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Physical Characterisation of Brown and White Fractions of Approved Rice Varieties of Pakistan

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Abstract. This study was carried out to assess the quality attributes of rice varieties named as Super Kernel, Super Basmati, Basmati-515, PK-386, Kainat and IRRI-9 after milling for the establishment of claimed standards for approved varieties to prohibit rice adulteration. Furthermore, brown and white fractions of selected varieties were evaluated for physical characteristics including grain size (grain length/grain width ratio) thousand kernel weight (TKW) and bulk density. Mean values for grain size (L/W ratio), bulk density and TKW were ranged from 3.86±0.30 to 4.59±0.32, 0.71±0.08 to 0.80±0.10g/mL and 16.74±1.18 to 17.96±0.85g among the rice cultivars. Overall, grain size (4.00±0.21 to 4.48±0.35 and 4.14±0.43 to 4.81±0.37), bulk density (0.66±0.05 to 0.72±0.09g/mL and 0.77±0.05 to 0.82±0.27g/mL) and TKW (18.00±0.48 to 19.22±0.35g and 15.91±0.84 to 16.78±0.32g) varied significantly in brown and white rice samples. The lowest decrease in length after milling was seen in white rice of Kainat (8.90%) followed by PK-386 (9.86%) and Basmati-515 (10.70%), while the IRRI-9 showed highest decrease (11.84%) as compare to brown rice. Likewise, lowest increase in width was observed in IRRI-9 (10.27%) as compared to Kainat (19.87%) which indicates that IRRI-9 had more width. Conclusively, grain dimensions, kernel weight and bulk density of both brown and white rice fractions were significantly influenced by genetic, environmental and socio-economic factors among locations and cultivars. There is an urgent need to discriminate among premium and local rice varieties of country to boost up the export and foreign earnings.

Keywords: rice varieties, grain size, kernel weight, bulk density

Introduction

Rice (*Oryza sativa* L.) is a leading food crop usually consumed as intact grain after cooking in Asian countries including India, Bangladesh and Pakistan. It contributes 40 to 80% of total energy requirements among Asians as well as feeds a large portion of population across the world (Cai *et al.,* 2011). Rice is a major crop in Pakistan after wheat in terms of consumption with a production of 6.90 million tonnes rice (GOP, 2017). A wide range of fine and coarse rice varieties are cultivated in Punjab and Sindh. Physicochemical and cooking attributes of rice have gained highest priority owing to its importance among cereals (Dong *et al.,* 2007). Grain size, thousand kernel weight (TKW) and bulk density are the main physical assessment tests for the quick determination of their suitable uses. Shape and size of individual rice grain was very essential for eating and cooking purpose (Thomas *et al.,* 2013). Variations in physical characteristics are mainly due to rice type, origin, genetic as well as environmental elements. Rice quality and consumer preferences are also influenced by all the above mentioned factors along with its cooking behaviour (Moongngarm, 2010). Knowledge regarding morphological characteristics of rice is necessary for the sufficient structure of drying, aerating, grading and storing equipment, processing and milling conditions, storage and nature of product (Ashtiani- Araghi *et al.,* 2010). It was reported that milling operations were designed according to crop properties (Yadav and Jindal, 2008). According to previous studies, the highest grain size (3.75) was recorded in white rice samples as compared to brown rice (2.09), respectively. Similarly, brown rice had highest weight (18.66g) followed by white grains (16.97g) of the same variety. Bulk density was found to be more in brown fraction (Bagheri *et al.,* 2013).

Physical assessment of rice grains is also a quality index which is based on parameters like degree of milling, head rice percentage, chalkiness, broken grain, grain length and width, colour, texture and TKW. After

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secondary milling, information regarding grain type and quality is needed for further analysis at next stages of product development (Shantaiya and Ansari, 2010). Inspection of varietal purity is one of the key elements that make scrutiny of the process more problematic and complex as compared to other factors. There is a little information on the milling as well as physical properties of rice varieties. Adulteration in rice (*Oryza sativa*) has become a matter of concern in recent years which is hindering the trade of millions of paddy as well as milled rice. Therefore, certification of standards for the approved rice varieties of country is required by rice research institutes. In this context, present study was conducted to determine the physical characteristics of the brown and white fractions of promising Pakistani rice varieties such as grain size, TKW and bulk density.

Materials and Methods

Procurement of samples. Six varieties of freshly harvested rice including Kainat, PK-386, Super Kernel, Super Basmati, Basmati-515 and IRRI-9 were selected to procure from seven different districts of the Punjab Province, Pakistan during the year 2016. Gujranwala, Hafizabad, Mandi Bahauddin, Sialkot, Jhang and Bahawalnagar as well as Rice Research Institute, Kala Shah Kaku were the locations allocated for collection of paddy samples. All analytical and chemical reagents were purchased from Merck and Sigma-Aldrich.

Preparation of samples. After manual cleaning of impurities, paddy samples were sun dried for 2 days to preserve its moisture contents at 12% which was 22-24% after harvesting followed by milling. Milling was performed by using laboratory scale De-husker (Husker THU358, Satake Corporation, Higashi-Hiroshima, Japan) for the removal of husk to obtain raw brown rice. Afterwards, Abrasive Polisher (NNCXN915207, Satake Corporation, Higashi, Hiroshima, Japan) was employed to separate the bran portion to get white milled rice. Both the rice fractions, brown and white grains were packed in polythene bags and stored for further analysis.

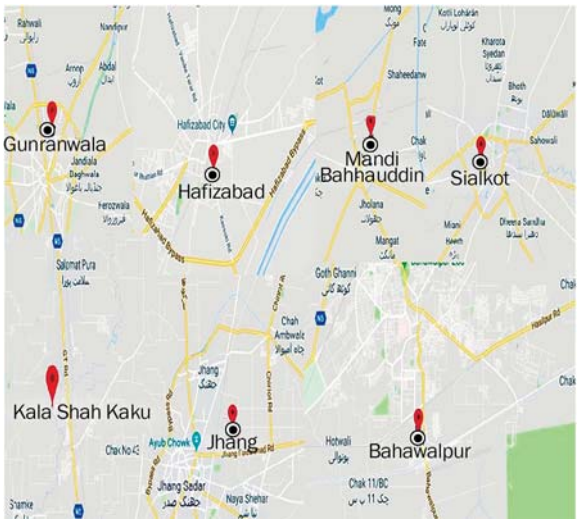

Fig. 1. Map of sampling areas under study.

Fig. 2. Sample of brown and white rice fraction.

Physical assessment. Physical characters of brown and white rice grains were evaluated by measuring their length, width and length to width ratio (grain size) using the appropriate Vernier Caliper. Other tests including thousand kernel weight and bulk density were determined by their respective procedures as described by Singh *et al*. *(*2005).

Grain size (length width ratio). Ten grains of each brown and white rice variety were taken randomly from the test samples after cleaning and grading. Length (L) and width (W) were measured by using micrometer (Vernier Caliper). Length to width ratio (L/W) of brown and white rice kernels were determined following the procedure of Thomas *et al.* (2013). Based on the length to width ratio, the grain size of the milled rice was determined.

$$\text{Grain size} = \frac{\text{Average grain length of milled rice}}{\text{Average grain width of milled rice}} \times 100$$

Based on the L/W ratio, grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB).

Table 1. Means for grain length (mm) of brown and white rice fractions of different cultivars collected from various locations.

Locations	F	Varieties						Mean±SD
		Super Kernel	Super Basmati	Basmati -515	PK-386	Kainat	IRRI-9	
KSK	B	8.62±0.25	8.87±0.50	8.50±0.25	8.10±0.27	9.00±0.52	8.00±0.50	8.51±0.40ab
	W	7.70±0.47	7.83±0.28	7.64±0.50	7.43±0.25	8.20±0.39	7.28±0.30	7.68±0.32efg
MB	B	8.57±0.20	8.81±0.48	8.44±0.20	8.06±0.20	8.80±0.50	7.95±0.55	8.43±0.36abc
	W	7.67±0.33	7.78±0.20	7.60±0.39	7.32±0.30	8.11±0.40	7.17±0.28	7.60±0.33efgh
SKT	B	8.60±0.10	8.70±0.40	8.48±0.10	8.09±0.20	8.84±0.55	8.00±0.47	8.45±0.33abc
	W	7.71±0.25	7.80±0.25	7.65±0.40	7.40±0.27	8.16±0.34	7.21±0.20	7.65±0.32fghi
GJW	B	8.52±0.17	8.84±0.50	8.39±0.28	8.00±0.25	8.70±0.46	7.96±0.42	8.40±0.36bcd
	W	7.63±0.36	7.72±0.15	7.53±0.35	7.35±0.21	8.00±0.20	7.10±0.37	7.55±0.31ghij
HFZ	B	8.40±0.25	8.68±0.55	8.35±0.12	8.05±0.20	8.75±0.29	7.91±0.50	8.35±0.33cde
	W	7.65±0.20	7.68±0.25	7.57±0.24	7.28±0.25	8.02±0.37	7.04±0.29	7.54±0.34ghi
JHG	B	8.37±0.18	8.60±0.40	8.28±0.19	7.96±0.21	8.56±0.50	7.88±0.50	8.27±0.30cdef
	W	7.57±0.30	7.62±0.20	7.48±0.43	7.23±0.20	7.89±0.44	6.95±0.21	7.45±0.32hijk
BWN	B	8.32±0.25	8.54±0.50	8.23±0.20	7.90±0.15	8.51±0.55	7.84±0.40	8.22±0.29gcdef
	W	7.51±0.42	7.60±0.28	7.43±0.50	7.12±0.27	7.73±0.46	6.91±0.20	7.38±0.30hijk
Mean±SD		8.06±0.38c	8.21±0.22b	7.96±0.11d	7.66±0.40e	8.37±0.36a	7.51±0.31f	

Means carrying same letters in a column are statistically non-significant (p>0.05); Means±S.D; KSK= Kala Shah Kaku; MB = Mandi Bahauddin; SKT = Sialkot; GJW = Gujranwala; HFZ = Hafizabad; JHG = Jhang; BWN = Bahawalnagar.

Thousand kernel weight. 50g intact brown and white rice kernels (1000) of all varieties from the test samples were counted and weighed(g/1000 kernel) on an electric balance by following the methods described by Singh *et al.* (2005) and Thomas *et al.* (2013).

Bulk density. Brown and white rice grains were evaluated for bulk density according to procedure stated by Singh *et al.* (2005). A graduated cylinder having 50mL volume was taken. 50g rice grains from the representative sample were added in the graduated cylinder of known volume (50mL) and note the volume occupied by rice grains in the cylinder. Bulk density (g/mL) was calculated from the ratio of given mass of rice grains to its volume.

Statistical analysis. Documented software Statistix 8.1 was used for the estimation of obtained data statistically under three factor factorial completely randomized design (ANOVA). Mean values in triplicates were analyzed and compared through Tukey,s Honestly Significance test (Steel *et al.,* 1997).

Results and Discussion

Grain length, grain width, grain size, TKW and bulk density were significantly varied among locations, varieties and their milling fractions ($p \leq 0.05$).

Grain length. Means for grain length of different among different rice cultivars showed values ranged from 8.37±0.36 to 7.51±0.31mm (Table 1). The maximum length (8.37±0.36mm) was observed in Kainat followed by 8.21±0.22mm in Super Basmati and Super Kernel (8.06±0.38mm), respectively. The minimum length was noted in IRRI-9 (7.51±0.31mm) followed by PK-386 (7.66±0.40mm) and Basmati-515 (7.96±0.11mm). As concerned for brown and white fractions, the maximum length was seen in brown and white fractions of Kainat (9.00±0.52mm and 8.20±0.39mm) followed by Super Basmati (8.87±0.50mm and 7.83±0.28mm) and Super Kernel (8.62±0.25mm and 7.70±0.47mm) whereas minimum length was in IRRI-9 (8.00±0.50mm and 7.28±0.30mm) followed by PK-386 (8.10±0.27mm and 7.43±0.25mm) and Basmati-515 (8.50±0.25mm and 7.64±0.50mm), respectively. Among the brown fraction from different districts, rice cultivars of Kala Shah Kaku showed the maximum length (8.51±0.40mm) followed by Sialkot (8.45±0.33mm) and Mandi Bahauddin (8.43±0.36mm) whereas minimum length was found in rice samples of Bahawalnagar (8.22±0.29mm) followed by Jhang (8.27±0.30mm) and Hafizabad (8.35±0.33mm). Likewise, similar trend was observed in white rice fractions grown in Kala Shah Kaku. Overall, grain length was ranged from 8.51±0.40 to 8.22±0.29mm

and 7.68±0.32 to 7.38±0.30mm, respectively in brown and white rice samples.

Grain width. Means for grain width among different rice cultivars revealed values ranged from 1.76±0.20 to 1.95±0.54mm (Table 2). The maximum width (1.95±0.54mm) was observed in IRRI-9 followed by 1.85±0.15mm in PK-386 and Kainat (1.83±0.23mm), respectively. The minimum width was noted in Super Kernel (1.76±0.20mm) followed by Basmati-515

Table 2. Means for grain width (mm) of brown and white rice fractions of different cultivars collected from various locations.

Locations	F	Varieties						Mean±SD
		Super Kernel	Super Basmati	Basmati -515	K-386	Kainat	IRRI-9	
KSK	B	1.72±0.24	1.89±0.13	1.89±0.21	1.94±0.07	2.00±0.16	1.99±0.10	1.90±0.10f
	W	1.51±0.16	1.51±0.19	1.59±0.24	1.60±0.20	1.63±0.20	1.75±0.17	1.59±0.09jkl
MB	B	1.78±0.22	1.90±0.26	1.90±0.10	1.95±0.18	2.05±0.10	2.01±0.20	1.93±0.10cde
	W	1.54±0.18	1.55±0.05	1.62±0.19	1.64±0.10	1.65±0.12	1.77±0.28	1.62±0.08jk
SKT	B	1.87±0.05	1.92±0.11	1.93±0.14	1.97±0.13	1.97±0.17	2.05±0.19	1.95±0.06cd
	W	1.57±0.17	1.62±0.15	1.65±0.15	1.66±0.20	1.64±0.21	1.80±0.23	1.65±0.07j
GJW	B	1.96±0.11	1.97±0.19	1.90±0.28	2.01±0.10	2.00±0.18	2.00±0.20	1.97±0.04abc
	W	1.62±0.24	1.70±0.20	1.70±0.21	1.70±0.15	1.68±0.10	1.85±0.25	1.70±0.07hi
HFZ	B	1.90±0.50	2.00±0.19	1.92±0.19	2.05±0.12	1.98±0.11	2.06±0.23	1.98±0.06abc
	W	1.68±0.17	1.71±0.26	1.68±0.12	1.72±0.10	1.69±0.10	1.88±0.11	1.72±0.07hi
JHG	B	2.00±0.20	2.03±0.10	1.97±0.32	2.00±0.10	1.99±0.28	2.10±0.21	2.01±0.04ab
	W	1.71±0.12	1.80±0.50	1.71±0.17	1.79±0.22	1.67±0.10	1.92±0.18	1.76±0.09h
BWN	B	2.02±0.1	2.06±0.22	2.00±0.19	2.09±0.10	2.00±0.10	2.12±0.15	2.04±0.05a
	W	1.78±0.05	1.86±0.10	1.71±0.15	1.87±0.11	1.70±0.24	2.00±0.18	1.82±0.11g
Mean±SD		1.76±0.20f	1.82±0.28d	1.80±0.17e	1.85±0.15b	1.83±0.23c	1.95±0.54a	

Means carrying same letters in a column are statistically non-significant (p>0.05); Means±S.D; KSK= Kala Shah Kaku; MB = Mandi Bahauddin; SKT = Sialkot; GJW = Gujranwala; HFZ = Hafizabad; JHG = Jhang; BWN = Bahawalnagar.

Table 3. Means for grain size of brown and white rice fractions of different cultivars collected from various locations.

Locations	F	Varieties						Mean±SD
		Super Kernel	Super Basmati	Basmati -515	PK-386	Kainat	IRRI-9	
KSK	B	5.01±0.10	4.69±0.10	4.49±0.10	4.17±0.28	4.50±0.21	4.02±0.17	4.48±0.35d
	W	5.09±0.13	5.18±0.19	4.80±0.10	4.64±0.10	5.03±0.15	4.16±0.10	4.81±0.37a
MB	B	4.81±0.10	4.63±0.24	4.44±0.11	4.13±0.19	4.29±0.19	3.95±0.10	4.37±0.31ef
	W	4.98±0.10	5.01±0.12	4.69±0.10	4.46±0.17	4.91±0.12	4.05±0.16	4.68±0.35b
SKT	B	4.59±0.15	4.53±0.26	4.39±0.15	4.10±0.10	4.48±0.14	3.90±0.14	4.33±0.27efg
	W	4.91±0.10	4.81±0.21	4.63±0.10	4.45±0.26	4.97±0.13	4.00±0.23	4.62±0.36bc
GJW	B	4.34±0.17	4.54±0.16	4.41±0.20	3.98±0.10	4.35±0.18	3.98±0.17	4.26±0.23h
	W	4.70±0.10	4.34±0.12	4.42±0.10	4.32±0.22	4.76±0.11	3.84±0.10	4.39±0.32ef
HFZ	B	4.42±0.18	4.50±0.15	4.34±0.17	3.92±0.14	4.41±0.16	3.83±0.10	4.23±0.28i
	W	4.55±0.14	4.23±0.19	4.50±0.26	4.23±0.23	4.74±0.16	3.74±0.11	4.33±0.35e
JHG	B	4.18±0.10	4.23±0.11	4.20±0.22	3.98±0.10	4.30±0.12	3.75±0.15	4.10±0.20l
	W	4.42±0.28	4.14±0.10	4.37±0.29	4.03±0.25	4.72±0.20	3.61±0.10	4.21±0.38j
BWN	B	4.11±0.10	4.08±0.19	4.11±0.19	3.77±0.10	4.25±0.10	3.70±0.19	4.00±0.21m
	W	4.21±0.12	4.53±0.10	4.34±0.10	3.80±0.10	4.54±0.10	3.45±0.19	4.14±0.43k
Mean±SD		4.59±0.32a	4.54±0.14b	4.44±0.11d	4.14±0.28e	4.51±0.19c	3.86±0.30f	

Means carrying same letters in a column are statistically non-significant (p>0.05); Means±S.D; KSK= Kala Shah Kaku; MB = Mandi Bahauddin; SKT = Sialkot; GJW = Gujranwala; HFZ = Hafizabad; JHG = Jhang; BWN = Bahawalnagar.

(1.80±0.17mm) and Super Basmati (1.82±0.28mm). Among the varieties, maximum width was seen in brown and white fraction of IRRI-9 (2.12±0.10mm and 2.00±0.10mm) followed by PK-386 (2.09±0.10mm and 1.87±0.11mm) and Super Basmati variety (2.06±0.10mm and 1.86±0.10mm) whereas minimum width was in Kainat (2.00±0.10 mm and 1.70±0.10 mm) followed by Basmati-515 (2.00±0.10mm and 1.71±0.10mm) and Super Kernel (2.02±0.10mm and 1.78±0.05mm), respectively.Regarding brown rice fractions, from different districts, rice cultivars of Bahawalnagar showed the maximum width (2.04±0.05mm) followed by Jhang (2.01±0.04mm) and Hafizabad (1.98±0.06mm) whereas minimum width (1.90±0.10mm)was found in rice samples of Kala Shah Kaku followed by Mandi Bahauddin (1.93±0.10mm) and Sialkot (1.95±0.06mm). Similar tendency of grain width was noticed in white rice fractions from these locations. Overall, width was ranged from 1.90±0.10 to 2.04±0.05mm and 1.59±0.09 to 1.82±0.11mm, respectively in brown and white rice samples.

Grain size. Means for grain size (L/W ratio) of different rice cultivars revealed values ranged from 3.86±0.30 to 4.59±0.32 (Table 3). The maximum grain size (4.59±0.32) was observed in Super Kernel followed by 4.54±0.14 in Super Basmati and Kainat (4.51±0.19), respectively. However, the minimum grain size was noted in IRRI-9 (3.86±0.30) followed by PK-386 (4.14±0.28). Among the brown rice fractions of different districts, rice cultivars from Bahawalnagar showed the minimum grain size (4.00±0.21) followed by Jhang (4.10±0.20) and Hafizabad (4.23±0.28).Likewise, in white fractions, the minimum grain size (4.14±0.43)was seen in samples collected from Bahawalnagar and Jhang (4.21±0.38). Overall, grain size was ranged from 4.00±0.21 to 4.48±0.35 and 4.14±0.43 to 4.81±0.37, respectively in brown and white rice samples. The variation in the length and width of brown and white rice of cultivars might be due to slight differences in degree of milling and presence of bran on brown rice, whereas differences among the varieties were due to different grain dimensions (size and shape), geological conditions and farming practices on field (Verma *et al.,* 2013).Super Basmati and Basmati-515 are classified as extra long grain having 7.45 and 7.38mm length as well as 1.62 and 1.65mm width whereas IRRI-9 has shorter in length (6.93mm) and more width (1.69mm), respectively (RRI, 2011). Pakistani Basmati rice varieties possessed average grain length i.e.>7.30mm. Grain kernal length among brown fraction of Basmati and coarse varieties were ranged from 7.31-7.43mm and 6.37-6.48mm, respectively (Shabbir, 2008). According to various studies, there was a wide variation in the grain length (3.6 to 6.5mm) and width (1.7 to 3.7mm) in Pakistani rice cultivars (Dipti *et al.,* 2002). Means for grain length and width showed variation among aromatic varieties (4.30 to 7.80mm; 1.54 to 1.88mm), pigmented brown rice (8.31 to 8.65mm; 3.00 to 3.04mm) and indigenous Indian aromatic varieties (4.90 to 12.40mm; 1.80 to 3.50mm), respectively grown in different countries (Meena *et al*., 2010; Mir *et al.*, 2013; Santhi and Vijayakumar, 2014). Slender shape of rice grain had more L/W ratio (3.51mm) as compared to medium shape grains (2.69mm) among the imported rice samples (Fofana *et al.,* 2011; Odenigbo *et al.,* 2014). According to IRRI, L/W ratio of rice grain was classified into 4 categories including slender (>3.00mm), medium (2.1-3mm), bold (1.1-2.1mm) and round grain (<1.00mm), respectively (IRRI, 1980). Twelve paddy samples of Basmati and coarse varieties were collected from Rice Research Institute, Kala Shah Kaku and Dokri. Length among basmati varieties ranged from 6.2-7.3mm whereas for coarse one 5.8-7.00mm, respectively (Sagar *et al.,* 1988).Coarse varieties possessed higher grain width (1.96 to 2.11mm) as compared to basmati rice i.e., 1.67 to 1.79 in brown fraction(Shabbir, 2008). Similarly, width among Indian brown rice samples was ranged from 2.02 to 3.00mm.The width of different Canadian rice varieties exhibited slight variations and ranged from 1.84mm, whereas nonsignificant differences were observed in length to width ratio which might be due to similarity in grain size dimensions. Physical properties of some Iranian rice seeds like length (7.43mm) and width (2.53mm) were noted (Jouki and Khazaei, 2012).Likewise, width among 10 Indian aromatic rice varieties ranged from 1.72 to 2.18mm (Subudhi *et al.,* 2012). Twelve paddy samples of Basmati and coarse varieties were collected from Rice Research Institute, Kala Shah Kaku and Dokri. Width among basmati varieties ranged from 1.6-1.8mm whereas for coarse one 1.6-3.00mm, respectively (Sagar *et al.,* 1988).

There was significant difference in length (6.20 to 8.32mm), width (1.51 to 3.10mm) and L/W ratio (3.93 to 4.80) among six Indian basmati rice samples (Bhonsle and Sellappan, 2010). Likewise, L/W ratio ranged from 2.25 to 4.25mm in Basmati varieties (Subudhi *et al.,* 2013). Twelve paddy samples of Basmati and coarse

varieties were collected from Rice Research Institute Kala Shah Kaku and Dokri. L/W ration among basmati varieties ranged from 3.7-4.6 whereas, for coarse one 1.9-4.00, respectively.The highest L/W ratio was found in white rice varieties (4.75) whereas, lowest values were observed in brown rice samples (2.09) collected from different locations (Thomas *et al.,* 2013; Falade *et al*., 2014). There was significant difference in L/W ratio (1.51 to 3.60) of all the samples (Mestres *et al.,* 2011).

Thousand kernel weight(TKW). Means for TKW showed values ranging from 16.74±1.18 to 17.96±0.85g

Table 4. Means for thousand kernel weight (g) of brown and white rice fractions of different cultivars collected from various locations.

Locations	F	Varieties						Mean±SD
		Super Kernel	Super Basmati	Basmati -515	PK-386	Kainat	IRRI-9	
KSK	B	19.85±1.10	18.08±1.50	19.81±0.78	18.62±1.00	19.04±1.50	19.29±1.18	19.14±0.70c
	W	17.15±2.00	16.82±0.40	15.15±1.30	14.84±1.10	16.38±1.10	16.72±1.23	16.17±0.95j
MB	B	18.67±0.80	19.56±1.19	18.50±1.40	19.60±1.30	18.21±1.58	19.05±1.11	18.94±0.56d
	W	16.72±1.50	16.34±0.10	16.54±1.00	15.31±1.11	15.40±2.00	16.44±1.00	16.12±0.61k
SKT	B	19.11±1.33	18.25±1.34	18.76±1.36	19.03±1.50	19.57±1.46	19.73±1.21	19.22±0.35a
	W	17.00±1.50	17.00±0.70	16.92±1.20	16.56±1.20	16.22±1.20	17.02±2.00	16.78±0.32h
GJW	B	18.00±0.69	18.78±1.28	19.20±1.43	18.48±1.16	18.77±1.17	19.20±0.80	18.47±0.49e
	W	16.88±1.16	16.86±0.50	15.67±1.00	15.14±1.26	14.86±1.60	17.11±1.00	16.08±0.98l
HFZ	B	19.40±1.23	19.60±1.50	18.45±1.24	19.00±1.00	19.39±1.05	18.91±1.30	19.17±0.33b
	W	16.14±1.50	16.49±0.50	16.78±1.36	16.51±1.60	16.29±1.48	16.57±1.00	16.46±0.22i
JHG	B	18.62±1.52	18.61±1.47	19.10±1.30	17.28±1.10	18.82±1.26	17.95±1.57	18.27±0.63f
	W	16.29±1.00	16.11±0.50	16.65±1.00	14.56±1.30	15.81±1.00	16.90±2.00	16.05±0.70m
BWN	B	17.87±0.76	17.09±1.00	18.50±1.08	17.51±1.26	17.95±1.30	18.46±1.29	18.00±0.48g
	W	16.48±2.20	15.78±0.43	15.86±1.70	15.83±1.50	14.67±1.12	17.23±1.67	15.91±0.84n
Mean±SD		17.96±0.85a	17.91±2.20b	17.65±1.00c	17.03±2.00e	16.74±1.18f	17.60±2.45d	

Means carrying same letters in a column are statistically non-significant (p>0.05); Means±S.D; KSK= Kala Shah Kaku; MB = Mandi Bahauddin; SKT = Sialkot; GJW = Gujranwala; HFZ = Hafizabad; JHG = Jhang; BWN = Bahawalnagar.

Table 5. Means for bulk density (g/mL) of brown and white rice fractions of different cultivars collected from various locations.

Locations	F	Varieties						Mean±SD
		Super Kernel	Super Basmati	Basmati -515	PK-386	Kainat	IRRI-9	
KSK	B	0.72±0.08	0.70±0.09	0.67±0.10	0.71±0.08	0.69±0.05	0.70±0.09	0.70±0.03fgh
	W	0.80±0.09	0.77±0.08	0.75±0.05	0.85±0.04	0.78±0.08	0.79±0.08	0.79±0.03cde
MB	B	0.70±0.04	0.69±0.05	0.65±0.09	0.66±0.11	0.70±0.04	0.68±0.08	0.69±0.03ghi
	W	0.81±0.05	0.75±0.09	0.77±0.06	0.84±0.09	0.79±0.09	0.79±0.09	0.79±0.03cde
SKT	B	0.75±0.04	0.65±0.05	0.60±0.07	0.70±0.06	0.65±0.07	0.65±0.07	0.66±0.05hij
	W	0.84±0.05	0.72±0.08	0.75±0.04	0.72±0.08	0.76±0.05	0.78±0.09	0.77±0.05efg
GJW	B	0.70±0.08	0.68±0.05	0.63±0.09	0.73±0.04	0.66±0.08	0.67±0.07	0.67±0.03hij
	W	0.79±0.07	0.76±0.10	0.79±0.05	0.79±0.07	0.78±0.07	0.79±0.08	0.78±0.04cde
HFZ	B	0.73±0.10	0.70±0.09	0.65±0.08	0.72±0.10	0.65±0.07	0.69±0.05	0.69±0.03ghi
	W	0.82±0.04	0.80±0.05	0.83±0.06	0.85±0.09	0.78±0.09	0.77±0.06	0.80±0.04abc
JHG	B	0.72±0.05	0.72±0.10	0.66±0.09	0.71±0.04	0.68±0.08	0.70±0.04	0.70±0.02fgh
	W	0.84±0.05	0.84±0.09	0.79±0.03	0.81±0.06	0.79±0.06	0.74±0.05	0.81±0.04ab
BWN	B	0.74±0.08	0.69±0.08	0.69±0.09	0.72±0.08	0.70±0.07	0.72±0.09	0.72±0.09fgh
	W	0.77±0.10	0.78±0.06	0.80±0.06	0.82±0.05	0.82±0.09	0.85±0.11	0.82±0.27a
Mean±SD		0.77±0.05b	0.74±0.19d	0.71±0.08e	0.80±0.10a	0.76±0.09c	0.74±0.23d	

Means carrying same letters in a column and row are statistically non-significant (p>0.05); Means±S.D; KSK= Kala Shah Kaku; MB = Mandi Bahauddin; SKT = Sialkot; GJW = Gujranwala; HFZ = Hafizabad; JHG = Jhang; BWN = Bahawalnagar.

(Table 4). The highest TKW (17.96 ± 0.85g) was observed in Super Kernel followed by 17.91 ± 2.20g in Super Basmati. The lowest TKW was observed in Kainat (16.74 ± 1.18g) followed by PK-386 (17.03 ± 2.00g). Among the brown fractions collected from different districts, rice from Sailkot showed the highest TKW (19.22 ± 0.35g) followed by Hafizabad (19.17 ± 0.33g) and Kala Shah Kaku (19.14 ± 0.70g) whereas the lowest was found in samples of Bahawalnagar (18.00 ± 0.48g) and Jhang (18.27 ± 0.63g). Similar, tendency of TKW was noticed in their white counterpart. Among the brown and white rice fractions, the maximum TKW was noted in brown samples (18.0 0 ± 0.48 to 19.22 ± 0.35g) as compared to white rice (15.91 ± 0.84 to 16.78 ± 0.32g). TKW was more in brown rice due to presence of bran layer which contains protein, fibre and fat contents. Variation among varieties might be due to differences in their genetic makeup and agro climatic conditions of the specific region (Shabbir, 2008). TKW decreased with the increased processing level that convert brown into white rice (Varnamkhasti *et al*., 2008). It is an indication of seed size of rice cultivars. It can significantly differ among varieties, within variety, cropping year and area because of variations in seed size due to variable number of plants in a field (Nalladulai *et al*., 2002).Among brown fraction, TKW was more in Pakistani coarse varieties like IRRI-6 (18.03g) and KS-282 (17.53g) as compared to Super Basmati (17.35g) and Basmati-2000 (17.07g), respectively. In numerous studies, TKW was ranging from 18.81 to 22.92g in brown fraction as well as 20.17 to 25.63g in white samples (Verma *et al.,* 2015).

Bulk density. Mean values for bulk density of various rice cultivars showed values ranged from 0.71±0.08 to 0.80 ± 0.10g/mL(Table 5). The highest bulk density (0.80 ± 0.10g/mL) was observed in PK-386 followed by 0.77 ± 0.05g/mL in Super Kernel and Kainat (0.76 ± 0.09g/mL) whereas the lowest value was found in Basmati-515 (0.71 ± 0.08g/mL). The brown rice fraction from Bahawalnagar showed the highest bulk density (0.72 ± 0.09g/mL) followed by Jhang (0.70 ± 0.02g/mL) whereas the lowest (0.66 ± 0.05g/mL) was found in brown samples of Sialkot followed by Gujranwala (0.67 ± 0.03g/mL). Likewise, in white fractions, the highest bulk density (0.82 ± 0.27g/mL) was seen in samples from Bahawalnagar followed by Jhang (0.81 ± 0.04g/mL) while the lowest was found in Sialkot samples (0.77 ± 0.05g/mL).Overall, bulk density was ranged from 0.66 ± 0.05 to 0.72 ± 0.09g/mL and 0.77 ± 0.05 to 0.82 ± 0.27g/mL, respectively in brown and white rice samples among all the locations. Among fractions, maximum bulk density was noted in white samples which was due to absence of bran layer as well as lower weight of grain after processing of brown rice. More the test weight, lower will be the bulk density. For the purpose of proper grain handling and storage, silos of specific size were designed based on the bulk density of grains (Siddiqui *et al.,* 2007). Bulk density was ranged from 0.73 to 0.86g/mL among rice samples (Chapagai *et al.,* 2017).

Conclusion

Axial dimensions of rice varieties were significantly different among brown and white grains resulted in varied weight and bulk density. Long grain varieties were more subjected to breakage during milling. Milling of rice was done at lower polishing duration, optimum temperature and moisture contents for improved grain quality and performance of de-husker and polisher. Good milling quality is considered significant to meet the interests of both consumers and rice millers. The foul practices like adulteration or admixing of premium Basmati cultivars with inferior varieties lower the export potential of pure varieties should be controlled through legislation.

References

Ashtiani-Araghi, H., Sadeghi, M., Hemmat, A. 2010. Physical properties of two rough rice varieties affected by moisture content. *International Agrophysics,* **24:** 205-207.

Bagheri, I., Alizadeh, M.R., Safari, M. 2013. Varietal differences in physical and milling properties of paddy grains. *International Journal of Agriculture Crop Sciences,* **5:** 606-611.

Bhonsle, S.J., Sellappan, K. 2010. Grain quality evaluation of traditionally cultivated rice varieties of Goa, India. *Recent Research Science and Technology,* **2:** 88-97.

Cai, Y., Liu, C., Wang, W., Cai, K. 2011. Differences in physicochemical properties of kernels of two rice cultivars during grain formation. *Journal of Science of Food and Agriculture,* **91:** 1977-1983.

Chapagai, M.K., Wan-Rosli, W.I., Wan-Manan, W.M., Jalil, R.A., Karrila, T., Pinkaew, S. 2017. Effect of domestic cooking methods on physicochemical, nutritional and sensory properties of different

varieties of brown rice from southern Thailand and Malaysia. *International Food Research Journal,* **24:** 1140-1147.

Dipti, S.S., Hossain, S.T., Bari, M.N., Kabir, K.A. 2002. Physicochemical and cooking properties of some fine rice varieties. *Pakistan Journal of Nutrition,* **1:** 188-190.

Dong, M.H., Sang, D.Z., Wang, P., Wang, X.M., Yang, J.C. 2007. Changes in cooking and nutrition qualities of grains at different positions in a rice panicle under different nitrogen levels. *Rice Science,* **14:** 141-148.

Falade, K.O., Semon, M., Fadairo, O.S., Oladunjoye, A.O., Orou, K.K. 2014. Functional and physico-chemical properties of flours and starches of African rice cultivars. *Food Hydrocolloids,* **39:** 41-50.

Fofana, M., Wanvoeke, J., Manful, J., Futakuchi, K., Van Mele, P., Zossou, E., Bleoussi, T.M.R. 2011. Effect of improved parboiling methods on the physical and cooked grain characteristics of rice varieties in Benin. *International Food Research Journal,* **18:** 715-721.

GOP, 2017. *Economic Survey 2016-17*. Government of Pakistan, Economic Adviser Wing, Finance Division. Islamabad, Pakistan.

IRRI, 1980. *Annual Report for 1980.* p 25- 38. International Rice Research Institute, Los Banos, Laguna, Philippines.

Jouki, M., Khazaei, N. 2012. Some physical properties of rice seed (*Oryza sativa*).*Research Journal of Applied Sciences and Engineering Technology,* **4:** 1846-1849.

Meena, S.K., Vijayalakshmi, D., Ravindra, U. 2010. Physical and cooking characteristics of selected aromatic rice varieties. *Journal of Dairying, Food and Home Sciences,* **29:** 227-231.

Mestres, C., Ribeyre, F., Pons, B., Fallet, V., Matencio, F. 2011. Sensory texture of cooked rice is rather linked to chemical than to physical characteristics of raw grain. *Journal of Cereal Science,* **53:** 81-89.

Mir, S.A., Bosco, S.J.D., Sunooj, K.V. 2013. Evaluation of physical properties of rice cultivars grown in the temperate region of India. *International Food Research Journal,* **20:** 1521-1527.

Moongngarm, A. 2010. Influence of germination conditions on starch, physicochemical properties, and microscopic structure of rice flour. *International Conference on Biology, Environment and Chemistry,* **1:** 78-82.

Nalladulai, K., Alagusundaram, K. Gayathri, P. 2002. Airflow resistance of paddy and its byproducts. *Biosyststems Engineering,* **831:** 67-75.

Odenigbo, A.M., Ngadi, M., Ejebe, C., Woin, N., Ndindeng, S.A. 2014. Physicochemical, cooking characteristics and textural properties of TOX 3145 milled rice. *Journal of Food Research,* **3:** 82-90.

RRI, 2011. *Characteristics of Approved Rice Varieties.* Rice Research Institute, Kala Shah Kaku, Pakistan.

Sagar, M.A., Ashraf, M., Khan, M.A. 1988. Grain quality characteristics of Pakistan commercial rice varieties. *Pakistan Journal of Agricultural Research,* **9:** 1-4.

Santhi, K., Vijayakumar, T.P. 2014. Physical and functional characteristics of milling fractions of Indian Kavun pigmented brown rice (*Oryza sativa* L.). *International Journal of Agricultural and Food Science,* **4:** 78-83.

Shabbir, M.A. 2008. Biochemical and technological characteristics of Pakistani rice and protein isolates. *Ph.D., Thesis*, Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.

Shantaiya, S., Ansari, M.U. 2010. Identification of food grains and its quality using pattern classification. *International Journal of Cereal Chemistry and Technology,* **2**: 3-4.

Siddiqui, S.U., Kumamaru, T., Satoh, H. 2007. Pakistan rice genetic resources-I: Grain morphological diversity and its distribution. *Pakistan Journal of Botany,* **39:** 841-848.

Singh, N., Kaur, L., Singh, S.N., Sekhon, K.S. 2005. Physicochemical, cooking and textural properties of milled rice from different Indian rice cultivars. *Food Chemistry,* **89:** 253-259.

Steel, R.G.D., Torrie, J.H., Dickey, D.A. 1997. *Principles and Procedures of Statistics: A Biometrical Approach*, 3rd edition. McGraw Hill Book Co. Inc., New York, USA.

Subudhi, H., Meher, J., Singh, O.N., Sharma, S.G., Das, S. 2013. Grain and food quality traits in some aromatic long and short grain rice varieties of India. *Journal of Food Agriculture and Environment,* **11:** 1434-1436.

Subudhi, H.N., Swain, D., Das, D., Sharma, S.G., Singh, O.N. 2012. Studies on grain yield, physico-chemical and cooking characters of elite rice varieties (*Oryza sativa* L.) in Eastern India. *Journal of Agricultural Science,* **4:** 269-275.

Thomas, R., Nadiah, W.A., Bhat, R. 2013. Physiochemical properties, proximate composition and cooking

qualities of locally grown and imported rice varieties marketed in Penang, Malaysia. *International Food Research Journal,* **20:** 1345-1351.

Varnamkhasti, M.G., Mobli, H., Jafari, A., Keyhani, A.R., Soltanabadi, M.H., Rafiee, S., Kheiralipour, K. 2008. Some physical properties of rough rice (*Oryza sativa* L.) grain. *Journal of Cereal Science,* **47:** 496-501.

Verma, D.K., Mohan, M., Prabhakar, P.K., Srivastav, P.P. 2015. Physico-chemical and cooking characteristics of Azad basmati. *International Food Research Journal,* **22:** 1380-1389.

Verma, D.K., Mohan, M., Asthir, B. 2013. Physico-chemical and cooking characteristics of some promising basmati genotypes. *Asian Journal of Food Agro-Industry,* **6:** 94-99.

Yadav, B.K., Jindal, V.K. 2008. Changes in head rice yield and whiteness during milling of rough rice (*Oryza sativa* L.). *Journal of Food Engineering,* **86:** 113-121.