Physico-Chemical Properties of Coarse Rice Cultivars Grown in Different Areas of Punjab and Sindh, Pakistan

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Abstract
Rice (*Oryza sativa L*) is the second largest important cultivated cereal. Rice being an invaluable alternative source of carbohydrate being easily digestible and has rare allergic reactions. Coarse rice is known for its puffing characters and used in many puffed or extruded products. Puffed rice is also very popular in other countries as breakfast cereal and essential component of cereal based snacks. Five coarse rice varieties namely IRRI-9, IRRI-6, KSK-133, KSK-434 and Shadab were milled to obtain brown rice and white rice. Proximate composition revealed that protein, ash, fat and fiber were significantly higher in brown rice than white rice. The length (7.67mm) and width (2.35mm) was higher in KSK-434 whereas higher thickness (2.05mm) was observed in KSK-133. The highest bulk density (0.93g/cm^3) was observed in IRRI-6 whereas IRRI-9 shows lowest (0.88g/cm^3) values. Thousand kernel weight (TKW) was ranged from 15.83 to 20.02g and 18.28 to 22.84g among the milling fractions of white and brown rice, respectively. Thousand kernel weight was found to be higher in KSK-434 followed by Shadab, KSK-133 and the lowest values were observed in IRRI-9. Moisture, ash, fiber, protein, fat and NFE (nitrogen free extract) contents ranged from 9.23 to 12.26g/100g, 0.67 to 3.81g/100g, 0.98 to 4.21g/100g and 6.04 to 8.98g/100g, 1.23 to 5.45g/100g and 65.87 to 80.28g/100g respectively among different milling fractions. The amylose contents for IRRI-9, IRRI-6, KSK-133, KSK-434 and Shadab ranged from 27.07 to 28.25%, 27.55 to 29.78%, 26.48 to 27.96%, 26.80 to 28.98% and 29.03 to 30.88% respectively among different varieties. With respect to amylose, length, thousand kernel weight and bulk density, higher values were observed in KSK-434 and Shadab. Shadab shows best values (higher amylose and lower protein) for extrusion and puffing purposes. Brown rice showed higher nutritional values with respect to protein, fiber, ash (minerals) and fat.
Keywords: Brown rice, White rice, Amylose, Fractions, Coarse rice
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1. Introduction

Rice (*Oryza sativa L.*) is one of the most important food crop feeding more than 2 billion people in Asia. Rice is the staple food of about 50% world population, regardless of lower micronutrient contents (Bhattacharya, 2004). The major rice producing countries of the world are China, Bangladesh, India, Vietnam and Indonesia. It is no longer a luxury food but has become a cereal which constitutes a main source of the calories for rural and urban population (Sasaki and Burr, 2000). Approximately 80% of daily calorie intake of three billion people is provided by rice. Paddy production in the world amounts to 718.35 million metric tons (MMT), out of which more than 90% production is in Asia (Kumar and Prasad, 2013). Pakistan produces about 6 million tonnes rice each year and together with rest of South Asia, supplying 25% paddy rice of the world (Prasad et al., 2010). According to Pakistan Economic Survey 2016-17, rice was cultivated on 2724 thousand hectares and production was 6849 thousand tonnes. It contributes 0.6% of the GDP and 3.0% value added in agriculture. Both fine (40%) and coarse cultivars (60%) are mainly grown in Punjab and Sindh provinces. Among the major rice varieties, Super Basmati, Super Kernal, Kainat, Basmati 515, Pk-386, IRRI-6, IRRI-9, KSK-133, KSK-434, KS-282, Shadab and Shua-92 are cultivated to cater the local needs as well as for export especially to the Middle East.

Rice, being rich in carbohydrates, contributes to about 60-70% of the daily energy needs and approximately 15% protein requirements of the masses. Seed is fully enveloped by the hull that is removed during milling and yielding brown rice. In second stage of milling, outer brown layer called rice bran is removed to produce white rice. Rice bran is composed of rice germ and several sub layers. Rice bran contains over 60% of nutrients found in each seed of rice. Rice is source of minerals like magnesium, calcium and phosphorus but nutritionally low in protein and micronutrients including iron, zinc, manganese, cobalt, *etc.* (Oko and Ugwa, 2011). Today, with advance technology, rice has emerged as an efficient vehicle for fortification. Pakistan produces about 6-7 million tonnes rice each year and together with rest of South Asia, supplying 25% paddy rice of the world (Prasad et al., 2010). Rice has been considered the best starchy staple food among all cereal crops that has high biological value, digestibility and protein efficiency ratio due to presence of higher lysine concentration (~ 4%). Rice starch is digested rapidly as compared with starch of other foods like sweet potato, noodles *etc.* (Frei and Becker, 2003). Rice is extensively used in convenience foods for example puffed, multigrain flakes, breakfast cereals, extruded and popped rice. Cooking and eating properties are generally determined by the characteristics of the rice starch that makes upto 90% of milled rice grain. The consumers are concerned to purchase high quality rice. Other important properties such as amylose content, volume expansion ratio, water absorption ratio and final starch gelatinization temperature also determine cooking and eating qualities of rice (Shabbir et al., 2008). Objective of this study was to characterize popular coarse rice cultivars (IRRI-9, IRRI-6, KSK-133, KSK-434 and Shadab) based on their physico-chemical properties.

2. Materials and Methods

2.1. Sample Collection

Five Pakistani popular coarse rice cultivars (IRRI-9, IRRI-6, KSK-133, KSK-434 and Shadab) were obtained from Rice Research Institute, Kala Shah Kaku, Punjab and Rice Research Institute Dokri, Sindh.

2.2. Milling of Paddy Samples

After drying, paddy was dehulled into brown rice using husker (Satake Rice Husker, Tokyo, Japan). Subsequently, brown rice was converted into white rice and co-products through rice polisher (Satake Rice Polisher, Tokyo, Japan). Furthermore, brown and white rice samples were milled through UDY Cyclone Mill (Cyclotec Sample Mill, Tecator, Sweden) to obtain flour for further analysis.

2.3. Physico-chemical Analysis

The physical characteristics including grain size (length, width and thickness) was measured by using micrometer (Vernier calliper) and thousand kernel weight (TKW) was recorded in g/1000 kernel by counting grains and weighing on an electric balance. Bulk density was determined by the ratio of the mass to a given volume (Park, 2001). The rice samples of each cultivar were analyzed individually in triplicate for moisture (Method No. 44-15 A), ash (Method 08-01), crude fiber (Method 32-10), crude protein (AACC Method 46-10), crude fat (Method 30-10) and NFE (nitrogen free extract) following respective procedures as described in AACC (2000). The amylose content in each rice sample was determined by using Spectrophotometer according to modified method of Juliano (1971) and Hoke et al. (2005).

2.4. Statistical Analysis

The data obtained for each parameter was analyzed statistically to determine the level of significance as described by Steel et al. (1997). Data was measured in triplicate and subjected to analysis of variance (ANOVA). Completely randomized design (CRD) was applied on the data to assess the significance level and differences ($p \leq 0.05$) among the means of treatments showing significant differences.

3. Results and Discussions

3.1. Physical Characteristics

Mean squares for physical characteristics of rice varieties, rice fractions and their interaction showed significant differences ($p \leq 0.05$) with respect to grain size (length, width and thickness), thousand kernel weight (TKW) and bulk density (Table 1). The highest length was observed in brown fraction as compared to white rice. Among the different cultivars, KSK-434 showed highest length (7.67±0.03mm) and width (2.35±0.04mm) whereas the lowest length (6.62±0.04mm) and width (1.76±0.01mm) values were noted in IRRI-9 and IRRI-6 respectively (Table 2). The lowest thickness (1.58±0.05mm) was noted in Shadab. In a study, comparative study of physicochemical properties of mutant rice varieties cultivated in Sindh, selected quality attribute of rice cultivars revealed length ranged from 6.95 to 7.5mm (Ansari et al., 2013). Similarly, in another study, cooking and physicochemical properties of five rice varieties produced in Ohaukwu local government area, length and width ranged from 5.95-7.53mm and 2.17-2.87mm respectively (Chukwuemeka et al., 2015). Likewise, in another study, KSK 133-a high yielding, stiff stemmed and extra long grain coarse rice variety, length (7.07mm), width (2.11mm) and thickness range (1.54-1.79mm) are reported for KSK-133 (Akhtar et al., 2007). In a study, some physical properties of rice seed (*Oryza sativa L*), selected quality attribute of rice cultivars revealed thickness in the range of 2.53-2.75mm (Jouki and Khazaei, 2012).

The brown fraction showed higher thousand kernel weight (TKW) whereas high bulk density was observed in white fraction. Among the different cultivars, KSK-434 showed highest thousand kernel weight (22.84±0.15g) followed by Shadab (21.92±0.16g) and KSK-133 (20.77±0.18g) whereas the lowest value (15.83±0.04g) was noted in IRRI-9 (Table 2). In a study, comparative study of physicochemical properties of mutant rice varieties cultivated in Sindh, selected quality attribute of rice cultivars revealed TKW ranged from 1.73-21.1g (Ansari et al., 2013). IRRI-6 showed highest bulk density (0.93±0.01g/cm^3) whereas the lowest value (0.90±0.01g/cm^3) was noted in KSK-133 (Table 2). In a study, effect of milling variables on the degree of milling of nonparboiled and parboiled rice, selected quality attribute of rice cultivars revealed bulk density ranged from 0.71-0.83g/cm^3 (Singh et al., 2002). The same parameter in another study, effect of parboiling on physico-chemical and cooking attributes of different rice cultivars, bulk density ranged from 0.72-2-0.82g/cm^3 in brown rice and 0.74-0.82g/cm^3 for white rice (Saeed et al., 2011).

3.2. Chemical characteristics

3.2.1. Proximate composition

Mean squares for proximate composition among different rice varieties, rice fractions and their interaction showed significant differences ($p \leq 0.05$) with respect to moisture, ash, crude fiber, crude protein, crude fat and nitrogen free extract (Table 3).

The moisture content varied from 9.23 to 12.26g/100g among rice varieties (Table 2). The highest moisture content was observed in brown fraction as compared to white rice. Among the different cultivars, IRRI-6 showed highest moisture (12.26±0.01g/100g), KSK-434 highest ash (3.81±0.05g/100g), IRRI-9 highest crude fiber contents (4.21±0.05g/100g) and KSK-434 showed highest crude protein contents (8.98±0.01g/100g). Means for crude fat contents showed values ranged from 1.23-4.02g/100g. Among the different cultivars, IRRI-9 showed highest crude fat contents (5.45±0.05g/100g) followed by KSK-434 (4.02±0.01g/100g) and IRRI-6 (3.78±0.01g/100g) whereas the lowest value (1.23±0.05g/100g) was noted in KSK-133 (Table 4). Milled rice crude fat is significantly lower than brown rice fraction due to the removal of bran. The highest NFE content (80.28g/100g) was observed in white fraction as compared to brown rice (65.87g/100g).

The variation in the proximate composition of rice is due to the difference of variety (genetic makeup) and climatic change and differences in different milling fractions was due to degree of severity during milling for the separation of bran. In a study, mineral composition of different rice varieties and their milling fractions, selected quality attribute of rice cultivars revealed moisture, ash, crude fiber and NFE content ranged from 9.19 to 11.10g/100g, 0.54 to 6.04g/100g, 2.17 to 2.57g/100g and 67.75 to 71.43g/100g respectively (Anjum et al., 2007). Likewise, in another study, effect of parboiling on physico-chemical and cooking attributes of different rice cultivars, moisture content ranged from 9.39-12.84g/100g for white rice and 12.10-13.50g/100g for brown rice and crude protein content ranged from 6.82-10.05g/100g in brown rice fraction and 6.08-9.83g/100g in white rice fraction (Saeed et al., 2011). Means for crude protein contents showed values ranged from 7.08-8.45%. Protein negatively effects puffiness of coarse rice varieties containing high amylose contents. In a study, comparative study of nutrient composition of commercial brown, parboiled and milled rice from Brazil, selected quality attribute of rice cultivars revealed crude protein and fat content 9.70g/100g and 1.29g/100g for brown rice and 6.85g/100g and 0.66g/100g for white rice respectively (Heinemann et al., 2005).

3.2.2. Amylose Content (%)

Mean squares for amylose contents of rice varieties, rice fractions and interaction of rice varieties and fractions revealed significant differences ($p \leq 0.05$) with respect to amylose content (Table 5). Means for amylose content showed values ranged from 27.22 to 29.95%. The amylose content was higher (29.17%) in white fraction as compared to brown fraction (27.38%). Among the different cultivars, Shadab showed the highest amylose (30.88%) followed by IRRI-6 (29.78%) and KSK-133 (28.98%) whereas the lowest value (26.48%) was noted in KSK-434 (Table 6). The variation in the amylose content of brown and white rice of some cultivar was might be due to slight differences in degree of milling and presence of bran on brown rice fraction which contain less amylose as compared to endosperm, whereas differences among the varieties were due to genetic variations. In a study, Pakistani rice cultivars showed amylose content ranged from 21.6 to 30.7% (Khurram et al., 2007). Likewise, in another study, cooking and eating characteristics of Rice (*Oryza sativa L.*) were investigated. The amylose content was ranged from 22.90% to 26.19% in brown rice and 24.14% to 25.31% in white rice (Asghar et al., 2012). The amylose content of rice plays an important role in its puffing characteristics. Amylose is composed of linear chain of glucose molecules which align themselves in the shear fields and thus are difficult to pull apart during the extrusion process (Moraru and Kokini, 2003). Since high-amylose content rice varieties are hard to shear, there is a greater chance that pressure will build up during the thermal treatment. This perhaps results in a sudden expansion of the endosperm, making it a highly preferred product as compared to their low amylose content counterparts. It has been observed that highly packed starch molecules have a better ability to expand compared to the loosely packed chalky grains (Kamaraddi et al., 2015).

4. Conclusion

In conclusion, brown rice of all coarse rice cultivars has better nutritional quality as compared with their white rice due to significantly more available nutrients in bran portion. Physiochemical properties are of major importance while developing a variety of rice. These properties include grain size (length, width and thickness), grain weight, protein and amylose contents. Weight of grain gives information about the size and density of grain. The rice grains density effects the cooking quality. So, grain weight should be uniform for netter cooking quality. It is concluded from the present study that Shadab and KSK-434 should get more attention by the rice breeders as these have better physiochemical characteristics (more TKW, length and amylose). It is required to characterize the rice cultivars, so that the knowledge can be used for rice export policies and for developing breeding strategies to increase yield keeping intact their physiochemical characteristic. Timely characterization of rice cultivars, will enhance the export of rice. Government should make polices to export more good quality brown rice in those European countries where the people like brown rice due to its more nutritional value as compared to white.

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Table 1. Mean Squares for Physical Characteristics of brown and white fractions of different rice cultivars

Source of Variations	df	Length	Width	Thickness	TKW	Bulk density
Rice Varieties (V)	4	0.4876**	0.1867**	0.133**	19.65**	0.0017**
Rice Fractions (F)	1	0.8003**	0.1051**	0.127**	34.71**	0.0007**
V*F	4	0.0075*	0.005*	0.005*	0.401**	0.0003**
Error	80	0.00187	0.0012	0.0012	0.0214	0.00001
Total	89					

Note: **= Highly Significant, * = Significant at P≤ 0.05

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Table 2. Effect of rice cultivar on physical Characteristics of brown and white rice fractions of different rice cultivars

Variety	Fraction	Length (mm)	Width (mm)	Thickness (mm)	Bulk density (g/cm$^{3)}$	TKW (g)
IRRI-9	Brown	7.18±0.02	1.96±0.03	1.70±0.04	0.88±0.01	18.28±0.03
	White	6.87±0.03	1.76±0.01	1.61±0.00	0.88±0.05	15.83±0.04
IRRI-6	Brown	6.80±0.07	2.18±0.05	1.78±0.02	0.90±0.02	19.03±0.02
	White	6.62±0.04	2.12±0.05	1.56±0.04	0.93±0.01	17.53±0.17
KSK-434	Brown	7.67±0.03	2.35±0.04	1.90±0.02	0.90±0.02	22.84±0.15
	White	7.25±0.05	2.28±0.02	1.79±0.02	0.91±0.03	20.02±0.07
KSK-133	Brown	7.46±0.05	2.29±0.03	2.05±0.05	0.89±0.03	20.77±0.18
	White	7.16±0.04	2.17±0.04	1.89±0.04	0.90±0.01	18.96±0.18
Shadab	Brown	7.62±0.01	2.10±0.05	1.66±0.05	0.92±0.01	21.92±0.16
	White	7.18±0.02	1.97±0.03	1.58±0.05	0.92±0.02	19.75±0.22

Note: Values are presented as Means±SD; n=9

Table 3. Mean squares for proximate composition of brown and white fractions of different rice cultivars

Source of Variations	df	Moisture	Ash	Fiber	Protein	Fat	NFE
Rice Varieties (V)	4	2.466**	43.54**	0.899**	2.398**	5.284**	37.2**
Rice Fractions (F)	1	10.54**	16.66**	34.56**	17.05**	22.23**	486**
V*F	4	0.545**	0.151**	0.117**	0.240**	0.109**	0.99**
Error	20	0.0003	0.0008	0.0001	0.0005	0.0007	0.003
Total	29						

Note: **= Highly Significant at P≤ 0.05

Table 4. Effect of cultivar on proximate Composition (g/100g) of brown and white rice fractions of different rice cultivars

Variety	Fraction	Moisture	Ash	Fiber	Protein	Fat	NFE
IRRI-9	Brown	12.21±0.05	3.75±0.05	4.21±0.05	8.49±0.02	5.45±0.05	65.87±0.01
	White	11.33±0.05	2.36±0.01	1.63±0.02	7.24±0.01	3.51±0.05	73.91±0.04
IRRI-6	Brown	12.26±0.01	3.46±0.01	3.77±0.05	8.27±0.05	3.78±0.01	68.60±0.02
	White	10.25±0.01	1.86±0.05	1.68±0.05	6.73±0.06	2.02±0.01	76.63±0.07
KSK-434	Brown	11.26±0.01	3.81±0.05	3.21±0.05	8.98±0.01	4.02±0.01	68.70±0.07
	White	09.23±0.01	1.88±0.01	0.98±0.05	7.92±0.01	2.06±0.01	77.92±0.02
KSK-133	Brown	11.03±0.02	1.73±0.05	3.06±0.05	8.28±0.01	2.53±0.07	73.36±0.11
	White	10.57±0.01	0.67±0.01	1.08±0.05	6.16±0.01	1.23±0.05	80.28±0.05
Shadab	Brown	12.09±0.02	2.10±0.01	3.58±0.01	8.13±0.05	3.57±0.05	68.42±0.02
	White	11.06±0.03	1.16±0.01	1.73±0.01	6.04±0.01	1.92±0.05	76.47±0.30

Note: Values are presented as Means±SD; n=3

Table 5. Mean squares for amylose content of brown and white fractions of different rice cultivars

Source of Variations	df	Amylose
Rice Varieties (V)	4	6.92**
Rice Fractions (F)	1	23.9**
V*F	4	0.30**
Error	20	0.001
Total	29	

Note: **= Highly Significant at P≤ 0.05

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Table 6. Effect of cultivar on amylose (%) of brown and white rice fractions of different rice cultivars

Variety	Fraction	Amylose
IRRI-9	Brown	27.07±0.01
	White	28.25±0.01
IRRI-6	Brown	27.55±0.01
	White	29.78±0.05
KSK-434	Brown	26.48±0.01
	White	27.96±0.05
KSK-133	Brown	26.80±0.10
	White	28.98±0.01
Shadab	Brown	29.03±0.05
	White	30.88±0.01

Note: Values are presented as Means±SD; n=3