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COOKING AND EATING QUALITY CHARACTERISTICS OF SOME PAKISTANI RICE VARIETIES

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Consumption pattern of cooked rice varies from individual to individual owing to their habitual perceptions. In this context, information about the cooking and eating quality attributes of rice cultivars grown in Pakistan may be helpful for the consumers for their personal selection as well as export purposes. The objective of the current study was to evaluate the quality attributes of six rice cultivars grown in major rice growing areas of the Punjab, Pakistan along with certified cultivars of Rice Research Institute Kala Shah Kaku. These cultivars were characterized for their physical, chemical, pasting and cooking characteristics. Mean values showed greater variations among the brown and white rice samples for peak viscosity (701±0.32 to 786±0.19RVU), set back viscosity (2038±0.46 to 2265±0.49RVU), break down viscosity (224±0.46 to 279±0.49RVU), final viscosity (2746±0.49 to 2258±0.50RVU), kernel elongation ratio (2.65±1.15 to 2.97±1.30), volume expansion ratio (3.47±0.37 to 4.13±0.35) and water absorption ratio (3.21±0.29 to 3.57±0.19). Eating quality of cooked rice samples showed maximum preference of white rice samples due to better color, aroma, taste, texture. This was might be due to routine consumption of white rice in Pakistan as compared to brown rice. The variations in characteristics of brown and white fractions of cultivars from various locations were might be due to climatic, agronomic and other agricultural practices adopted during the rice cropping season as well as rice processing conditions. It is concluded from the current study that Basmati varieties especially grown in popular areas for rice cultivation are considered best for processors, consumers as well as exporters.
Keywords: *Oryza sativa*, Basmati rice, cooking performance, starch gelatinization, pasting characteristics, sensory attributes

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important Kharif crop as well as staple diet for Pakistani nation and is playing significant role in boosting economy of country. Total cropped area is 11% which produces 6.90 million tonnes of rice (GOP, 2017). Share of Pakistani rice in world production is 11%. It has emerged as major export commodity of the country and accounts for 27% of foreign exchange earnings. Rice is the 2nd largest crop in terms of production and ranks 3rd in area wise after wheat and cotton in Pakistan. Globally, Pakistan is ranked at 12th position among rice producing countries. Pakistan produces good quality rice which is locally consumed as well as a major export item. Two types of cultivars are cultivated in Pakistan *i.e.* fine and coarse. Fine varieties are aromatic in nature and showed good cooking characteristics while coarse varieties have no specific flavor attributes and are less liked across the world. High yielding coarse varieties (30%) are cultivated in Sindh for intact as well as other food-based applications. Basmati rice is cultivated on 52% of the total rice cropped area in Pakistan (Abbas *et al.*, 2011) and enjoys monopoly in world export and fetch three to four times more sale price in international markets. Coarse varieties mostly produced in Sindh are also exported to Gulf countries (Ansari *et al.*, 2013). Quality of rice grain has been mainly dependent upon array of physical and chemical attributes that govern the texture of cooked rice and cooking performance in water (Moongngarm and Saetung, 2010).

Cooking quality is the one of the basic demands of consumer which is greatly influenced by processing procedures such as cooking in excess and scarcity of water. The extent of swelling of each rice variety and differences in its colloidal structure on cooking are assumed to be well known factors influencing quality criteria. Cooking and pasting qualities can be analyzed in terms of water absorption ratio, grain elongation ratio, volume expansion during cooking and cooking time. During cooking, various diffusive processes like heating, water absorption and swelling of rice occur simultaneously within the grains that are ultimately responsible for starch gelatinization. This information is also important for health-conscious consumers for maintaining its desired physical characteristics like texture and taste during the cooking and also minimizing the fuel consumption (Thomas *et al.*, 2013). Each rice cultivar is supposed to have a typical pasting, cooking and eating quality. Gelatinization is also known as pasting which involves swelling of starch granules, extrudation of molecular components and disruption of starch arrangements. Rice flour has a good pasting quality which adds an essential feature of thickening and sizing to food and non-food applications (Shafie *et al.*, 2016). Amylose, fat, protein contents, chain length of amylopectin, nature of varieties and cropping atmosphere are the main elements that influenced the pasting. Fiber contents of rice grain have little impact on pasting during heating due to low hydration, strong structural bonding and restricted swelling and dispersion of starch matrix (Shabbir *et al.*, 2013). Pasting viscosity is increased upon cooling of starch granules and subjected to shearing action (Lee *et al.*, 2014).Cooking and pasting qualities can be analyzed in terms of water absorption ratio, grain elongation ratio, volume expansion during cooking and cooking time. During cooking, various diffusive processes like heating, water absorption, swelling of rice particles occur simultaneously within grain that are responsible for starch gelatinization. Higher the gelatinization temperature during cooking, less rate of grain elongation compared to low and medium temperature (Lu *et al.*, 2011). Grain and cooking quality are the basic demands of consumer that mostly intake rice while quality traits also differ according to processing procedures such cooking in excess and scarcity of water. The extent of swelling of each rice variety and differences in its colloidal structure on cooking are assumed to be well known factors which always determine its quality criteria (Diako *et al.*, 2011; Druvashree *et al.*, 2013). Diversity among physiochemical and cooking qualities of various rice cultivars is needed for multi-dimensional end-products. Polished rice contains up to 90% of starch in grains. Starch granules are composed of growth rings of semi crystalline lamella, amylopectin chains and amylose. Cooking characteristics are considered as useful component for the selection of varieties with respect to their end use quality (Payman *et al.*, 2014).

Cooking characteristics of rice grains are also evaluated by researchers (Usha *et al*., 2012). It was reported that protein contents of rice (6-10%) showed positive association with elongation ratio. Higher volume expansion ratio was correlated to gelatinization of amylose and starch contents which readily swollen rice grains by absorbing water and other dissolved solid matrix. The high amylose to amylopectin ratio among varieties is attained and acknowledged as extra pleasant for eating and cooking. It was studied that grain elongation was more in minimum cooking time with thickness of grains. Cooked rice is considered as a composite plasticizer product made from various biopolymers such as water, proteins, lipids, starches. Rice consumers mostly prefer white end translucent grains and palatability of cooked rice is directed by its textural attributes (Kanchana *et al.,* 2012). Cooked rice texture *i.e.* tenderness and stickiness were greatly affected by rice variety, amylose content, gelatinization temperature, cooking procedures and time. In urban areas, people prefer to eat rice that expands more in lengthwise arrangement while in working class, they don't have any special choice regarding the rice texture. Rice becomes soft and sticky on cooking with low amylose contents whereas firmer with increase in amylose contents. Apart from consumption of intact rice, a wide range of nutritious products are prepared from brown and white rice and also used itself as important component of foods across the globe. Keeping in view the above mention quality criteria, the present project was designed to assess the cooking, pasting and eating quality of the selected rice cultivars for product diversification, industrial benefit as well as for customer demand.

MATERIALS AND METHODS

***Sample selection and preparation*:** Samples of some promising rice cultivars like Super Kernel, Super Basmati, Basmati-515, Kainat, Pk-386 and IRRI-9 were collected from commercially grown regions of the Punjab *i.e.* Gujranwala, Hafizabad, Mandi Bahauddin, Sialkot, Jhang and Bahawalnagar. Likewise, samples of selected cultivars were also obtained from Rice Research Institute, Kala Shah Kaku, Lahore. Freshly harvested paddy samples were cleaned manually by removing foreign objects followed by sun drying till 13% moisture content. Afterwards, paddy samples were milled into brown rice by using laboratory scale De-husker. Abrasive Polisher was employed for separation of rice bran to obtain white rice fraction. All white and brown rice samples were stored in air tight polyethylene bags and kept at room temperature (25°C) for further analysis. A small portion of each sample was converted into fine powder (<120 u mesh size) for assessment of pasting attributes.

***Pasting and cooking characteristics*:** Brown and white rice flour pasting properties were determined using Rapid Visco Analyzer following procedure as described by Bao (2012). The test was performed for 13 minutes first at 960 rpm (95°C) and then at 160rpm and terminate automatically when the desired temp (50°C) was achieved. The peak viscosity (PV), breakdown (BD), final and setback (SB) viscosity were recorded and measured in Rapid Visco Units (RVU). Volume expansion ratio (VER), water absorption ratio (WAR) and kernel elongation ratio (KER) of both brown and white rice samples were determined by using their respective formulas as stated by Billiris *et al.* (2012) as following 1, 2 and 3:

$$1. Volume\ expansion\ ratio = \frac{Cooked\ rice\ volume}{Raw\ rice\ volume}$$

$$2. Water\ absorption\ ratio = \frac{Cooked\ rice\ wieght}{Raw\ rice\ weight}$$

$$3. Elongation\ ration = \frac{\text{Average length of 10 cooked rice grains}}{\text{Average length of 10 raw rice grains}}$$

***Eating quality*:** All rice samples (brown and white) were cooked and analyzed for sensory attributes such as color, aroma, taste, texture and overall acceptability using 9-Point Hedonic Score System as described by Shobana *et al.* (2011). Samples of brown and white rice (300 g) were cooked at uniform conditions in a household rice cooker. The top 1 cm layer of cooked rice was discarded and samples for analysis were taken from the middle of the cooking bowl. Cooked rice was fluffed gently with a ladle and transferred into a glass container with a plastic lid for sensory evaluation. Color or whiteness was evaluated first as the surface quality of cooked rice. Aroma was perceived by the olfactory sense and assessed by sniffing the cooked rice before putting into the mouth. The descriptive panel also rated the cooked rice samples for consumer acceptability without any undue bias towards other sensory attributes.

***Statistical analysis*:** The analysis of variance technique (ANOVA) was used to analyze the collected data in triplicates for each parameter by following the method described by Steel *et al.* (1997) using the Statistical Package (Costat-2003, Co-Hort, version 6.1). Accordingly, mean values were further compared with Tukey's Honestly Significant Difference Test at 5% significance level.

RESULTS

Mean squares for pasting characteristics such as peak viscosity (PV), set back viscosity, break down viscosity and final viscosity of rice varieties collected from selected locations showed significant difference with respect to varieties, locations and rice fractions. Moreover, interaction between rice varieties, locations and rice fractions were non-significant. Mean values for peak viscosity were ranged from 701±0.32 to 786±0.19RVU. The highest value was seen in IRRI-9 (786±0.19RVU) followed by Super Basmati (745±0.06RVU) and Basmati-515 (718±0.63RVU). The lowest peak viscosity was observed in PK-386 (701±0.32RVU) followed by Kainat (703±0.72RVU) and Super Kernel (705±0.46RVU). Brown rice from Kala Shah Kaku showed the highest value (782±0.05RVU) followed by Sialkot (775±0.05RVU) whereas the lowest peak viscosity was found in samples from Gujranwala (560±0.05RVU) and Mandi Bahauddin (577±0.06RVU). Among the white rice fractions, Kala Shah Kaku samples showed the highest peak viscosity (821±0.05RVU) and the lowest values were noted in Gujranwala samples (700±0.05RVU) followed by Mandi Bahauddin (709±0.06RVU). White rice flour showed more values for peak viscosity (700±0.05 to 821±0.05 RVU) than that of brown rice flour (560±0.05 to 732±0.05 RVU).

Mean values for setback viscosity were ranged from 2038±0.46 to 2265±0.49RVU with the highest value in IRRI-9 (2265±0.49RVU) followed by Super Basmati (2215±0.47RVU) and Kainat (2201±0.50RVU). The lowest set back viscosity was observed in Super Kernel (2038±0.46RVU) and Basmati-515 (2128±0.51RVU). Brown rice fractions of cultivars from Kala Shah Kaku showed the highest values (1943±1.05RVU) followed by Jhang (1847±1.05RVU) whereas lowest values were seen in rice samples from Gujranwala (1728±1.06RVU). In case of white rice fractions, the highest set back viscosity was found in Kala Shah Kaku samples (2592±0.05RVU) followed by Mandi Bahauddin (2573±0.06RVU) and the lowest was noted in varieties from Gujranwala (2445±0.05RVU). It is obvious from the results that white rice showed more values for setback viscosity (2445±0.05 to 2592±0.05RVU) as compared to brown rice (1729±1.06 to 1943±1.05 RVU). Mean values for final viscosity revealed significant variations among varieties and values were ranged from 2746±0.49 to 2258±0.50RVU with the highest in IRRI-9 (2746±0.49RVU) followed by Super Basmati (2468±0.47RVU) and Super Kernel (2446±0.46RVU) whereas the lowest in Kainat (2258±0.50RVU) and PK-386 (2274±0.50RVU). Similarly, brown rice fractions of Kala Shah Kaku showed the highest values (2309±0.05RVU) followed by Sialkot (2301±0.05RVU) whereas the lowest values were seen in Gujranwala (1894±0.05RVU) followed by Mandi Bahauddin (1948±0.05RVU). Among the white rice fractions, the highest final viscosity (2787±0.05RVU) was in Kala Shah Kaku samples. Mean values for break down viscosity were ranged from 224±0.46 to 279±0.49RVU in rice cultivars from diverse locations. The highest value was seen in IRRI-9 (279±0.49RVU) followed by Basmati-515 (246±0.51RVU) and Kainat (243±0.50RVU), respectively whereas the lowest viscosity was observed in Super Kernel (224±0.46RVU) and PK-386 (232±0.50RVU). Among the brown rice fractions, samples from Kala Shah Kaku showed the highest values (247±0.05RVU) whereas the lowest break down viscosity was in Gujranwala samples (222±0.05RVU). Among the white fractions, higher values were found in samples of all cultivars irrespective of cultivation locations. Overall, white rice fractions showed more break down viscosity as compared to brown rice fractions of the same cultivar and same location.

Mean squares for cooking characteristics such as kernel elongation, volume expansion and water absorption ratio of rice varieties collected from selected locations showed significant differences among the varieties and rice fractions whereas these were not affected by locations. Moreover, interactions between rice varieties, locations and rice fractions were non-significant. Means for KER of different cultivars showed values ranged from 2.65±1.15 to 2.97±1.30 after cooking. The highest KER (2.97±1.30) was observed in Super Kernel followed by 2.94±1.47 in Basmati-515 whilst the lowest value was observed in IRRI-9 (2.65±1.15) and Kainat (2.84±1.34) and PK-386 (2.89±1.37). Among the cooked brown fractions, rice cultivars of Gujranwala showed the highest KER value (1.71±0.33) followed by Mandi Bahauddin (1.58±0.26) whereas the lowest ratio was found in samples from Bahawalnagar (1.31±0.29) followed by Jhang (1.47±0.36). In white rice fractions, the highest KER was in samples collected from Gujranwala (4.33±0.53) and Mandi Bahauddin (4.25±0.47). Among brown and white fractions of cooked rice, maximum KER was noted in white rice samples (3.52±0.18 to 4.33±0.53) as compared to brown rice which showed the minimum KER (1.31±0.29 to 1.71±0.33). Means for volume expansion ratio (VER) showed values ranged from 3.47±0.37 to 4.13±0.35 after cooking. The highest VER (4.13±0.35) was observed in IRRI-9 followed by Super Kernel (3.73±0.35) and Super Basmati (3.71±0.39) whereas the lowest VER was in Kainat (3.47±0.37) and PK-386 (3.53±0.36). In case of brown rice fractions from different districts, rice cultivars of Sialkot showed the highest VER value (3.68±0.50) followed by Mandi Bahudin (3.51±0.43) whereas lowest VER was found in samples of Kala Shah Kaku (3.24±0.32). In white fractions, highest VER was seen in samples collected from Kala Shah Kaku (3.96±0.54) followed by Sialkot (3.95±0.14) while the lowest VER was found in Bahawalnagar samples (3.89±0.29). If we compare the VER values in brown and white fractions of cooked rice, the maximum VER was noted in white samples (3.89±0.29 to 3.96±0.54) as compared to brown rice (3.24±0.32 to 3.68±0.50). Means for water absorption ratio (WAR) showed values ranged from 3.21±0.29 to 3.57±0.19 with the highest value (3.57±0.19) in IRRI-9 followed by 3.43±0.26 in PK-386. However, the lowest WAR was observed in Basmati-515 (3.21±0.29) and Super Kernel (3.26±0.30) and Super Basmati (3.35±0.37). Among the cooked samples of brown rice fractions from different districts, rice cultivars of Kala Shah Kaku showed the highest value (3.18±0.19) followed by Mandi Bahauddin (3.15±0.18) whereas the lowest WAR was in rice samples of Jhang (3.07±0.16) and Bahawalnagar (3.07±0.20). In white fractions, the highest value was seen in samples collected from Kala Shah Kaku (3.67±0.09) followed by Mandi Bahauddin (3.66±0.10) while the lowest WAR was in Jhang samples (3.58±0.09) followed by Bahawalnagar (3.59±0.12). Among the brown and white rice fractions, maximum WAR was noted in white rice samples (3.58±0.09 to 3.67±0.09) as compared to brown rice which showed the minimum WAR (3.07±0.16 to 3.18±0.19).

Mean squares for eating quality including color, aroma, taste, texture and overall acceptability of rice varieties after cooking were displayed significant differences among the rice varieties, rice fractions and selected cultivation locations. Moreover, interactions between rice varieties, locations and rice fractions were non-significant. Mean values for color of cooked samples of brown and white rice exhibited (Table 1) the maximum score for Super Basmati followed by Basmati-515 and Super Kernel whereas minimum value was obtained by PK-386 and Kainat. Among the locations, white rice samples of Sialkot were more liked by the judges followed by Gujranwala and Hafizabad while the rice samples from districts Bahawalnagar were ranked at the tail. Similarly, maximum score for appearance was attained by brown rice samples from Sialkot followed by Gujranwala and Hafizabad. Means for aroma of cooked samples of brown and white rice showed (Table 2) the maximum aroma in Super Basmati for aroma followed by Basmati-515 and Super Kernel, respectively whereas minimum value was found in Kainat followed by PK-386 followed by IRRI-9. The impact of cultivation locations was also evident from the varietal ranking by the judges. The white rice samples of Sialkot were apparently more aromatic followed by Gujranwala and Hafizabad) as compared to samples from Bahawalnagar, Jhang and Mandi Bahauddin. Similar trend was noticed in

Table 1. Means for color of cooked 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	7.19±0.27	7.28±0.05	7.22±0.06	6.52±0.07	6.49±0.10	6.94±0.06	6.94±0.35i
	W	7.49±0.08	7.90±0.08	7.86±0.08	6.68±0.08	6.71±0.08	6.87±0.08	7.25±0.56d
MB	B	7.13±0.10	7.22±0.08	7.17±0.06	6.50±0.07	6.40±0.07	6.90±0.05	6.88±0.35j
	W	7.40±0.08	7.88±0.05	7.82±0.08	6.63±0.08	6.67±0.07	6.84±0.32	7.20±0.56e
SKT	B	7.30±0.05	7.39±0.08	7.40±0.21	6.70±0.10	6.65±0.08	7.21±0.08	7.10±0.34f
	W	7.60±0.08	8.09±0.08	8.00±0.06	6.83±0.07	6.90±0.06	6.99±0.05	7.40±0.57a
GJW	B	7.27±0.05	7.40±0.05	7.37±0.10	6.67±0.08	6.66±0.07	7.17±0.06	7.09±0.35fg
	W	7.56±0.08	8.10±0.08	7.98±0.06	6.80±0.07	6.89±0.07	7.00±0.08	7.38±0.57b
HFZ	B	7.25±0.07	7.38±0.11	7.38±0.08	6.65±0.08	6.60±0.10	7.10±0.10	7.06±0.35g
	W	7.55±0.05	8.07±0.06	7.96±0.05	6.79±0.07	6.83±0.06	6.97±0.05	7.36±0.57c
JHG	B	7.00±0.08	7.20±0.06	7.14±0.08	6.40±0.08	6.28±0.07	6.80±0.06	6.80±0.38k
	W	7.27±0.27	7.76±0.08	7.60±0.05	6.50±0.07	6.58±0.08	6.73±0.05	7.07±0.54g
BWN	B	7.03±0.08	7.12±0.06	7.07±0.08	6.38±0.08	6.24±0.07	6.76±0.08	6.76±0.37l
	W	7.22±0.08	7.74±0.06	7.61±0.05	6.47±0.07	6.56±0.08	6.70±0.07	7.05±0.55h
Mean±SD		7.30±0.19c	7.60±0.36a	7.54±0.33b	6.60±0.14f	6.62±0.20e	6.92±0.15d	

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 2. Means for aroma of cooked 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	7.02±0.08	7.14±0.08	7.15±0.08	5.48±0.06	5.41±0.08	5.56±0.10	6.29±0.88i
	W	7.73±0.05	7.94±0.05	7.81±0.05	6.12±0.05	6.15±0.05	6.23±0.06	6.99±0.91c
MB	B	7.00±0.08	7.10±0.08	7.09±0.19	5.40±0.26	5.36±0.08	5.53±0.08	6.24±0.89j
	W	7.69±0.27	7.90±0.08	7.77±0.25	6.09±0.06	6.11±0.11	6.20±0.29	6.96±0.90d
SKT	B	7.32±0.05	7.29±0.25	7.30±0.05	5.60±0.05	5.60±0.05	5.72±0.08	6.47±0.90f
	W	7.87±0.10	8.12±0.31	7.94±0.08	6.30±0.08	6.26±0.08	6.42±0.06	7.15±0.92a
GJW	B	7.29±0.06	7.26±0.08	7.27±0.06	5.61±0.06	5.57±0.17	5.68±0.08	6.44±0.91g
	W	7.88±0.05	8.00±0.05	7.99±0.05	6.28±0.05	6.26±0.05	6.40±0.23	7.13±0.90ab
HFZ	B	7.25±0.61	7.27±0.08	7.22±0.29	5.56±0.11	5.54±0.08	5.65±0.08	6.41±0.92h
	W	7.85±0.06	8.05±0.25	7.97±0.06	6.26±0.08	6.23±0.18	6.37±0.06	7.12±0.91ab
JHG	B	6.90±0.05	7.00±0.05	7.12±0.05	5.32±0.05	5.27±0.05	5.46±0.06	6.17±0.91k
	W	7.60±0.06	7.81±0.21	7.68±0.08	6.00±0.06	6.09±0.21	6.14±0.28	6.88±0.89e
BWN	B	6.87±0.05	7.01±0.10	7.07±0.24	5.30±0.08	5.25±0.08	5.43±0.06	6.15±0.91k
	W	7.61±0.52	7.80±0.05	7.65±0.38	6.02±0.25	6.04±0.11	6.13±0.06	6.87±0.89
Mean±SD		7.42±0.37c	7.55±0.42a	7.50±0.35b	5.81±0.37e	5.79±0.39f	5.92±0.38d	

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 taste of cooked brown and white rice fractions of different rice cultivars collected from various locations.

Locations	F	Varieties						Mean±SD
		Super Kernel	Super Basmati	Basmati - 515	PK-386	Kainat	IRRI-9	
KSK	B	6.52±0.10	6.63±0.07	6.59±0.08	6.11±0.08	5.28±0.08	5.07±0.08	6.03±0.70h
	W	7.84±0.08	8.55±0.11	8.37±0.07	7.47±0.08	7.20±0.05	7.24±0.08	7.77±0.57b
MB	B	6.50±0.08	6.60±0.07	6.56±0.08	6.10±0.08	5.26±0.08	5.04±0.11	6.01±0.69h
	W	7.80±0.08	8.45±0.08	8.23±0.10	7.35±0.07	7.24±0.05	7.11±0.08	7.69±0.55c
SKT	B	6.58±0.06	6.70±0.07	6.69±0.08	6.26±0.10	5.39±0.08	5.21±0.06	6.15±0.67f
	W	7.89±0.06	8.56±0.07	8.35±0.10	7.50±0.05	7.37±0.08	7.25±0.06	7.82±0.54a
GJW	B	6.56±0.08	6.71±0.08	6.68±0.07	6.25±0.07	5.37±0.05	5.23±0.11	6.13±0.66f
	W	7.90±0.08	8.58±0.06	8.37±0.08	7.53±0.05	7.38±0.08	7.27±0.08	7.83±0.54a
HFZ	B	6.55±0.08	6.68±0.03	6.65±0.08	6.25±0.08	5.30±0.08	5.18±0.08	6.10±0.68g
	W	7.81±0.07	8.49±0.08	8.26±0.07	7.37±0.07	7.26±0.05	7.14±0.06	7.72±0.55b
JHG	B	6.42±0.07	6.54±0.08	6.47±0.08	6.05±0.05	5.17±0.08	5.00±0.06	5.94±0.68i
	W	7.76±0.08	8.40±0.06	8.12±0.08	7.29±0.07	7.13±0.05	7.00±0.08	7.61±0.56d
BWN	B	6.38±0.08	6.50±0.08	6.47±0.07	6.00±0.11	5.09±0.05	5.01±0.08	5.90±0.68j
	W	7.70±0.05	8.36±0.06	8.10±0.08	7.22±0.05	7.08±0.08	7.03±0.06	7.58±0.56e
Mean±SD		7.15±0.68c	7.55±0.96a	7.42±0.87b	6.76±0.65d	6.25±1.02e	6.12±1.06f	

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

case of brown rice samples of Sialkot, Gujranwala and Hafizabad.

Means for taste of cooked brown and white rice samples revealed (Table 3) maximum appreciation for taste by the panelists by Super Basmati followed by Basmati-515 and Super Kernel, whereas minimum value was found in IRRI-9, Kainat and PK-386 by the judges. Among the locations, maximum score for taste was observed in white rice samples of Gujranwala followed by Sialkot and Kaka Shah Kaku while the rice samples from districts Bahawalnagar and Jhang got the lowest scores. Similarly, brown rice samples of Sialkot and Gujranwala were preferred by the judges. Means for texture of cooked rice samples revealed (Table 4) that judges showed more likeness for the texture of Super Basmati followed by Basmati-515 and Super Kernel whereas minimum score was attained by IRRI-9 and Kainat. Among

Table 4. Means for texture of cooked 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	6.69±0.05	6.89±0.07	6.71±0.05	6.34±0.08	6.12±0.07	5.98±0.08	6.45±0.36f
	W	7.94±0.08	8.37±0.08	8.23±0.07	7.78±0.07	7.67±0.05	7.48±0.07	7.91±0.33b
MB	B	6.67±0.05	6.86±0.07	6.68±0.05	6.32±0.05	6.09±0.07	5.95±0.08	6.42±0.36g
	W	7.91±0.07	8.34±0.08	8.19±0.13	7.76±0.07	7.64±0.05	7.43±0.07	7.87±0.34c
SKT	B	6.74±0.05	6.95±0.07	6.78±0.05	6.43±0.08	6.21±0.07	6.00±0.08	6.51±0.36e
	W	7.96±0.05	8.45±0.08	8.38±0.07	7.81±0.05	7.70±0.07	7.52±0.08	7.97±0.37a
GJW	B	6.75±0.08	6.94±0.07	6.77±0.15	6.40±0.08	6.18±0.11	6.03±0.07	6.51±0.36e
	W	7.98±0.07	8.46±0.08	8.37±0.05	7.83±0.05	7.72±0.07	7.54±0.07	7.98±0.36a
HFZ	B	6.70±0.07	6.88±0.07	6.73±0.05	6.37±0.14	6.15±0.07	5.60±0.07	6.40±0.47h
	W	7.95±0.08	8.35±0.08	8.25±0.08	7.80±0.08	7.69±0.05	7.50±0.07	7.92±0.32b
JHG	B	6.65±0.05	6.80±0.07	6.67±0.04	6.30±0.05	6.05±0.13	5.91±0.08	6.39±0.36h
	W	7.87±0.07	8.26±0.07	8.20±0.17	7.73±0.10	7.63±0.09	7.40±0.07	7.84±0.33d
BWN	B	6.60±0.05	6.79±0.08	6.64±0.07	6.28±0.05	6.01±0.05	5.88±0.08	6.36±0.36i
	W	7.84±0.07	8.25±0.07	8.18±0.05	7.71±0.08	7.60±0.11	7.40±0.07	7.83±0.33d
Mean±SD		7.30±0.64c	7.61±0.77a	7.48±0.80b	7.06±0.74d	6.89±0.80e	6.68±0.81f	

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 overall acceptability of cooked 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	6.85±0.10	6.98±0.07	6.92±0.11	6.23±0.07	5.82±0.06	5.76±0.07	6.42±0.56c
	W	7.74±0.07	8.10±0.05	8.00±0.10	7.00±0.10	6.93±0.05	6.81±0.06	7.43±0.58c
MB	B	6.80±0.15	6.92±0.07	6.90±0.06	6.17±0.06	5.78±0.05	5.72±0.05	6.38±0.56d
	W	7.71±0.05	8.06±0.06	7.90±0.06	6.83±0.05	6.88±0.07	6.76±0.10	7.35±0.59e
SKT	B	6.88±0.07	6.98±0.06	6.95±0.06	6.28±0.12	5.85±0.05	5.80±0.16	6.45±0.55c
	W	7.80±0.06	8.15±0.05	8.15±0.07	7.20±0.07	6.95±0.10	6.89±0.07	7.52±0.58a
GJW	B	6.89±0.07	7.00±0.05	6.97±0.11	6.29±0.07	5.88±0.05	5.80±0.06	6.47±0.55b
	W	7.81±0.06	8.16±0.10	8.17±0.07	7.21±0.06	6.99±0.06	6.90±0.14	7.54±0.57a
HFZ	B	6.86±0.05	6.98±0.07	6.93±0.10	6.25±0.06	5.83±0.05	5.77±0.05	6.43±0.54c
	W	7.75±0.11	8.12±0.05	8.00±0.07	7.06±0.14	6.96±0.07	6.83±0.07	7.45±0.56c
JHG	B	6.76±0.07	6.82±0.07	6.84±0.06	6.19±0.10	5.72±0.06	5.67±0.06	6.33±0.54f
	W	7.58±0.06	8.02±0.06	7.89±0.10	6.93±0.06	6.85±0.07	6.71±0.07	7.33±0.57f
BWN	B	6.70±0.05	6.79±0.07	6.83±0.05	6.15±0.07	5.68±0.10	5.60±0.11	6.29±0.56g
	W	7.55±0.10	8.00±0.05	7.84±0.05	6.89±0.05	6.83±0.06	6.69±0.05	7.30±0.57g
Mean±SD		7.26±0.46c	7.50±0.60a	7.44±0.57b	6.62±0.42d	6.35±0.58e	6.26±0.55f	

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

cultivation locations, maximum score for texture was observed in white rice samples of Gujranwala followed by Sialkot and Hafizabad while the minimum score was noticed in rice samples from districts Bahawalnagar, Jhang and Mandi Bahauddin. Similarly, maximum score was got in brown samples of Sialkot and Gujranwala while the samples from Bahawalnagar showed the minimum scores. Means for overall acceptability of cooked rice samples (Table 5) showed that panelist assigned maximum score to Super Basmati followed by Basmati-515 and Super Kernel whereas minimum score was given to IRRI-9 followed by Kainat by the judges. Among the locations, maximum score for overall acceptability was observed in brown rice samples of Gujranwala followed by Sialkot while the samples from district Bahawalnagar attained the minimum score.

DISCUSSION

Pasting attributes serve as an effective tool for the evaluation of functional properties of rice grain. On cooling, starch granules re-association and retrogradation starts at 50°C. There was a significant variation in the setback values among the varieties, locations and their milling fractions due to differences in amylose content (25-30%) as well as more endosperm starch and low levels of bran. Coarse varieties such as IRRI-9 showed differences in peak viscosity *i.e.* 825-880RVU in brown fractions whereas 745 to 900RVU in white fractions. In rice samples, peak viscosity ranged from 90 to 280 RVU, final viscosity (111 to 390RVU), break down viscosity (1 to 130RVU), setback viscosity (44 to 205RVU). Break down (26-146 RVU) and set back viscosity (54-160 RVU) varied in 499 rice genotypes. Pasting viscosity of rice flour was also influenced by presence of protein (5-7%) and fat contents (0.5-1%) which may affect the starch physicochemical properties (Fitzgerald *et al.*, 2009; Xu *et al.*, 2014). In current study, amylose content in white rice fractions was 24.71±1.70 to 25.10±1.72%. It is indicator to measure the hardening and retrogradation attributes of the cooked rice samples upon cooling. Basmati varieties showed lower values for setback viscosity of cold paste which was due to having intermediate amylose contents as well as formation of harder gel of better stability (Asghar *et al.*, 2012). It has been documented that all the pasting attributes are affected by water absorption in starch granules, protein and lipids interaction as well as working condition of the instrument (Bao, 2008; Wang *et al.*, 2014).

Increase in the viscosity was might be due to more swelling of starch granules and amount of solubilized carbohydrates upon heating in presence of water. Difference between peak and final viscosity is known as break down viscosity which expresses the paste stability of rice flour. Break down viscosity is greatly influenced by hydration, starch swelling behavior and shear resistance of starch paste upon heating and cooling cycles (Shafie *et al.*, 2016). It was found that long grain rice varieties have comparatively high pasting temp, set back and final viscosity as compared to medium and short grain varieties which have higher peak and break down viscosities (Tong *et al.*, 2014; Wua *et al.*, 2015). Pasting attributes like peak viscosity, final viscosity and set back viscosity were showed significant difference among the Pakistani rice varieties including IRRI-6, KS-282, Basmati-2000 and Super Basmati and their milling fractions. Set back and final viscosity was more in high amylose rice flours due to more leaching of amylose from starch granules while break down viscosity was more in low amylose rice due to earlier swelling ability. It was reported that low amylose rice varieties exhibited the lowest values for pasting attributes. It is obvious from previous studies that low BDV of flour showed more stable paste whereas high PV resulted in higher degree of starch swelling (Asante *et al.*, 2013).

Cooking attributes were varied due to presence of more amylose and starch contents as well as alkaline spreading value in white rice than that of brown rice fraction which was might be due to more absorption of water that produces greater volume in cooked rice samples. Similarly, kernel elongation ratio was ranged from 1.46-1.85, 1.55-1.71 and 1.40-1.80, respectively among Indian varieties of different locations (Subudhi *et al.*, 2013). Likewise, volume expansion ratio was ranged from 3.79-4.25, 3.30-3.97 and 3.00-5.25 among Indian varieties of different ecologies. Higher volume expansion and flakiness were observed in high amylose rice cultivars upon cooling, grains become dry and harder. In contrast, grains of low amylose rice cook tender and remain sticky. Water uptake ratio among cooked rice grains of Indian varieties were ranged from 1.90-2.20 (Mohapatra and Bal, 2006). Means for kernel elongation (1.38 to 2.20) and volume expansion (3.25 to 4.00) also varied among Basmati samples (Verma *et al.*, 2015). Normally, increase in length of rice grain is a desirable quality trait whereas increase in width is not considered good regarding quality during cooking and both characters are influenced by chemical composition, thermal properties during cooking, amylose contents, structure of starch molecules and L/W ratio (Singh *et al.*, 2005). Water uptake ratio during cooking was correlated with amylose content (Lee *et al.*, 2014). Basmati rice is non-glutinous due to presence of intermediate amylose contents 25%. Temperature of the cooking medium is also important for the absorption of water into cooked grains. Tenderness, cohesiveness and palatability of cooked grains are greatly linked with water uptake ratio. Basmati varieties have highest kernel elongation ratio after cooking. More the bran removal (10-14%) more will be the grain length and volume within lower cooking time. Water absorption ratio of cooked rice was also affected by degree of bran removal (12-15%). In other cases, coarse varieties (thicker grain) have higher cooking time with minimum kernel elongation ratio. It was noted that some of the physico-chemical traits were correlated directly or inversely with cooking attributes like amylose content, cooking method, cooking water temperature and cooking time. It was reported that high amylose and moisture contents of raw rice absorbs more due to hygroscopic nature of starch (Oko *et al.*, 2012).

It is obvious that the color of white rice samples was more appreciated than that of brown rice. This was might be due to regular consumption of white rice in Pakistan whereas brown rice is seldom used in the country and mostly exported. The whitish look of cooked white rice samples was linked with the increased degree of polishing and predominantly starchy nature of polished grain (Shobana *et al.*, 2011). In a study, higher intensities of nutty, corn starch, metallic and woody aroma were reported in brown rice samples by the judges (Billiris *et al.*, 2012). Variations in aroma were associated with initial moisture content, type of variety, storage conditions and agro-climatic conditions of particular region. Likewise, aromatic varieties are more preferred for consumption by the people and consequently have higher market demand. 2-Acetyl-1-pyrroline (2-AP) was found responsible for fragrance in rice samples and its quantity differ among varieties because of geological and climatic conditions (Rita and Sarawgi, 2008; Bhonsle and Sellappan, 2010). Taste, aroma and mouth feel also showed intense differences among premium and second-best varieties (Champagne *et al.*, 2010). The primary elements that influenced the sensory attributes or eating quality are nature of varieties, cultivation methods, postharvest practices, degree of bran removal, storage period, cooking processes, ethnicity and dietary habits of individuals (Zhong *et al.*, 2014). Texture of milled rice was softer resulting in reduction in hardness due to more bran removal from 8 to 14%. Rice grains having more protein content take longer cooking time due to less water absorption by formation of starch protein complex (Yadav *et al.*, 2007; Syafutri *et al.*, 2016). Cooked rice samples of IRRI varieties showed rough surface which was might be due to higher protein contents. Aroma, color, texture and overall acceptability are more evident in Basmati rice varieties (Super Basmati and Basmati-2000) than that of coarse one *i.e.* IRRI-9 (Javed, 2004).

***Conclusion*:** Pasting and cooking quality of white rice is considered good because white rice gains more water (more swelling power) and volume on heating as compared to brown rice which contain bran layers acting as barrier to water absorption. Sialkot, Gujranwala and Hafizabad are regarded as premium rice producing areas of the country as well as more preferred by the local consumers than that of samples from Bahawalnagar, Jhang and Mandi Bahauddin due to best agricultural practices, geographical conditions, environmental factors and eating and cooking quality. Promising fine varieties including Super Basmati, Super Kernel, Basmati-515, PK-386 and Kainat showed the good eating attributes such as color, aroma, taste and texture than that of coarse variety *i.e.* IRRI-9 due to variation in amylose 25-29%, starch and alkaline spreading value as well as proximate composition.

REFERENCES

Abbas, A., S. Murtaza, F. Aslam, A. Khawar, S. Rafique and S. Naheed. 2011. Effect of processing on nutritional value of rice (*Oryza sativa*). World J. Med. Sci. 6:68-73.

Ansari, I.T., A.N. Memon, A.B. Ghanghro, M.A. Sahito, N.T. Narejo, J.H. Umrani, S. Khan and A.M. Shah. 2013. Comparative study of physicochemical properties of mutant rice varieties cultivated in Sindh. Sindh Univ. Res. J. Sci. Ser. 45:17-20.

Asante, M.D., S.I.K. Offei, V. Gracen, H. Adu-Dapaah, E.Y. Danquah and R. Bryant. 2013. Starch physicochemical properties of rice accessions and their association with molecular markers. Starch 65:1022-1028.

Asghar, S., F.M. Anjum, M.R. Amir and M.A. Khan. 2012. Cooking and eating characteristics of rice (*Oryza sativa* L.)- a review. Pak. J. Food Sci. 22:128-132.

Bao, J.S. 2008. Accurate measurement of pasting temperature by the rapid visco analyser: a case study using rice flour. Rice Sci. 15:69-72.

Bao, J.S. 2012. Toward understanding the genetic and molecular bases of the eating and cooking qualities of rice. Cereal Foods World 57:148-156.

Bhonsle, S.J. and K. Sellappan. 2010. Grain quality evaluation of traditionally cultivated rice varieties of Goa, India. Recent Res. Sci. Technol. 2:88-97.

Billiris, M.A., T.J. Siebenmorgen, J.F. Meullenet and A. Mauromoustakos. 2012. Rice degree of milling effects on hydration, texture, sensory and energy characteristics. Part 1. Cooking using excess water. J. Food Eng. 113:559-568.

Champagne, E.T., L. Karen, A. Melissa, C. Casey, J. Lea, S. Jongdee, L. Xie, P.Z. Bassinello, A. Resurreccion, R. Ahmad, F. Habibi and R. Reinke. 2010. Important sensory properties differentiating premium rice varieties. Rice 3:270-281.

Diako, C., E. Sakyi-Dawson, B. Bediako-Amoa, F.K. Saalia and J.T. Manful. 2011. Cooking characteristics and variations in nutrient content of some new scented rice varieties in Ghana. Ann. Food Sci. Technol. 12:39-44.

Druvashree, R., R. Chandru and M.P. Rajanna. 2013. Grain quality and physico-chemical characteristics of some promising rice genotypes. Mysore J. Agric. Sci. 47:498-501.

Fitzgerald, M.A., S.R. McCouch and R.D. Hall. 2009. Not just a grain of rice: The quest for quality. Trends Plant Sci. 14:133-139.

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

Javed, M.K. 2004. Role of different storage temperatures in chemical and sensory characteristics of coarse varieties of rice. M.Sc (Hons) Thesis. Inst., Food Sci. Technol. Univ., Agri. Fsd., Pakistan.

Kanchana, S., S.L. Bharathi, M. Ilamaran and K. Singaravadivel. 2012. Physical quality of selected rice varieties. World J. Agric. Sci. 8:468-472.

Lee, Y., A. Mauromoustakos and Y. Wang. 2014. Effects of heat treatments on the milling, physicochemical, and cooking properties of two long-grain rice cultivars during storage. Cereal Chem. 91:56-64.

Lu, S., J.J. Chen, Y.K. Chen, C.Y. Lii, P. Lai and H.H. Chen. 2011. Water mobility, rheological and textural properties of rice starch gel. J. Cereal Sci. 53:31-36.

Mohapatra, D. and S. Bal. 2006. Cooking quality and instrumental textural attributes of cooked rice for different milling fractions. J. Food Eng. 73: 253-259.

Moongngarm, A. and N. Saetung. 2010. Comparison of chemical compositions and bioactive compounds of germinated rough rice and brown rice. Food Chem. 122:782-788.

Oko, A.O., B.E Ubi and N. Dambaba. 2012. Rice cooking quality and physicochemical characteristics: a comparative analysis of selected local and newly introduced rice varieties in Ebonyi State, Nigeria. Food Pub. Health. 2:43-49.

Payman, S.H., I. Bagheri and H. Zareiforoush.2014. Milling characteristics of rice grains as affected by paddy mixture ratio and moisture content. Int. J. Biosci. 4:87-97.

Rita, B. and A.K. Sarawgi. 2008. Agro-morphological and quality characterization of Badshah Bhog group from aromatic rice germplasm of Chhattisgarh. Bangladesh J. Agric. Res. 33:479-492.

Shabbir, M.A., F.M. Anjum, M.R. Khan, M. Nadeem and M. Saeed. 2013. Assessment of heavy metals and aflatoxins in export quality Indica rice cultivars in different milling fractions. Afr. J. Agric. Res. 8:3236-3244.

Shafie, B., S.C. Cheng, H.H. Lee and P.H. Yiu. 2016. Characterization and classification of whole-grain rice based on rapid visco analyzer (RVA) pasting profile. Int. Food Res. J. 23:2138-2143.

Shobana, S., N.G. Malleshi, V. Sudha, D.S. Piegelman, B. Hong, F.B. Hu, W.C. Willett, K. Krishnaswamy and V. Mohan. 2011. Nutritional and sensory profile of two Indian rice varieties with different degrees of polishing. Int. J. Food Sci. Nutr. 2:1-11.

Siddiq, E.A., L.R. Vemireddy and J. Nagaraju. 2012. Basmati Rice: Genetics, breeding and trade. Agric. Res. 1:25-36.

Siddiqui, S.U., T. Kumamaru and H. Satoh. 2007. Pakistan rice genetic resources- I: Grain morphological diversity and its distribution. Pak. J. Bot. 39:841-848.

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

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

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

Syafutri, M.I., F. Pratama, F. Syaiful and A. Faizal. 2016. Effects of varieties and cooking methods on physical and chemical characteristics of cooked rice**.** Rice Sci. 23:282-286.

Thomas, R., W.A. Nadiah and R. Bhat. 2013. Physiochemical properties, proximate composition and cooking qualities of locally grown and imported rice varieties marketed in Penang, Malaysia. Int. Food Res. J. 20:1345-1351.

Tong, C., Y. Chen, F. Tang, F. Xu, Y. Huang, H. Chen and J. Bao. 2014. Genetic diversity of amylose content and RVA pasting parameters in 20 rice accessions grown in Hainan, China. Food Chem. 161:239-245.

Usha, R., L. Menon, G. Gomathy, C. Parimala and R. Rajeshwari. 2012. Quality analysis of indigenous organic Asian Indian rice variety - *Salem Samba*. Ind. J. Trad. Knowl. 11:114-122.

Verma, D.K., M. Mohan, P.K. Prabhakar and P.P. Srivastav. 2015. Physico-chemical and cooking characteristics of Azad Basmati. Int. Food Res. J. 22:1380-1389.

Wang, K., J. Hasjim, C.A. Wu, R.J. Henry and R.G. Gilbert. 2014. Variation in amylose fine structure of starches from different botanical sources. J. Agric. Food Chem. 62:4443-4453.

Wua, Y., C. Pub, H. Linb, H. Huang, Y. Huang, C. Hong, M. Chang and Y. Lin. 2015. Three novel alleles of floury endosperm 2 (FLO2) confer dull grains with low amylose content in rice. Plant Sci. 233:44-52.

Xu, F.F., F.F. Tang, Y.F. Shao, Y.L. Chen, C. Tong and J.S. Bao. 2014. Genotype-environment interactions for agronomic traits of rice revealed by genome-wide association mapping. Rice Sci. 21:133-141.

Yadav, R.B., B.S. Khatkar and B.S. Yadav. 2007. Morphological, physicochemical and cooking properties of some Indian rice (*Oryza sativa* L.) cultivars. J. Agric. Technol. 3:203-210.

Zhong, Y., L. Wei, X.U. Xingfeng, L. Chengmei and T.U. Zongcai. 2014. Correlation analysis between color parameters and sensory characteristics of rice with different milling degrees. J. Food Proc. Preserv. 38:1890-897.