Interaction effects of variety on moisture and temperature and LSD test regarding the rice breakage percentage (average ±standard deviation)

Interaction effects			Average of rice breakage percentage (%)
Variety	Moisture	Temperature	
Tarom	8-10	40	33.29±1.36 [hi]
Tarom	8-10	45	32.59±079 [hi]
Tarom	8-10	50	36.18±0.97 [fgh]
Tarom	8-10	55	42.96±1.07[bcd]
Tarom	10-12	40	34.97±0.70 [gh]
Tarom	10-12	45	35.50±0.31 [gh]
Tarom	10-12	50	34.97±1.70 [gh]
Tarom	10-12	55	40.32±0.93 [de]
Tarom	12-14	40	40.09±0.45 [def]
Tarom	12-14	45	44.49±3.05 [bc]
Tarom	12-14	50	39.40±1.44 [def]
Tarom	12-14	55	39.34±0.42 [def]
Hasemi	8-10	40	14.09±0.88 [n]
Hasemi	8-10	45	14.78±0.55 [mn]
Hasemi	8-10	50	17.42±0.46 [mn]
Hasemi	8-10	55	25.55±3.77 [kl]
Hasemi	10-12	40	15.55±0.44 [mn]
Hasemi	10-12	45	16.67±1.18 [mn]
Hasemi	10-12	50	18.14±2.03 [m]
Hasemi	10-12	55	21.94±1.34 [l]
Hasemi	12-14	40	23.57±0.98 [l]
Hasemi	12-14	45	22.80±0.43 [l]
Hasemi	12-14	50	23.47±0.84 [l]
Hasemi	12-14	55	23.16±1.78 [l]
Shiroodi	8-10	40	39.68±1.97 [def]
Shiroodi	8-10	45	37.77±2.27 [efg]
Shiroodi	8-10	50	51.48±9.41 [a]
Shiroodi	8-10	55	27.32±0.72 [jk]
Shiroodi	10-12	40	40.74±1.79 [cde]
Shiroodi	10-12	45	39.63±1.68 [def]
Shiroodi	10-12	50	45.11±2.14 [b]
Shiroodi	10-12	55	28.66±0.23 [jk]
Shiroodi	12-14	40	45.33±2.41 [b]
Shiroodi	12-14	45	42.28±2.84 [cd]
Shiroodi	12-14	50	30.13±0.84 [ij]
Shiroodi	12-14	55	30.94±0.74 [ij]
	F		67.229**
	Sig.		0.000

Different letters in each column (a, b, c ...) indicate significant differences at the level of one percent.

CONCLUSIONS

In this study, the effects of using a fluidized bed dryer on the quality of milling characteristics of Iranian rice varieties such as *Tarom-domsiah*, *Hashemi* and *Shiroodi* were investigated. For all three varieties, degree of whiteness had a direct relationship with the moisture and with raised moisture, the degree of whiteness increases in all temperatures. By increasing temperature (40-55 °C), the whiteness level of *Tarom-domsiah* variety can increase but it is in the maximum level for two varieties of *Hashemi* and *Shiroodi* in temperatures of 45 and 55 °C, respectively. Therefore, to the final moisture of 12-14%, drying of *Tarom-domsiah* varieties in 55 °C and *Hashemi* and *Shiroodi* varieties in 45 and 55 °C will result in the best degrees of whiteness. Unlike the *Shiroodi* variety, the breakage percentages of *Tarom-domsiah* and *Shiroodi* varieties increase with increased moisture. The least breakage levels for varieties of *Tarom-domsiah*, *Hashemi* and *Shiroodi* are in temperatures of 40, 40 and 55 °C, respectively. In order to achieve the least breakage levels in milling operations for drying the varieties, thus, it is better to use these temperatures.

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