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PHYSICO-CHEMICAL CHANGES IN GRAINS OF SOME ADVANCE LINES/ VARIETIES OF RICE (*ORYZA SATIVA* L.) AFTER PARBOILING

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ABSTRACT:- Some of the advance lines/varieties developed at Rice Research Institute, Kala Shah Kaku, including approved fragrant (Basmati) rice variety i.e., Basmati-2000, were used to assess interactive efficacy of parboiling on these varieties/lines and practical expediency of using standardized parboiling technique for improving nutritional, milling and cooking qualities of these lines/varieties. For this purpose, white milled and parboiled rice samples of ten 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 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. Less percentage of broken, burst and curled grains may result in augmented net income.

Key Words: Rice; Promising Basmati Varieties/Lines; Parboiling; Vitamin B6; Crude Protein; Crude Fat; Crude Fiber; Broken Grains; Bursting ; Curling Percentage; Pakistan.

INTRODUCTION

Rice is utilized as a basic source of sustenance for 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., 2010 a, b, c). About 50% of the world's paddy production is parboiled. Parboiled rice, sometimes also called 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,

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Spain, Nigeria, Thailand, Switzerland, USA and France (Pillaiyar, 1981).

Parboiling drives nutrient, 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 Subbarao, 1966; Elbert et al., 2000).

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

MATERIALS AND METHOD

During the study conducted at Rice Research Institute, Kala Shah Kaku in 2012, nutritional, milling, and cooking quality of white milled raw and parboiled rice samples of the ten rice varieties/lines namely, PK-7392, PK-8677 (OP-154), PK-7429, Basmati-515, PS-2, Super Basmati, PK-8431, PK-7909, PK-99404 and PK-99723 were analyzed.

Parboiling Treatment

Five to six kilograms of the ten selected rice varieties/lines were treated accordingly based on the treatment matrix having 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 (LSPU). The drying temperatures noted during the first and second pass were 95^{0}C and 75^{0}C, respectively. The steamed paddy was dried at 95^{0}C during first pass, below the starch gelatinization 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 first pass, the partially dried paddy was tempered at room temperature for 2-3 h. Presoaking below the GT minimizes the splitting of grains. After tempering, drying temperature during the second drying cycle was 75^{0}C, till the treated paddy reaches 11% moisture content. The treated and dried paddy samples were milled to determine nutritional, milling and cooking quality parameters.

Nutritional Quality Parameters

These include ash %, dry matter (DM%), crude fat (CF%), crude protein (CP%), crude fiber (CFI%) and vitamin B6 (B6). These were analyzed using LSPU 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 Parameters

Parboiled and un-parboiled samples of each variety/line were cleaned with a seed blower. 1 kg 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 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 including total milling recovery percentage (TMR%), head rice recovery (HRR) and broken percentage. Head rice recovery (HRR%) was calculated as percentage of whole milled grains respect to the brown rice, then the average value was calculated (Bello et al., 2004). 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^{0}C) at cooking time of respective variety/line. Then cooking quality parameters such as cooked grain length (CGL in mm), percent curling and bursting percentage of all the samples were measured.

RESULTS AND DISCUSSION

On average basis, comparing the means of parboiled and un-parboiled rice samples, there was significant increase in total milling recovery, head rice recovery, ash% and vitamin B6. While broken%, curling%, bursting% and crude fat% decreased significantly on average basis after parboiling. Average crude fiber% remained stable showing no significant influence of parboiling (Table 1). Results revealed that almost all the genotypes were significantly different showing remarkable diversity among various characters (Table 2 and 3).

Ash and Dry Matter Percentage

Ash increases in parboiled samples of all the varieties. Maximum increase in ash was recorded for line 99417 (54.3%) followed by line Basmati 2000 (53.2%) while minimum (12%) was recorded in line PK8892 (Table 2). As ash represents the mineral contents, so it showed that parboiling process increases the mineral content in rice kernel. The brown rice, produced by removing the hull only, contains much minerals in outermost layer. The complete milling

Table 1. Physico-chemical parameters of un-parboiled and parboiled samples of all genotypes

Parameter	Un-parboiled		Parboiled	
	Range	Mean	Range	Mean
Total milling recovery (%)	69.6-72.5	70.66	69.25-77.5	73.95
Head rice recovery (%)	36.5-57.5	48.56	36.50-71.75	63.87
Broken (%)	18.5-21.6	19.91	3.5-33.2	10.04
Curling (%)	3.0-13.0	6.87	0-13	3.91
Bursting (%)	3.0-13.0	5.67	1.0-18.0	4.13
Ash (%)	0.46-0.62	0.518	0.65-0.78	0.722
Dry matter (%)	90.8-93.7	92.61	88.7-92.9	91.15
Crude fat (%)	0.86-0.97	0.927	0.87-0.76	0.811
Crude protein (%)	6.48-8.31	7.36	6.56-7.79	7.14
Crude fiber (%)	0.38-0.51	0.46	0.37-0.49	0.45
Vitamin B_6 (ppm)	0.07-1.31	0.27	1.02-13.17	4.962

and polishing removes more than 70% of minerals therein, resulting in reduced nutritional white rice. In contrast, parboiling pushes these minerals from 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 was decreased by 1 - 5 % in all parboiled samples except for Basmati 2000 (0.80%) and PK8660 (2.30%).

Crude Fat, Crude Protein and Crude Fiber

A significant difference was recorded in all the parboiled and un-parboiled samples (Table 2 and 3). The results clearly indicate that crude fat percentage was decreased in all parboiled samples and maximum decrease (16.10%) was recorded in PK8667 while minimum in 99417 (10.5%). 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 (Table 3). Among the ten selected genotypes, crude protein increases in three and for the rest genotypes it decreased. Maximum increase (20.2%) in crude protein was recorded for line PS3 followed by line PK8892 (13.7%) while minimum increase in 99417 (5.3%). The same

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

Sr.#	Lines/ varieties	Ash (%)			Dry matter (%)			Crude Fat (%)		
		WR	PBR	Increase/ decrease	WR	PBR	Increase/ decrease	WR	PBR	Increase/ decrease
1	SUPRA	0.51^{cde}	0.71^{def}	+39.2	92.50^{g}	89.50^{h}	-3.2	0.96^{ab}	0.85^{ab}	-11.5
2	99417	0.46^{h}	0.71^{efg}	+54.3	93.00^{f}	90.60^{g}	-2.6	0.86^{j}	0.77^{hi}	-10.5
3	Basmati -2000	0.47^{fg}	0.72^{de}	+53.2	91.30^{h}	92.00^{de}	+0.8	0.92^{fgh}	0.80^{ef}	-13.0
4	PK-8892	0.62^{a}	0.70^{fgh}	+12.9	$93.60a^{b}$	91.60^{f}	-2.1	0.95^{de}	0.84^{bc}	-11.6
5	PS-3	0.49^{def}	0.65^{ij}	+32.7	93.50^{abc}	88.70^{j}	-5.1	0.96^{bc}	0.82^{cd}	-14.6
6	PK 8677a	0.54^{bc}	0.78^{a}	+44.4	93.40^{bcd}	92.10^{d}	-1.4	0.91^{hi}	0.80^{fg}	-12.1
7	PK 8677b	0.54^{bc}	0.74^{cd}	+37.0	93.70^{a}	92.40^{b}	-1.4	0.89^{ij}	0.76^{ij}	-14.6
8	PK 8667	0.55^{b}	0.78^{ab}	+41.8	93.30^{cde}	92.40^{bc}	-1.0	$0.93e^{f}$	0.78^{ghi}	-16.1
9	PK 8660	$0.53c^{d}$	0.75^{bc}	+41.5	90.80^{ij}	92.90^{a}	+2.3	0.97^{a}	0.87^{a}	-10.3
10	PK8337	0.47^{gh}	0.68^{ghi}	+44.7	91.00^{i}	89.30^{hi}	-1.9	0.92^{gh}	0.82^{de}	-10.9

** WR = Raw Rice*
*** PBR = Parboiled rice*
Means followed by same letter do not differ significantly at 5% level of probability

Table 3. Comparison of nutritional quality parameters among un-parboiled (raw) and parboiled rice samples of all the studied genotypes

Sr.#	Lines/ varieties	Crude protein (%)			Crude fiber (%)			Vitamin B_6		
		WR	PBR	Increase/ decrease	WR	PBR	Increase/ decrease	WR	PBR	Increase/ decrease
1	SUPRA	7.09^{fg}	6.74^{g}	-4.9	0.46^{b}	0.48^{cd}	+4.3	0.31^{b}	2.61^{f}	+727.2
2	99417	6.65^{h}	7.00^{f}	+5.3	0.46^{bc}	0.37^{j}	-19.6	0.07^{hi}	1.86^{hi}	+2315.6
3	Basmati -2000	7.79^{bcd}	7.75^{ab}	-0.5	0.47^{b}	0.46^{e}	-2.1	0.09^{fg}	7.24^{c}	+7862.6
4	PK-8892	6.65^{hi}	7.56^{bc}	+13.7	0.51^{a}	0.42^{h}	-17.6	0.10^{d}	5.30^{e}	+5112.2
5	PS-3	6.48^{hij}	7.79^{a}	+20.2	0.45^{de}	0.49^{a}	+8.9	0.10^{de}	1.02^{j}	+917.8
6	PK 8677a	8.31^{a}	7.44^{cd}	-10.5	0.47^{b}	0.45^{ef}	-4.3	ND	7.44^{b}	+744.0
7	PK 8677b	7.88^{bc}	6.65^{gh}	-15.6	0.38^{f}	0.45^{fg}	+18.4	1.31^{a}	13.17^{a}	+904.4
8	PK 8667	7.53^{e}	6.56^{ghi}	-12.9	0.49^{ab}	0.40^{i}	-18.4	0.09^{gh}	2.00^{h}	+2030.9
9	PK 8660	7.96^{b}	7.35^{de}	-7.7	0.45^{f}	0.49^{ab}	+8.9	0.26^{c}	2.19^{g}	+716.0
10	PK8337	7.26^{f}	6.56^{ij}	-9.6	0.46^{cd}	0.49^{bc}	+6.5	0.10^{ef}	6.79^{d}	+6686.0

** WR = Raw Rice*
*** PBR = Parboiled rice*
Means followed by same letter do not differ significantly at 5% level of probability

level of reduction was also recorded in other varieties. Maximum decrease in crude protein percentage was recorded in line PK8677b (15.6%) while minimum decrease in line Basmati 2000 (0.5%). Padua and Juliano (1974) also reported decrease in protein contents due to parboiling, which may be due to leaching of protein during soaking phase of parboiling as well as rupturing that occurs in molecules during steaming phase. Parboiling makes the protein sink into the compact gelatinized starch grain mass, that makes protein bodies less extractable ultimately decreasing its contents (Chukwu and Oseh, 2009). However, Patindol et al. (2008) concluded that parboiling sparingly changed protein content and the reduction in protein content might be due to the oil and protein that diffuse outward during parboiling, based on microscopic observations, they cannot diffuse as readily through cell walls as water-soluble vitamins.

The findings further showed that in most parboiled samples, crude fiber was decreased and its maximum decrease was observed in line PK8667 (18.4%) whereas minimum in Basmati-2000 (2.1%). Similarly maximum increase of crude fiber percentage was recorded in line PK8677b (18.4%) with minimum in line Supra (4.3%) (Table 3). Collectively, the results indicated that crude fiber was decreased in Basmati-2000, 99417, PK8892, PK8677 and PK8667 and increased in Supra, PS3, PK8677b, PK8660 and PK8337. Sareepuang et al. (2008) also reported significant increase in crude fat, crude protein and crude fiber after parboiling at 50^{0}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 also obtained by Rhao and Juliano (1970). Newton et al. (2011) also found increase in these nutritional indices in parboiled rice samples.

Vitamin B6

Vitamin B6 was considerably increased in all parboiled samples with maximum increase in variety Basmati-2000 (7862%) and minimum in line PK8660 (716%) (Table 3). 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% vitamin B3, 80% vitamin B1, 90% vitamin B6, half of the manganese, half of the phosphorus, 60% iron, and all 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 agrees to the findings of Gariboldi (1973) who reported that during steaming, water soluble vitamins are spread throughout the grain, thus altering their distribution and concentration.

Milling and Cooking Quality Parameters

Significant variation was found among the studied genotypes for these traits. It can be concluded that total milling recovery (TMR%) increased in all the studied samples that showed significant variation among themselves (Table 2). Total milling recovery (TMR%) ranged from 69.6 to 72.5 in raw rice samples with average of 70.66; while in parboiled samples, it ranged from 69.25 to 77.5 with an average of 73.95. Almost all the lines also showed significant increase in cooked grain length when subjected to parboiling. Cherati et al. (2012) while analyzing the parboiling methods, found that fracture or broken percentage and bran percentage decreased while head rice recovery increased after parboiling in Iranian rice in paddy conversion phase. Results clearly emphasizes that bursting of cooked grain was reduced significantly for almost all the genotypes. Head rice recovery (HR%) was also found to increase from 48.56 to 63.87 as an average for all the studied varieties and lines, after parboiling. Curling and bursting percentages were also found decreased after parboiling from 6.87 to 3.91 and from 5.67 to 4.13, respectively. Broken percentage (B%) was significantly reduced after undergoing the samples through parboiling and average Broken% of unparboiled raw rice samples was 19.91; which was reduced to 100 after parboiling the rice samples to the average 10.04 (Table 1). Rao and Juliano (1970) also showed 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 broken percentage. Insect infestation is also reduced due to the hardness.

The study concludes that by using proper techniques of parboiling, nutrition of rice may be conserved within endosperm, even after removal of 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. Moreover, 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, PK8660, PK8892, PK8677b, Basmati-2000 and PK8677a, respectively, were found best for parboiling. Among others, variety Basmati-2000 and lines 99417, PK8892, PS3 and PK8337 were found more responsive to parboiling, respectively. Other lines/varieties showed less suitability to parboiling.

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AUTHORSHIP AND CONTRIBUTION DECLARATION

S. No	Author Name	Contribution to the paper
1.	Dr. Muhammad Akhter	Conducted research, Data analysis and wrote up
2.	Mr. Muhammad Azhar Ali	Conducted research, Data analysis
3.	Mr. Zulqarnain Haider	Conducted research, Statistical work and write up
4.	Dr. Shahzad Muzammil	Conducted research

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