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EFFICACY OF PARBOILING ON PHYSICO-CHEMICAL PROPERTIES OF SOME PROMISING LINES/VARIETIES OF RICE (*Oryza sativa* L.)

MUHAMMAD AKHTER [1]*, MUHAMMAD AZHAR ALI[2], ZULQARNAIN HAIDER[1] AND SHAHZAD MUZAMMIL[3]

[1]Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan.

[2]Post Harvest Research Centre, Faisalabad, Pakistan.

[3]Institute of Agricultural Sciences, Punjab University, Lahore, Pakistan.

Abstract

Some of the promising lines/varieties of Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan, including approved fragrant (Basmati) rice varieties, e.g., Basmati-515, PS-2 and Super Basmati, were used to assess interactive efficacy of parboiling on these varieties/lines and practical expediency of using standardised parboiling technique for improving nutritional, milling and cooking qualities of these lines/varieties. For this purpose, white milled and parboiled rice samples often lines/varieties were analyzed for nutritional quality parameters, such as, ash, dry matter, crude fat, crude protein, crude fiber, vitamin B6; milling quality parameters, such as, total milling recovery, head rice recovery, ratio of broken grains; and cooking quality parameters such as curling, bursting and cooked grain length. The study showed significant variation in efficacy of parboiling to different varieties/lines. The results clearly showed average increase in mineral contents in terms of ash% increase, dry matter, longer cooked grain length and considerable rise in vitamin B6 contents, higher total milling recovery and head rice recovery in almost all the samples, while crude fiber, crude protein and crude fat decreased non-significantly. Furthermore, quality reducing factors, such as, number of broken grains, bursting and curling percentage of cooked rice were also found reduced significantly in parboiled samples. It may, therefore, be suggested that parboiling offers a better alternative to conserve and increase nutritional, milling and cooking quality values of rice varieties/lines. Moreover, smaller percentage of broken, burst and curled grains may result in augmented net income.

Keywords: Rice, Promising basmati varieties/lines, Parboiling, Vitamin B6, Crude protein, Crude fat, Crude fiber, Broken grains, Bursting and curling percentage.

Introduction

Rice is utilised as a basic source of sustenance by more than half of the world's population, thus, making it a second most important cereal grain after wheat (Ghadge and Prasad, 2012; Bhatia et al, 2009; Prasad et al., 2010a, b, c). About 50% of the world's paddy production is parboiled. Parboiled rice, sometimes also called as converted rice, is a partially boiled un-husked rice. The three basic steps of parboiling are soaking, steaming and drying (Miah et. al., 2002). The treatment is practiced in Pakistan as well as many other parts of the world, such as, India, Bangladesh, Myanmar, Malaysia, Nepal, Sri Lanka, Guinea, South Africa, Italy, Spain, Nigeria, Thailand, Switzerland, USA and France (Pillaiyar, 1981).

Parboiling drives nutrients, especially, thiamine, from the bran to endosperm (Kyritsi et al., 2011), hence parboiled white rice is 80% nutritionally similar to brown rice. Because of this, parboiling is now being adopted by more than 80% countries of the world. Parboiled rice takes less time to cook and is firmer and less sticky. In most of the countries, parboiled rice is either partially or fully precooked before sale. The major reasons for parboiling rice include higher milling yields, higher nutritional value and resistance to spoilage by insects and mold (Bhattacharya and Roa, 1966; Elbert et al., 2000).

However, the suitability and efficacy of parboiling for Pakistani local varieties and lines is still needed to be determined. Therefore, a study was conducted whereby ten promising lines having average grain length (AGL) more than 8.0 mm with very good milling and cooking qualities, were developed by Rice Research Institute, Kala Shah Kaku, along with approved basmati varieties of Pakistan, and analysed for their suitability to be used for parboiling and improvement of their physico-chemical properties were also studied to ascertain the effectiveness of parboiling with special reference to these varieties and lines.

Materials and Methods

* director_rice@yahoo.com

The study was conducted during 2012, in which nutritional, milling and cooking quality analysis of white milled raw and parboiled rice samples of 10 rice lines/varieties, i.e., PK-7392, PK-8677 (OP-154), PK-7429, Basmati-515, PS-2, Super Basmati, PK-8431, PK-7909, PK-99404 and PK-99723 was conducted.

Parboiling treatment: The rough rice samples (5-6 kg) of ten selected lines/varieties were treated according to the treatment matrix that included two drying cycles. The most suitable soaking temperatures and soaking durations for all the ten lines/varieties were predetermined in the laboratory of Rice Research Institute using Lab Scale Parboiling Unit. The drying temperature during 1st pass was 95 °C and during 2nd pass it was 75 °C. The steamed paddy was dried at a temperature of 95 °C during first pass, below the starch gelatinisation Temperatures (GT), till moisture content of treated paddy reaches 18%. GT helps in determining the optimum soaking temperature for a particular rice line/variety. After the first pass, the partially dried paddy was tempered at room temperature for a minimum period of 2-3 hours. Presoaking below the GT minimises the splitting of grains. After tempering, drying temperature during the second drying cycle was 75 °C, till the treated paddy reaches 11% moisture content. The treated and dried paddy samples were milled to determine various grain nutritional, milling and cooking quality parameters as described below.

Nutritional quality parameters: Parameters for nutritional quality, such as, ash %, dry matter (DM %), crude fat (CF %), crude protein (CP %), crude fiber (CFi %) and vitamin B6 (B6) contents were analysed, using lab scale parboiling unit (LSPU) in order to determine the effects of parboiling on these nutritional quality parameters. Specifications for LSPU were developed and the unit was procured and installed accordingly.

Milling and cooking characteristics: Parboiled and un-parboiled samples of each variety/line were cleaned with a seed blower. 1kg of each treated and raw dried (less than 12% moisture content) paddy samples of each line/ variety were hulled with a testing husker (THU, 35H, Satake Engineering Co. Ltd., Japan). The moisture content of each sample was predetermined using a Steinlite Model 500 RC Electronic moisture tester. Then 500 g of brown rice of each sample obtained was then whitened in a single pass friction rice pearler (BS08A, Satake Engineering Co. Ltd., Japan) with the degree of whiteness set between 'Low' and 'Medium' on the equipment. After milling, rice bran was removed with a 1.7 mm sieve. A cleaned sample of milled rice was weighed and used to determine milling recovery parameters, such as, total milling recovery percentage (TMR %), head rice recovery (HRR) and percentage of brokens. Head rice recovery (HRR %) was calculated as percentage of whole milled grains with respect to the brown rice, then the average value was calculated (Bello et. al., 2006). De-husked rice of both parboiled and un-parboiled samples of each variety/line was cooked in excess water. Twenty grains of each sample were cooked with a colander in a boiler placed on an electric heater (98°C) at cooking time of the respective variety/line. Then cooking quality parameters, such as, cooked grain length (CGL in millimeters), percent curling and bursting percentage of all the samples were measured.

Results and Discussion

The results showed that almost all the genotypes were significantly different among themselves in respect with all the studied characters, showing remarkable diversity in these characters ((Table 2); Figs. 1 and 2). Table 1 shows range and means of values for all the studied characters obtained from all parboiled and un-parboiled milled rice samples of each genotype. By comparing the means of parboiled and un-parboiled rice samples, it was evident that there was an increase in total milling recovery, head rice recovery, ash %, dry matter %, crude protein % and vitamin B6 on an average basis. While broken %, curling %, bursting % and crude fat % was found to decrease on average basis after parboiling. Average crude fiber % remained stable showing no significant influence of parboiling (Table 1).

Ash and dry matter percentage: Table 1 shows significant difference among all the genotypes for their ash and dry matter percentages. These results show that ash increases in parboiled samples except for two varieties/lines, i.e., Super Basmati and line PK99404 as indicated by the line graph that is below the reference line at zero (Fig. 1a). Maximum increase in ash was recorded for line PK7429 (32.1%) followed by line PK7909 (27.3%), while minimum (3.9%) was recorded in case of line PK8677 (OP154) as depicted in Fig. 1(a). As ash represents the mineral contents, showing that parboiling process increases the mineral contents in rice kernel. The brown rice, produced by removing the hull only, contains most of the minerals in outer most layer. The complete milling and polishing removes more than 70% of minerals therein, resulting in reduced nutritional white rice. Contrary to this, parboiling pushes these minerals from the outer layer of brown rice into the endosperm, by high temperature and pressure, thus maintaining the nutritional value of rice. However, the process that produces brown rice removes only the outermost layer, the hull, of the rice kernel and is the least damaging to its nutritional value. Chukwu and Oseh (2009) also demonstrated that temperature had significant influence on ash percentage. Dry matter percentage also showed increase in all parboiled samples with maximum recorded in PK7429 (6.8%)

and minimum in line PK7392 (1.6%) graphically demonstrated in Fig. 1(b).

Table 1. Range and means of studied physico-chemical parameters of raw and parboiled samples of all genotypes.

Parameters	Un-parboiled		Parboiled	
	Range	Mean	Range	Mean
Total milling Recovery (%)	70-72	71.01	71.5-72.6	72.03
Head rice Recovery (%)	50-54	51.95	63.9-66.5	65.22
Broken (%)	17.5-20.5	19.06	5.5-8.2	6.81
Curling (%)	3.0-8.0	6.15	3.5-5.5	4.4
Bursting (%)	2.0-7.5	5.85	1.5-5.0	3.25
Ash (%)	0.49-0.65	0.569	0.55-0.76	0.645
Dry matter (%)	87.65-89.41	88.37	90.16-94.57	93.006
Crude fat (%)	0.91-1.12	1.014	0.85-0.97	0.912
Crude protein (%)	7.09-9.01	7.893	6.91-8.93	7.959
Crude fiber (%)	0.37-0.51	0.456	0.38-0.50	0.454
Vitamin B6 (ppm)	0.076-0.078	0.077	1.010-3.797	1.676

Table 2. Comparison of nutritional quality parameters among raw rice and parboiled rice samples of all the studied genotypes.

Sr.#	Lines/ varieties	Ash (%)		Dry matter (%)		Crude fat (%)		Crude protein (%)		Crude fiber (%)		Vitamin B6	
		WR	PBR	WR	PBR	WR	PBR	WR	PBR	WR	PBR	WR	PBR
1	PK7392	0.49^{ij}	0.55^{i}	88.70^{c}	90.16^{j}	1.04^{cde}	0.94^{bcd}	8.75^{bc}	6.91^{j}	0.46^{d}	0.47^{bcd}	0.077^{a}	1.687^{c}
2	PK8677 (OP154)	0.51^{hi}	0.53^{ij}	89.41^{a}	92.77^{g}	1.04^{cd}	0.95^{ab}	7.26^{gh}	8.93^{a}	0.42^{hi}	0.49^{ab}	0.076^{c}	1.366^{def}
3	PK7429	0.56^{e}	0.74^{ab}	88.54^{d}	94.57^{a}	0.97^{fg}	0.88^{g}	7.35^{g}	8.14^{e}	0.37^{j}	0.50^{a}	0.077^{b}	1.202^{fg}
4	Basmati - 515	0.54^{efg}	0.63^{ef}	88.21^{f}	92.94^{ef}	1.10^{ab}	0.94^{cde}	7.09^{i}	7.61^{g}	0.51^{a}	0.49^{abc}	0.078^{a}	1.515^{cde}
5	PS-2	0.62^{bc}	0.76^{a}	87.65^{j}	92.55^{ah}	0.97^{f}	0.85^{hi}	9.01^{a}	8.31^{d}	0.49^{ab}	0.47^{bcde}	0.077^{b}	1.591^{cd}
6	Super Basmati	0.61^{bcd}	0.59^{h}	88.02^{gh}	93.59^{d}	0.96^{gh}	0.92^{def}	8.84^{b}	7.53^{gh}	0.46^{de}	0.44^{gh}	ND	2.528^{b}
7	PK8431	0.63^{ab}	0.68^{cd}	88.89^{b}	92.97^{e}	1.12^{a}	0.97^{a}	7.70^{e}	8.66^{b}	0.46^{def}	0.46^{defg}	0.078^{a}	1.029^{ghi}
8	PK7909	0.55^{ef}	0.70^{c}	88.30^{e}	94.22^{b}	0.91^{ij}	0.85^{hij}	8.23^{d}	7.09^{i}	0.46^{defg}	0.38^{i}	ND	1.010^{hij}
9	PK99404	0.65^{a}	0.62^{fg}	88.03^{g}	93.78^{c}	0.95^{ghi}	0.87^{gh}	7.61^{ef}	8.58^{bc}	0.44^{efgh}	0.38^{ij}	0.077^{b}	1.039^{gh}
10	PK99723	0.53^{fgh}	0.65^{e}	87.97^{ghi}	92.51^{hi}	1.08^{abc}	0.95^{abc}	7.09^{ij}	7.79^{f}	0.49^{abc}	0.47^{acdef}	ND	3.797^{a}

***WR = Raw rice**

****PBR = Parboiled rice**

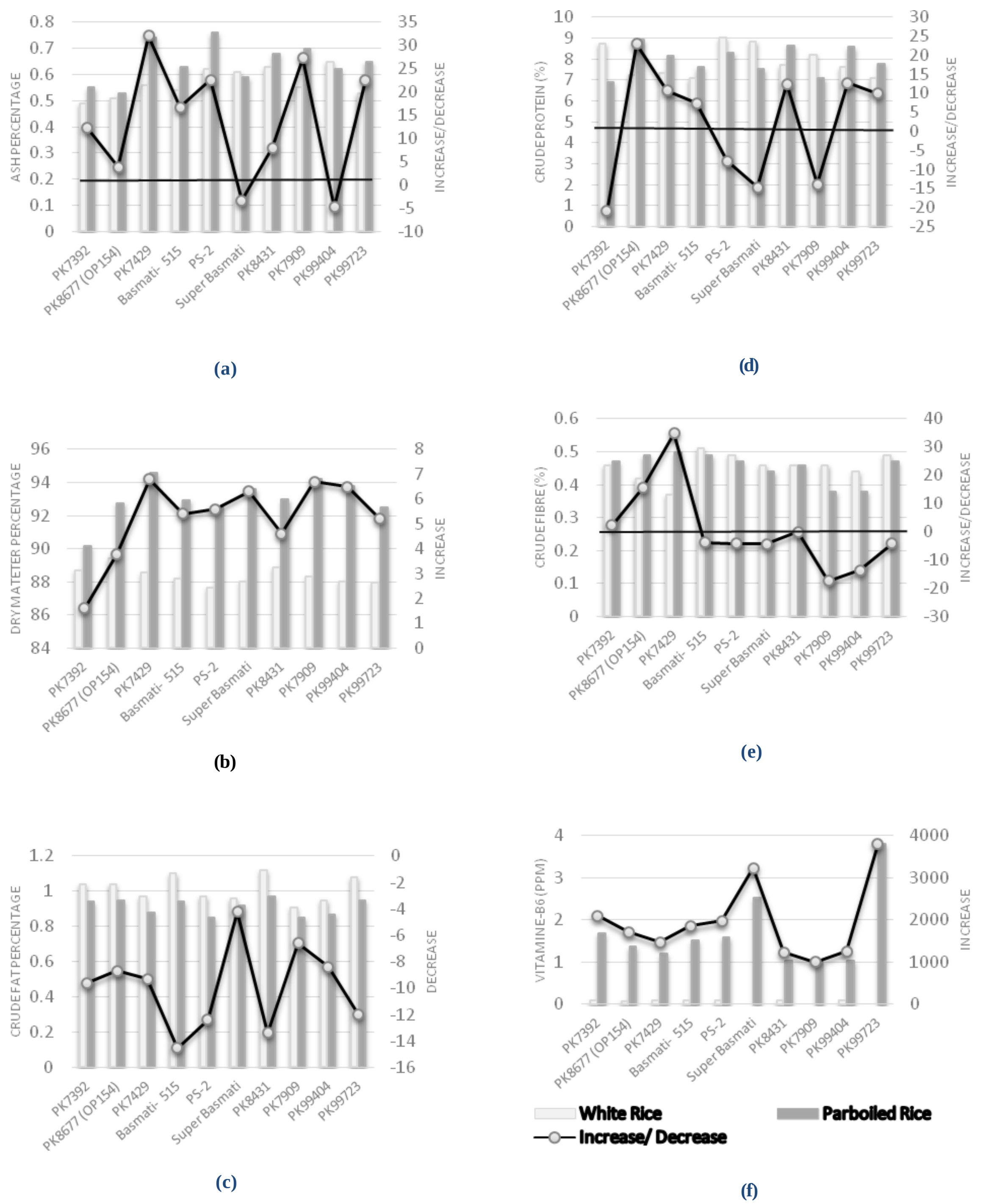

Fig. 1. **Nutritional quality parameters of parboiled and un-parboiled milled samples of all the studied lines/varieties of rice. Line graph indicates increase or decrease in percentage. Points in graph line above and below the reference line at zero indicate increase and decrease respectively.**

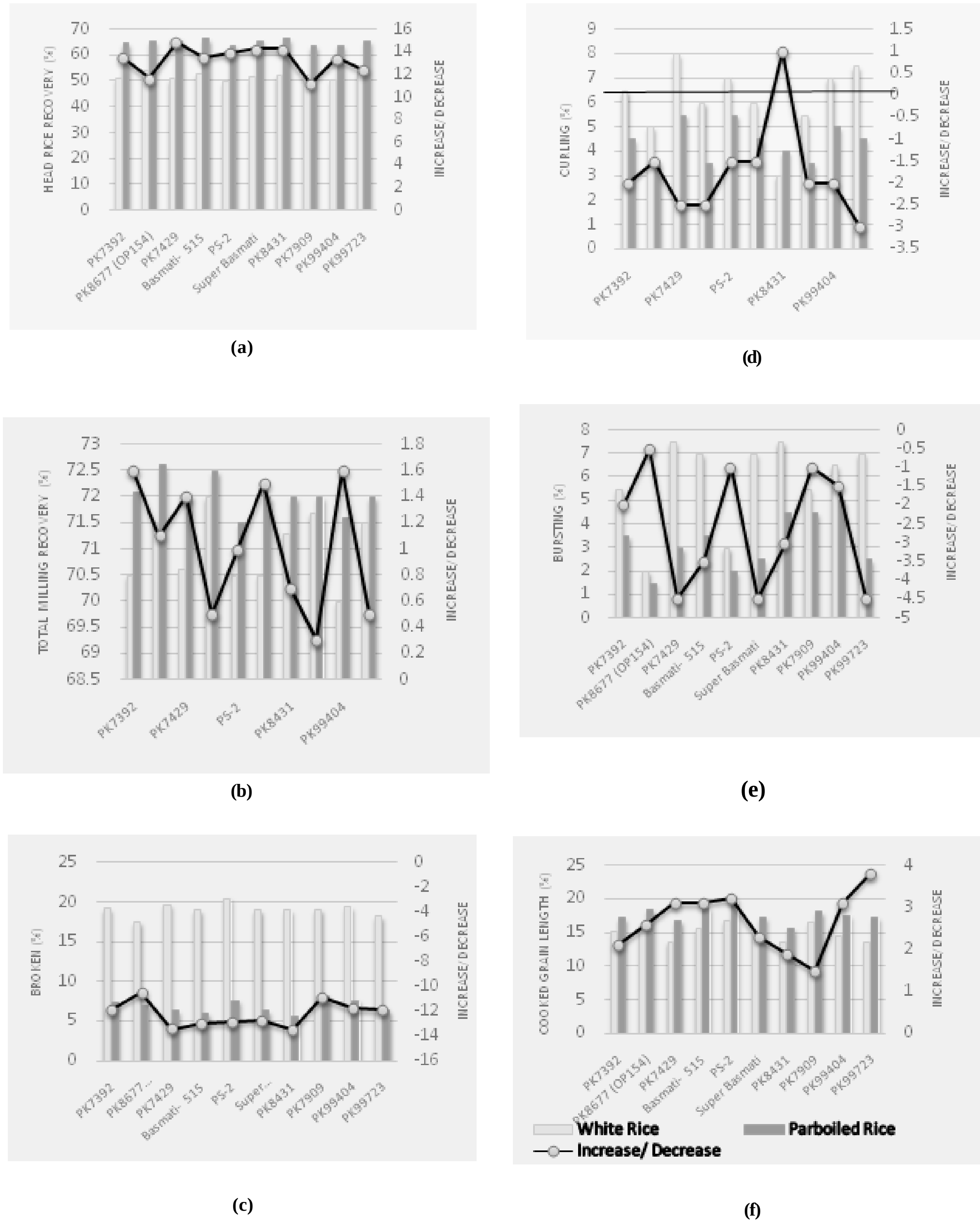

Fig. 2. Nutritional quality parameters of parboiled and un-parboiled milled samples of all the studied lines/varieties of rice. Line graph indicates increase or decrease in percentage. Points in graph line above and below the reference line at zero indicates increase and decrease respectively.

Crude fat, crude protein and crude fiber: A significant difference was recorded in all the parboiled and un-parboiled samples (Table 2). The results given in Fig. 1 (c) clearly indicate that crude fat percentage was decreased in all parboiled samples and in this context maximum decrease (14.5%) was recorded in Basmati-515, while minimum in Super Basmati (4.2%). The decrease or loss of crude fat in parboiled samples may be due to the heating process and leaching of fat into the soaking water. Rao and Juliano (1970) also showed that fat content decreases during parboiling process. On the other hand, there were mixed results for crude protein percentage. For six rice genotypes, crude protein increases while in four it decreases (Fig. 1d). Maximum increase (23.0%) in crude protein was recorded for line PK8677 (OP-154) followed by line PK99404 (12.7%) while minimum increase in case of Basmati-515 (7.3%) as shown in Fig. 1(d). Maximum decrease in crude protein percentage was recorded in line PK7392 (21.0%), while minimum decrease was observed in line PK1121 (7.8%). Padua and Juliano (1974) also reported a decrease in protein contents due to parboiling, which may be due to leaching of protein during socking phase of parboiling as well as rupturing that occurs in molecules while steaming phase. Parboiling makes the protein sink into the compact gelatinised starch grain mass, that makes protein bodies less extractable ultimately decreasing its contents. (Chukwu and Oseh, 2009). However, Patindol et al. (2008) in their study on laboratory scale parboiled rice, concluded that parboiling sparingly changed protein content. They concluded that reduction in protein content might be due to the fact that oil and protein diffuse outward during parboiling, based on microscopic observations, they cannot diffuse as readily through cell walls as water-soluble vitamins.

These findings further showed that in most parboiled samples, crude fiber was found to decrease and a maximum decrease was observed in line PK7909 (17.4%) whereas minimum in Basmati-515 (3.9%). Similarly, maximum increase of crude fiber percentage was recorded in line PK7429 (35.1%) with minimum in case of line PK7392 (2.2%) as shown in Fig. 1(e). Line graph in Fig. 1(e) indicates an increased percentage in crude fiber after parboiling for each genotype separately. Line graph points below the reference line at zero indicate that crude fiber decreased as in case of Basmati-515, PS-2, Super Basmati, PK7909, PK99404 and PK99723, while crude fiber increased in case of PK7392, PK8677 and PK7429 as indicated by line graph above the reference line at zero.

Sareepuang et al. (2008) also reported significant increase in crude fat, crude protein and crude fiber after parboiling at 50 ^{o}C. It has already been found that dietary fiber, crude fat and crude protein increases after germination, probably because of formation of new compounds (Jung et al., 2005 and Lee et al., 2007). The same results were obtained by Rao and Juliano (1970). Newton et al. (2011) also found an increase in these nutritional indices in parboiled rice samples.

Vitamin B6: Vitamin B6, as presented in Fig. 1 (f), considerably increased in all parboiled samples with a maximum increase in line PK99723 (3797.0%) and the minimum in line PK7909 (1010.0%). This increase in vitamin B6 content in parboiled rice samples may be attributed to the migration of vitamin B6 content from bran layers into the kernel. The complete milling and polishing that converts brown rice into white rice destroys 67% of the vitamin B3, 80% of vitamin B1, 90% of vitamin B6, half of the manganese, half of the phosphorus, 60% of iron, and all of the dietary fiber and essential fatty acids (Ituen and Ukpakha, 2011). Fully milled and polished white rice is additionally required to be "enriched" with vitamins B1, B3 and iron. Therefore, parboiling can be used to increase nutritionally essential vitamins that are lost during milling and processing. This agreed with the findings of Gariboldi (1973) that it may be due to the fact that during steaming, water soluble vitamins are spread throughout the grain, thus altering their distribution and concentration.

Milling and cooking quality parameters: Fig. 2(a-f) summarises the results of milling and cooking quality of raw milled rice (Pre-parboiled) and parboiled milled rice (post-parboiled). Significant variation was found among the studied genotypes for the traits. It may be concluded from Fig. 2(a) that total milling recovery (TMR %) was increased in all the studied samples that showed significant variation among themselves. Highest TMR was obtained for line PK99404, followed by line PK7392 and Super Basmati, respectively. Minimum TMR was shown by line PK7909. Likewise, among the lines tested, maximum HRR (54.0%) was recorded for line PK8677 (Fig. 2b), while minimum (50.0) in case of PS-2. Maximum cooked grain length (CGL) (16.9 mm) was recorded for PS-2, while minimum in case of PK99723 (13.5 mm) as shown in Fig. 2(c). Almost all the lines showed significant increase in cooked grain length when subjected to parboiling. Cherati et al. (2012) also analysed and studied the parboiling methods and the following impact on waste reduction and yield increase in Iranian rice in paddy conversion phase. They found a fracture or broken percentage and bran percentage decreased, while head rice recovery increase after parboiling. Fig. 2 (d) clearly emphasizes that bursting of cooked grain was reduced significantly for almost all the genotypes except for PK8431. Bursting of grains in all the parboiled samples was also found to be significantly low as compared to un-parboiled white rice (Fig. 2f). Rao and Juliano (1970) also showed an increase in head rice recovery and cooking quality in parboiled rice.

Miah et al. (2002) also observed a large reduction in fissured grains in parboiled samples of rice as compared to non-parboiled. They further added that it is due to the fact that parboiling fills the void spaces in the endosperm and hence the cracks within the grains are cemented, making the grain harder leading it to less brokens. Insect infestation is also reduced due to the hardness.

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Conclusion

As a conclusion to the study, it may be abridged that using proper techniques of parboiling, nutrition of rice may be conserved within endosperm, even after removal of the outer layer, i.e., bran, during milling and processing. Hence, parboiling maintains nutritional quality of milled and polished rice that is often lost during milling and polishing processes. It can further be concluded that parboiling process could be a good tool to save time when trying to improve certain physical and nutritional quality traits of freshly harvested rice that additionally assist in improving head rice recovery, total milling recovery and enhances shelf life of rice grains. Among all, the studied varieties and lines, basmati-515 and PK7429, respectively, were found the best for parboiling. Among others, variety PS-2 and lines PK8677, PK99723 and PK7392 were found more responsive to parboiling respectively. Other lines/varieties showed less suitability to parboiling.

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