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EFFECT OF VARYING PARBOILING CONDITIONS ON HEAD RICE YIELD FOR COMMON PADDY VARIETIES IN IRAN

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Various conditions of a parboiling process affect the qualitative parameters of paddy milling. In this study, the effects of drying temperature (45 and 60 °C), moisture content (8, 10 and 12% w.b.), steaming time (10, 20 and 30 min) and paddy varieties (Hashemi and Alikazemi) were investigated on head rice yield (*HRY*). The samples were husked using a rubber roller husker and whitened by a laboratory abrasive whitener. Results showed that the main effects of all parameters were significant on *HRY* (P <0.01). The utilization of higher temperature (60 °C), in comparison with non-parboiled rice, without reducing the milling quality was found as one of the advantages of parboiling. Among all experiments, the highest *HRY* (68.647%) was achieved in the combination of Alikazemi/45 °C/10 min/8%. In the majority of cases, the combinations including Alikazemi variety had higher *HRY* than Hashemi. For Hashemi variety, the highest *HRY* (67.297%) was achieved in combination 45 °C/10 min/8%. In terms of *HRY*, parboiling causes an increase of 25.8% and 43.3% respectively for Hashemi and Alikazemi. Therefore, it is highly recommended in processing of Alikazemi variety.

Keywords: drying temperature; steaming time; moisture content; milling; rice variety

Rice is one of the staple foods in Asia that provides a considerable part of energy intake of people. World rice production is approximately 618 million tons per year; about 50% of the production is under parboiling process. Paddy parboiling is carried out in many countries, including India, Bangladesh, Pakistan, Myanmar, Malaysia, Sri Lanka, Guinea, South Africa, Italy, Spain, Thailand, Switzerland, and France (Pillaiyar, 1981). The main reasons for impressive reception of the parboiled rice are the increase in grain strength (which increases the *HRY* and decreases the milling losses), enhancement of rice nutritional properties including vitamin B and minerals, especially phosphorus and potassium (up to 18%), and increase in quality while in storage (Juliono, 1985; Chakraverty and Paul Singh, 2001). During the common milling stage (non-parboiled method), the bran surrounding the outer layer of brown rice is removed despite having nutrients. In the process of rice parboiling, the nutrients of the bran move to the grain centre and consequently enhance the grain quality. Considering its economic and nutritional benefits, the extension of this technology is essential in milling rice units, especially in developing countries where the rate of rice lost due to the old machinery is very high. In addition, the application of such technologies is essential for the rice self-sufficiency of these countries. The conventional method of parboiling includes three stages: soaking in water, steaming (to complete the gelatinization of starch) and drying. Surveying the optimal values for every the effective variable has significant impacts on the milling properties, as well as the energy consumption.

Many studies have been conducted in the field of parboiling that focused on several aspects, including developing parboiling systems, supplying and consuming energy in parboiling and optimizing the parboiling stages (Kwofie and Ngadi, 2017). Recently, for instance, a research group investigated the influence of soaking variables on parboiled rice quality (Da Fonseca et al., 2011). Another group surveyed the influence of soaking time on the crushing strength of raw parboiled rice and reported an inverse relationship (Jagtap et al., 2008). Oyedele and Adeoti (2013) found that a minimum breakage for rice kernel is obtained at the steaming time of 41.5 minutes and milling moisture content of 16%. The parboiling efficiency of 95% and milling quality of 91% at 70 °C soaking temperature and three hours of soaking time were reported as optimal conditions for parboiling by Imonigie et al. (2017). Considering the large diversity in parboiling variables and their effects on *HRY*, further research on its different conditions is noteworthy, especially for popular varieties highly susceptible to breakage. Mostly, different combinations of the related variables provide different results.

Despite the mentioned reasons about the benefits of parboiling in the milling quality, it has not developed in Iran industries and there is no comprehensive research about its optimal conditions and effective approaches to it. However, the local-domestic characteristics, especially variety type may have a significant effect on the procedure. Hence, the objective of present study is to survey the efficiency level of parboiling on *HRY* and compare it for two studied varieties. In addition, another objective is to investigate the effects

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of certain parboiling parameters on *HRY* for two popular paddy varieties in Iran.

Material and methods

The varieties of Hashemi and Alikazemi were selected for the experiments because they are the most cultivated varieties of rice in northern Iran. Some their are given in Table 1.

At first, the grains were manually cleaned from foreign materials. The initial moisture content was calculated according to ASAE standard (2000). Three paddy samples of 10 g were placed into an oven heated to temperature of 130 °C for 24 hours. Then, samples were brought out in the desiccators and cooled for 10 min. The initial moisture content of the samples ω_0 was calculated based on wet basis according to Eq. (1) (Vitázek and Vereš, 2013):

$$\omega_0 = \left(1 - \frac{m_2}{m_1}\right) \cdot 100, \quad \% \tag{1}$$

where:
ω_0 – initial moisture content, % w.b.
m_1 – the initial mass of paddy, g
m_2 – the mass of paddy after drying, g

In the next stage, the samples were washed with the cold water so that the remaining foreign materials were removed. Then, soaking as the first step of parboiling process was performed at the temperature of 75 °C for three hours. This is the gelatinization temperature of rice grain (Juliono, 1985; Chakraverty and Paul Singh, 2001). Afterwards, the samples were drained and divided to three sections, and the steaming stage was performed for the time durations of 10, 20 and 30 min. Steaming was performed using the methods of steam bath in autoclave under the pressure of 100 kPa. At the end of this stage, the samples were drained and spread on the absorber paper to remove the excessive water. The drying stage was carried out with two temperature levels of 45 and 60 °C by means of a laboratory oven. During the staying time in the oven, the moisture content of the samples was frequently measured using a digital moisture meter (GMK model 303RS, Korea) in order to attain the desired moistures of 8, 10 and 12% (w.b.). After achieving of the desired moisture content, the samples were placed in the sealed polyethylene bags and left in a room with normal temperature to cool slowly for three hours. Then, the samples were placed to a refrigerator with a temperature of 4 °C to keep a constant moisture content of the samples. Before performing the milling process, the samples were brought out from the refrigerator and placed in the room with ambient temperature for three hours. Then, the samples were weighted by means of a digital balance to divide into groups of 50 g and consequently husked using a rubber roller husker (Satake Engineering Co., Ltd. Japan). After husking, the samples were weighted again and whitened by means of a laboratory whitener (model: JNMJ3). Finally, a laboratory separator was used for separating the head rice grains (at least 75% of the grain length) from broken grains. *HRY* was calculated according to Eq. (2):

$$HRY = \frac{m_h}{m_p} \cdot 100, \quad \% \tag{2}$$

where:
m_h – the mass of head rice, g
m_p – the initial mass of paddy sample, g

To obtain the values of *HRY* for non-parboiled rice, separate experiments were performed for two levels of drying temperature (45 and 60 °C) and three levels of moisture content (8, 10 and 12%).

The independent parameters included the paddy varieties Hashemi and Alikazemi (these varieties are the most popular in northern Iran), the steaming times of 10, 20 and 30 min, the drying temperatures of 45 and 60 °C and the paddy moisture content values of 8, 10 and 12% (w.b.). The dependent variable was *HRY*. The experimental data were analysed using the analysis of variance (ANOVA). The statistical design utilized in analysing the data was a completely randomized design with a factorial arrangement of treatment. Duncan's Multiple-Range Test was used for the mean comparison of the effects at the probability level of 5% using SAS 9.0 software program.

Results and discussion

The results of the analysis of variance relating to *HRY* data (Table 2) revealed that all the main effects including variety (V), drying temperature (*T*), moisture content (ω) and steaming time (*t*) had significant impacts on *HRY*. These results were consistent with the results of other researchers (Chakraverty and Paul Singh, 2001; Patindol et al., 2008; Kaddus Miah et al., 2011).

In addition, the dual interaction effects of V/ω, V/t, T/ω and ω/t were significant on *HRY*, while the interaction effects of V/T and T/t were not significant on *HRY*. Except $V/T/t$, all triplet interaction effects were significant on *HRY*. The interaction effect relating to four factors of $V/T/\omega/t$ was also significant. The mean comparison relating to the interaction effect of V/T (Fig. 1a) showed that *HRY* increased for both varieties with increasing *T* from 45 to 60 °C; however, it was not significant in Hashemi. The result is in contrast with the results of previous studies concerning raw rice (Zhang and Lan, 2007). Zhang and Lan (2007) in a study on the effect of drying temperature (45 and 60 °C) observed that the best

Table 1 Some physical and chemical properties of the tested varieties (non-parboiled grain)

Variety	1000-grain weight in g	Grain length in mm	Grain width in mm	Ratio of length to width	Amylose in %
Hashemi	25	7.2	1.9	3.8	20.1
Alikazemi	30	7.2	2.1	3.4	16.7

Table 2 The analysis of variance relating to the independent parameters in paddy parboiling

Variation sources	Degree of freedom	*HRY*
Replication	2	0.097^{ns}
Variety (*V*)	1	191.574**
Drying temperature (*T*)	1	1.527**
Interactions (*V* · *T*)	1	0.2133^{ns}
Moisture content (ω)	2	12.449**
Interactions (*V* · ω)	2	1.759**
Interactions (*T* · ω)	2	1.318**
Interactions (*V* · ω · *T*)	2	0.880**
Steaming time (*t*)	2	6.221**
Interactions (*V* · *t*)	2	1.847**
Interactions (*T* · *t*)	2	0.230^{ns}
Interactions (*V* · *T* · *t*)	2	0.173^{ns}
Interactions (ω · *t*)	2	0.603*
Interactions (*V* · ω · *t*)	4	1.300**
Interactions (*T* · ω · *t*)	4	2.462**
Interactions (*V* · *T* · ω · *t*)	4	1.450**
Error	78	0.294
Total	107	–

**, * and ns are significant effects at the probability of 5%, 1% and non-significant, respectively

temperature for paddy drying is 45 °C. They mentioned that paddy drying at higher temperatures results in a sharp increase in thermal gradient and consequently the occurrence of cracks in the grain. The reason of this contradiction is related to the specific process of parboiling. Steaming in parboiling, with gelatinizing the grain and homogenizing its components, removes the cracks in the grain and consequently allows the application of higher temperature for drying in comparison to raw rice. This is one of the benefits of parboiling allowing the performance of faster milling, which leads to time savings.

For each tested variety, there were considerable differences in *HRY* on different levels of ω (Fig. 1b). For both varieties, the highest and lowest *HRYs* were obtained at ω: 8 and 10% (w.b.), respectively. The result is consistent with the previous research performed on the raw rice in which ω: 8% was introduced as optimal moisture content (Nasir Ahmadi et al., 2014). According to Fig. 1b, at ω: 12% higher *HRY* (66.301%) was obtained than 10% (65.095%). It seems that two factors – higher milling recovery due to higher brittleness property in the grain at lower ω (factor *a*) and lower breakage due to higher hardness of the grain (factor *b*) – are effective on *HRY* (Kim et al., 2014). At ω: 8%, both factors (*a* & *b*) and at 12%, the factor of *b* were determinant for enhancing of *HRY*. The moisture content of 10% was an intermediate state concerning the effectiveness of two factors (*a* & *b*).

In all tests of Hashemi variety, the considerable differences were observed for all levels of *t* (Fig. 1c). For both varieties, the highest and lowest *HRYs* were obtained at *t* 10 and 30 min, respectively. In Alikazemi variety, the level of 20 min did not differ from levels of 10 and 30 min in any significant way. On the other hand, the interaction effect of *V*/*t* was more considerable in Hashemi variety than Alikazemi. Overall, *t*: 10 min is introduced as an appropriate steaming time for parboiling of both varieties. The mean comparison results related to the interaction effect of ω/*T* on *HRY* (Fig. 2) revealed that in the experiments including ω: 8%, the highest *HRY* was achieved at *T*: 45 °C; however, the difference between the levels was not significant.

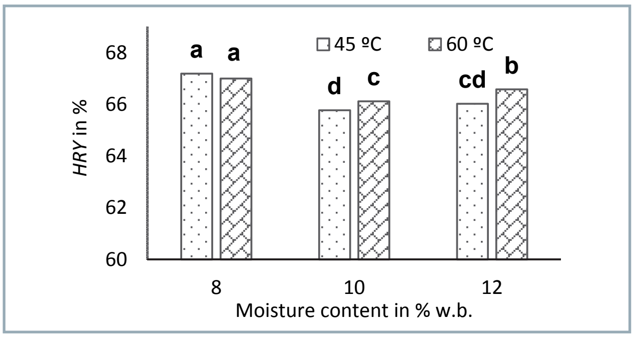

Fig. 2 The mean comparison related to the interaction effect of *V*/*T* on HRY
The different letters indicate the significant differences (P <0.05). The letters *a* and *d* indicate the highest and lowest means, respectively

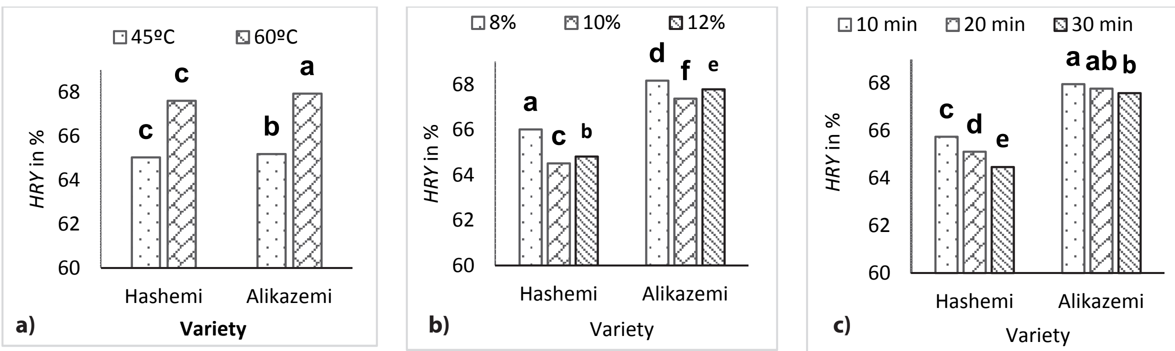

Fig. 1 Mean comparison results related to the interaction effect of *V* with a) *T*, b) ω and c) *t* on *HRY*
The different letters indicate the significant differences between the effects (P <0.05). The letters *a* and *f* indicate the highest and lowest means, respectively

In the experiments including both ω: 10 and 12%, increasing in *T* from 45 to 60 °C resulted in a significant increase in *HRY*. However, there is no difference (statistically) between *T*: 45 °C and 60 °C at the moisture level of 8%. This means that at ω higher than 8% (w.b.), increase in temperature causes an increase in the grain strength. In addition to the description given for Fig. 1a (about the gelatinization of grain under the impression of steaming), at ω: 8%, the grain is not able to endure simultaneously stresses due to the high *T* and low ω. Therefore, at this moisture level, *HRY* did not increase with increasing *T*, similarly to the other moisture levels.

According to Fig. 3, increasing *t* from 10 to 30 min caused a significant decrease in *HRY* for all levels of ω. However, the level of 20 min did not differ from the levels of 10 and 30 min in any considerable way. As a result, *t*: 10 min is an optimal time for paddy parboiling when ω is set between 8 and 12%.

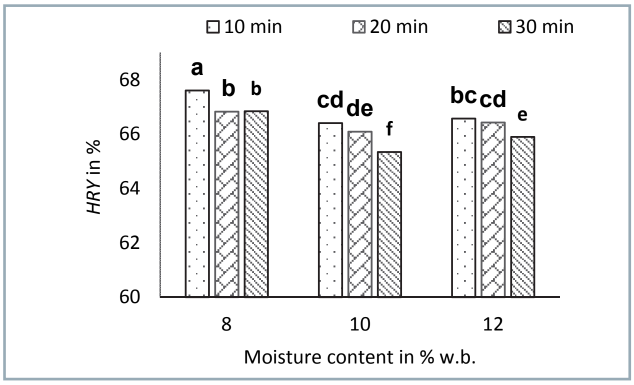

Fig. 3 Mean comparison results related to the interaction effect of ω/*t* on HRY
The different letters indicate the significant differences (*P* <0.05). The letters *a* and *f* indicate the highest and lowest means, respectively

The result was obtained earlier in surveying the interaction effect of ω/*t*.

The mean comparison results related to the interaction effects of *V*/*T*/ω on *HRY* were given in Table 3. It is revealed that in Hashemi variety and at *T*: 45 °C, increasing ω resulted in decreasing *HRY*. This decrease at the levels of 8% and 10% was very significant.

Overall, in all levels of *V* and *T*, the highest and lowest values of *HRY* were obtained at ω: 8% and 10%, respectively, and the value of 12% has shown an intermediate status. As it was mentioned earlier, ω: 10% does not show the brittleness property as high as paddy wih ω: 8%. In addition, the occurrence rate of hidden cracks in the paddy with higher ω (12%) is lower due to lower stress of dehydration. The highest *HRY* for Hashemi variety at *T*: 60 °C was achieved at ω: 8%; however, it does not differ from the value obtained at *T*: 45 °C in any significant way. For Alikazemi variety, the highest *HRY* was achieved at *T*: 45 °C and at ω: 8%. According to Table 3, if using paddy with ω: 10%, better *HRY* result was achieved at *T*: 60 °C for Alikazemi variety; however, in Hashemi variety, changing *T* has not any significant effect on *HRY*. The mean comparison results related to the interaction effects V/ω/t on *HRY* are given in Table 4.

In Hashemi variety, the highest and lowest *HRYs* were achieved at *t*: 10 and 30 min, respectively, for all levels of ω. In Alikazemi variety and at ω: 8%, a significant difference among *HRYs* was not observed; however, the highest *HRY* was achieved at *t*: 10 min. At ω: 10%, the *HRY* values were almost identical and a significant difference was observed only between the levels of 10 (67.737%) and 20 min (67.145%). At moisture of 12%, *HRYs* have not shown any significant difference between *t*: 10 and 20 min. The lowest *HRY* was achieved at *t*: 30 min.

The interaction effects related to three factors of *T*/ω/*t* (Table 5) showed that the highest *HRY* value (67.972%) was

Table 3 The mean comparison related to the interaction effect of *V*/*T*/ω on *HRY*

Variety	*T* in °C	ω in % w.b.	*HRY* in %	Variety	*T* in °C	ω in % w.b.	*HRY* in %
Hashemi	45	8	66.011[e]	Alikazemi	45	8	68.366[a]
		10	64.557[g]			10	66.996[d]
		12	64.577[g]			12	67.488[c]
	60	8	66.022[e]		60	8	68.087[ab]
		10	64.476[g]			10	67.760[bc]
		12	65.073[f]			12	67.982[ab]

The different letters indicate the significant differences (*P* <0.05). The letters a and g indicate the highest and lowest means, respectively

Table 4 The mean comparison related to the interaction effect of *V*/ω/*t* on *HRY*

Variety	ω in % w.b.	*t* in min	*HRY* in %	Variety	ω in % w.b.	*t* in min	*HRY* in %
Hashemi	8	10	66.952[c]	Alikazemi	8	10	68.260[a]
		20	65.612[d]			20	68.053[a]
		30	65.487[de]			30	68.208[a]
	10	10	65.077[ef]		10	10	67.737[ab]
		20	65.035[ef]			20	67.145[c]
		30	63.437[h]			30	67.252[bc]
	12	10	65.240[de]		12	10	67.907[a]
		20	64.713[fg]			20	68.147[a]
		30	64.492[g]			30	67.308[bc]

The different letters indicate the significant differences (*P* <0.05). The letters *a* and *g* indicate the highest and lowest means, respectively

Table 5 The mean comparison related to the interaction effect of *T*/ω/*t* on *HRY*

T in °C	ω in % w.b.	*t* in min	*HRY* in %	*T* in °C	ω in % w.b.	*t* in min	*HRY* in %
45	8	10	67.972^{a}	60	8	10	67.240^{bc}
		20	66.738^{cde}			20	66.927^{bcd}
		30	66.855^{bcd}			30	66.840^{bcd}
	10	10	66.682^{def}		10	10	66.132^{ghij}
		20	65.620^{j}			20	66.560^{defg}
		30	65.027^{k}			30	65.662^{ij}
	12	10	65.827^{hij}		12	10	67.320^{b}
		20	66.613^{defg}			20	66.247^{efgh}
		30	65.627^{j}			30	66.173^{fghi}

The different letters indicate the significant differences (P <0.05). The letters *a* and *k* indicate the highest and lowest means, respectively

obtained at *T*: 45 °C, *t*: 10 min and ω: 8%. This is followed by the combination including *T*: 60 °C, ω: 12% and *t*: 10 min which has shown the second highest *HRY* value (67.320%). The combination including the *T*: 60 °C, ω: 8% and *t*: 10 min has shown the third highest *HRY* value (67.240%). Overall, the steaming time of 10 min had the most positive impact on *HRY* in all combinations including *T* and ω. Although in a few cases higher *HRY* were achieved at the steaming time of 20 min than 10 min, the difference was not significant.

The mean comparison results related to the interaction effect of four factors including *V*/*T*/ω/*t* (Table 6) showed that the highest *HRY* (68.647%) was achieved in Alikazemi variety, at *T*: 45 °C, *t*: 10 min and ω: 8%. The combination of Alikazemi/45 °C/12%/20 min showed the second highest *HRY* value (68.507%). The combination including Alikazemi variety has proved to have higher *HRY* than the combination including Hashemi variety. For Hashemi variety, the highest *HRY* (67.297%) was achieved at *T*: 45 °C, *t*: 10 min and ω: 8%. The combination of Hashemi/60 °C/8%/10 min showed the second highest *HRY* (66.607%).

At *T*: 45 °C and at both ω: 8% and 12%, the highest *HRY* values were obtained at *t*: 10 min in Hashemi variety. Although *t*: 30 min showed higher *HRY* than 20 min, the differences were not significant. However, at ω: 10%, the mean of *HRY* significantly decreased with increasing *t* from 10 min to 30 min. In the experiments including Hashemi variety, *T*: 60 °C and ω: 8%, *HRY* decreased with increasing *t*. In the same combination, but including ω: 10%, the highest *HRY* was obtained at *t*: 20 min; however, it does not differ from *t*: 10 min in any significant way. As a result, in this combination *t*: 10 min had contributed towards the best value of *HRY*. For Alikazemi variety at *T*: 45 °C and ω: 8%, the significant differences were not observed among the levels of *t*; however, the highest *HRY* was achieved at *t*: 10 min. At ω: 10%, the highest *HRY* was obtained at *t*: 10 min as well. At ω: 12%, the highest *HRY* was observed at *t*: 20 min.

Table 6 The mean comparison relating to the interaction effect of *V*/*T*/*M*/*t* on *HRY*

Variety	*T* in °C	ω in %	*t* in min	*HRY* in %	Variety	*T* in °C	ω in %	*t* in min	*HRY* in %
Hashemi	45	8	10	67.297^{efg}	Alikazemi	45	8	10	68.647^{a}
			20	65.247^{lmno}				20	68.230^{abcd}
			30	65.490^{klmn}				30	68.220^{abcd}
		10	10	65.717^{jklm}			10	10	67.647^{cdef}
			20	64.950^{nopq}				20	66.290^{ij}
			30	63.003^{s}				30	67.050^{fgh}
		12	10	64.260^{qr}			12	10	67.393^{ef}
			20	64.720^{opq}				20	68.507^{ab}
			30	64.690^{opq}				30	66.563^{hi}
	60	8	10	66.607^{ghi}		60	8	10	67.873^{abcde}
			20	65.977^{ijkl}				20	67.877^{abcde}
			30	65.483^{klmn}				30	68.197^{abcd}
		10	10	64.437^{pqr}			10	10	67.827^{bcde}
			20	65.120^{mnop}				20	68.000^{abcde}
			30	63.870^{r}				30	67.453^{def}
		12	10	66.220^{ijk}			12	10	68.420^{abc}
			20	64.707^{opq}				20	67.787^{bcdef}
			30	64.293^{qr}				30	68.053^{abcde}

The different letters indicate the significant differences (P <0.05). The letters *a* and *s* indicate the highest and lowest means, respectively

It is noteworthy that in all experiments including Alikazemi, *T*: 45 °C and at all levels of ω, the lowest *HRY* values were achieved at *t*: 30 min. In the experiments including Alikazemi, ω: 8% and *T*: 60 °C, the results similar to values achieved at *T*: 45 °C, therefore, the significant differences between the individual of *t* had not been observed. This case was true for ω: 10 and 12%. Considering the results, the increasing of *t* levels from 10 to 30 min has not shown significant impacts on *HRY* in Alikazemi variety and at *t*: 60 °C and all levels of ω.

Comparison between *HRY* obtained from raw rice and parboiled rice

The mean of *HRY* for Hashemi variety at all levels of drying temperature and moisture content were compared in Fig. 4. The results indicate that in all experiments, the values of *HRY* related to the parboiled rice (HRY_p) were considerably higher than the values of *HRY* of raw rice (HRY_r). At *T*: 45 °C, there were the increases of 34, 24 and 21%, respectively for the moisture levels of 8, 10 and 12% in HRY_p in comparison to HRY_r. Corresponding values in *T*: 60 °C were 33, 31 and 34%. Therefore, the highest increase in HRY_p in comparison to HRY_r was observed at ω: 8% , which is common in the milling factories.

The results of experiments for Alikazemi variety showed that a considerable increase in HRY_p in comparison to HRY_r (Fig. 5). At 45 °C, HRY_p increased by 46, 43 and 43% in comparison to HRY_r, for ω: 8, 10 and 12%, respectively. Corresponding values at *T*: 60 °C were 54, 55 and 59%. Therefore, the highest increase in HRY_p in comparison to HRY_r was obtained at ω: 8 and 12%, respectively for *T*: 45 and 60 °C. As a result, the parboiling process plays a much more important role in relation to *HRY* for Alikazemi variety than Hashemi.

For Hashemi variety, the best HRY_p (67.297%) was obtained in the treatment combination of 45 °C/8%/10 min and the best HRY_r (53.49%) in the combination of 45 °C/12%. Considering the values of HRY_p and HRY_r, it is concluded that for Hashemi variety, parboiling causes an increase of 25.8% in *HRY*. For Alikazemi, the best HRY_p (68.647%) was obtained in the treatment combination of 45 °C/8%/10 min and the best HRY_r (47.91%) in the combination of 45 °C/12%. Considering the values of HRY_p and HRY_r, it is concluded that for Alikazemi variety, parboiling causes an increase of 43.3% in *HRY*.

Conclusions

The time of 10 min was introduced as the most appropriate steaming time for parboiling of tested varieties from both aspects of milling quality and energy consumption. Optimal *T* for parboiled rice is 60 °C, while it is 45 °C for raw rice. In other words, parboiling with gelatinizing of the grain and homogenizing its components allows the application of higher drying temperature than non-parboiled rice. In Hashemi variety, changes in *T* (between 45 and 60 °C) have not shown any significant effects on *HRY*. Therefore, higher *Ts* (60 °C) are proposed due to time saving. The combinations including Alikazemi variety had higher *HRY* in the most cases in comparison to Hashemi variety. Of all experiments, the highest *HRY* (68.647%) was achieved in the treatment combination of Alikazemi/45 °C/10 min/8%. For Hashemi variety, the highest *HRY* (67.297%) was achieved in the combination of 45 °C/10 min/8%. If the appropriate treatment combinations concerning HRY_p and HRY_r are

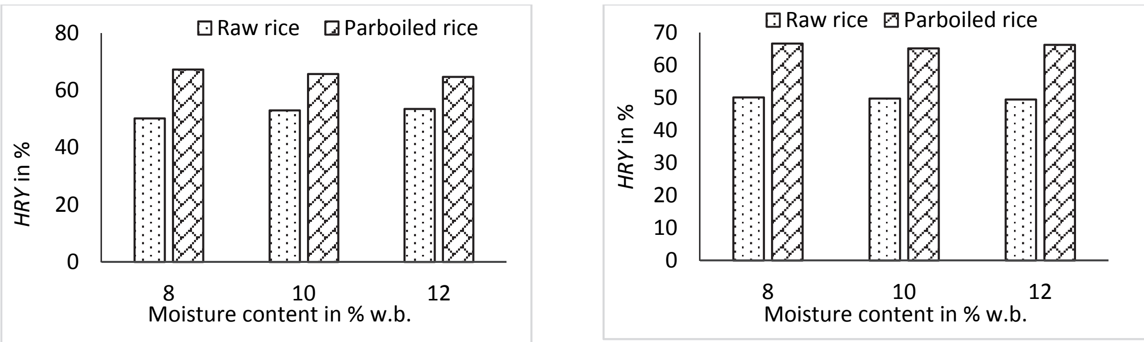

Fig. 4 The mean of *HRY* for Hashemi at different levels of ω and *T*: a) 45 and b) 60 °C

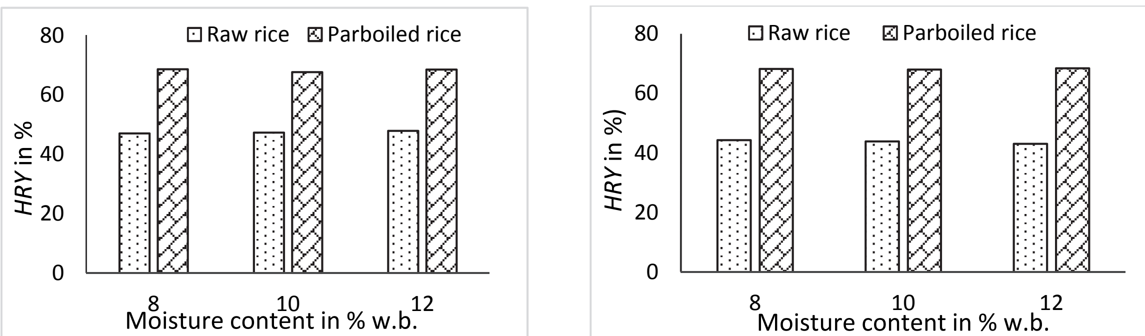

Fig. 5 The mean of *HRY* for Alikazemi at the different levels of ω in *T*: a) 45 and b) 60 °C

selected, parboiling causes an increase of 25.8% in *HRY*. This value is 43.3% for Alikazemi variety.

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