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Physicochemical, Pasting, Cooking and Textural Quality Characteristics of Some Basmati and Non-Basmati Rice Varieties Grown in India

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Abstract Physicochemical, cooking, pasting and textural properties of some Indian rice varieties of basmati (PB-1, PB-1401, P-2511, and PP-1509) and non-basmati (HKR-47, HKR-127) were studied. L/B ratio for the grains of all the studied varieties was more than 3.0 and the L/B ratio of basmati varieties grains was significantly higher than non-basmati grains ($p \leq 0.05$). The hardness of rice kernels varied from 64.6 to 213.7 N with P-2511 showing the highest hardness among all the varieties. PP-1509 and P-2511, PB-1 and PB-1401 cultivars had intermediate amylose content and HKR-47 and HKR-127 were grouped as low amylose containing cultivars. P-2511 exhibited the highest value of gelatinization temperature (70˚C). The water absorption index and water solubility index varied from 4.50 to 7.26 g/g and 2.00 to 7.66 % respectively. Rice flours from different cultivars showed different behavior in regard to their pasting characteristics including peak, hot paste and cold paste viscosities. PV and HPV of different flour samples varied from 620 to 2588 cP and 549 to 1853 cP respectively. The cooking time of different cultivars varied from 17 to 25 min with PB-1401 showed the highest water uptake ratio. Hardness value of the cooked rice cultivars varied from 1419.76 to 3417.56 g with maximum hardness observed in case of PB-1. Significant varietal differences were observed in the physicochemical, pasting, cooking and textural properties of studied rice cultivars.

Keywords: basmati rice, cooking characteristics, textural properties, pasting properties

Introduction

Rice is only the cereal crop cooked and consumed mainly as whole grain, and quality considerations are much more important than for any other food crop (Hossain *et al.*, 2009). Although production, harvesting and post harvesting operations affect overall quality of milled rice, cultivars remains the most important determinant of market and end use qualities. Quality desired in rice vary from one geographical region to another and consumer demand

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certain cultivars and favors specific quality traits of milled rice for home cooking (Juliano *et al*., 1964). One of the major concerns in rice production has to do with seed and grain quality (Traore, 2005). While many components contribute to rice quality, the most important are cooking and eating qualities. While many components contribute to rice quality, the most important are cooking and eating qualities. These parameters primarily involve the physical and chemical characteristics of starch. The constituents that play important roles in cooking and eating quality are amylose content, gelatinization temperature, and gel consistency (Traore, 2005). According to Horna *et al.* (2005) grain quality is one of the key selection criteria highly prioritized by farmers and consumers of rice and therefore farmer select rice with traits that are desirable for consumption as well as for production and sale. However defining quality is very difficult since it is defined by the end user and their preferences are highly variable.

There are several cultivars of rice under cultivation worldwide. These are selected based primarily on the quality of their seed and grain by consumers as well as producers (Horna *et al.*, 2005). The rice millers prefer cultivars with high milling and head rice out turn, whereas consumers prefer cooking and textural quality attributes (Merca and Juliano, 1981). Different cultures have different preferences regarding the taste, texture, colour and stickiness of the rice cultivars that they consume. For example, dry flaky rice is eaten in South Asia and the Middle East; moist sticky rice in Japan, Taiwan Province of China, the Republic of Korea, Egypt and northern China; and red rice in parts of southern India. The physical and mechanical properties of rice, which are important in the design and selection of storage structures and storage and processing equipment, depend on grain moisture content.

Therefore, the determination and consideration of properties such as bulk density, true density, angle of internal friction and static coefficient of friction of grain has an important role. Knowing the grain's bulk density, true density and porosity can be useful in sizing grain hoppers and storage facilities they can affect the rate of heat and mass transfer of moisture during the aeration and drying processes. The economic value of rice depends on its cooking and processing quality, which can be measured in terms of water uptake ratio, grain elongation during cooking, solids in cooking water and cooking time. Rice cultivars with amylose content of more than 25% absorb more water and have a fluffy texture after cooking. The cooking quality of rice is dependent on the large extent properties of starch, mainly amylose content (Juliano, 1985). Consumer choice of rice cultivars are largely based on cooking and eating qualities. Rice quality differs according to the variety as well as processing methods. The differences in quality which are mainly attributed to differences in colloidal structure and the extent of swelling of any variety of rice on cooking have always been used as index of its quality. The varietal differences in the quality characteristics of rice grain are attributed to differences in the physical composition and other functional parameters. Therefore, the present investigation was undertaken with a view to study the varietal impact on the quality characteristics of some recently released basmati and non-basmati Indian rice varieties.

Materials and methods

Materials

Four basmati (PB-1, PB-1401, P-2511, PP-1509) and two non-basmati (HKR-47, HKR-127) were respectively procured from Indian Agricultural Research Institute (IARI) Pusa, New Delhi and Rice Research Center of CCS Haryana Agricultural University, Hisar at Kaul (Kaithal) Haryana, India. All the varieties were released during 2005 to 2013. Paddy samples were parboiled at laboratory scale and samples were dehusked and polished uniformly using dehusker and polisher (Indosaw, India)

Physical quality characteristics of the grains

Length and breadth of raw rice kernels of six cultivars were measured by using vernier caliper. The measurements were repeated three times in each sample and thus an average of 10 grains was recorded. Ratio of length and breadth was represented as L/B ratio. Thousand kernel weights of grains of each variety was recorded in grams/1000 kernel as measured using the procedure given by AACC (2000) by counting and weighing 1000 clean, unbroken and sound kernels**.** Bulk density of kernels of milled rice was calculated as mass per unit volume (Kg/m^3). The particle density or true density was determined by measuring the actual volume of a known weight of a random grains sample. The actual volume of the grains was determined using the toluene displacement method (Matouk *et al.*, 2004). The volume of toluene displaced was found by immersing a weighed quantity of rice grains in the known volume of toluene taken in a measuring cylinder. The porosity is the ratio of free space between grains to total of bulk grains. The porosity was calculated from the following relationships suggested by Jouki and Khazaei (2012).

$$\text{Porosity } (P) = \frac{(Pg - Pb)100}{Pg}$$

Where P is the porosity in %, ρ_g is the bulk density in kg/m^3 and ρ_p is the particle density in kg/m^3.

Rice grain hardness was evaluated by compression test using a TA-XT-plus Texture Analyzer (Stable Micro Systems, UK). The following parameters were used: load cell = 50 kg, probe = aluminum cylinder with P/35(35 mm diameter), test speed = 5 mm/s, and trigger force = 0.2 g, strain = 95% (according to height), time 5 second. Grain hardness was defined as the maximum force needed to compress the disk to 40% of its height. The equivalent diameter (D) of grains was calculated by using the following relations as used by Sahay and Singh (1994)

$D = (L \times W \times T)^{1/3}$, Where, L=Length; W=Width; T = Thickness

The sphericity (φ) defined as the ratio of the surface area of the sphere having the same volume as that of grain to the surface area of grain, was determined using following formula as given by Jouki and Khazaei (2012).

$\varphi = \frac{D}{L}$, Where, D = Equivalent diameter; L = Length

Grain volume (V) and surface area (S) was determined by using the equation as used by Jouki and Khazaei (2012).

Grain volume $(V) = 0.25\left[\left(\frac{\pi}{6}\right)L(W+T)^2\right]$, Where, L = Length; W = Width; T = Thickness

Surface area $(S) = \frac{\pi B L^2}{(2L-B)}$

For determining chalkiness of the endoserms, 10 dehusked rice grains were placed on a light box and visually identified. The grains with more than 50% chalkiness were weighed and percentage of chalkiness was calculated by using method as given by Cruz and Khush (2000).

Chemical composition

The flour samples from different varieties were analyzed for ash, moisture, crude fat, protein using standard methods of AACC (2000). The amylose content was determined employing the method of William *et al.* (1970).

Functional properties

Gelatinization temperature (GT) was indexed by alkali spreading test. The degree of spreading of individual milled rice kernel in a weak alkali solution (1.7% KOH) at room temperature (32±2°C) was evaluated on a 7-point numerical scale (Jennings *et al*., 1979). Each test was conducted three times, each time, 10 intact milled grains were placed on a petri-dish to which 15 ml of 1.7% KOH was added. The grains were carefully separated from each other and incubated at ambient temperature for 23 h to allow spreading of the grains. Grains swollen to the extent of a cottony centre and a cloudy collar were given an alkali spread value (ASV) score 4 and used as check for scoring the rest of the samples in the population. Grains that were unaffected were given ASV of 1, and grains that were dispersed and disappeared completely were given a score of 10. A low ASV correspond to a high gelatinization temperature, conversely, a high alkali spreading value ASV indicates a low GT.

The WAI and WSI of rice flour samples were determined following the method described by (Kadan *et al.,* 2008). Dried flour sample (1.0g) was accurately weighed and suspended in 20 mL of distilled water and shaken in water- bath at 80°C for 30 min. The contents were centrifuged at 3000 rpm for 10 min. The supernatant was carefully poured into an aluminum dish of known weight before drying at 105°C for 10 h and weighing. The sediment was collected and weighed. The WAI and WSI were calculated from equations as given below

$$\text{WAI} = \frac{\text{Weight of wet sediment}}{\text{Dry Weight of flour}}$$

$$\text{WAI} = \frac{\text{Weight of dried solids in the supernatant x100}}{\text{Dry Weight of flour}}$$

The swelling power of rice flour samples was determined by measuring water uptake by the samples (Schoch, 1964). One gram (1.0g) of dried flour sample was accurately weighed and suspended in 20 ml of distilled water and shaken in water- bath at 80°C for 30 min. The content was centrifuged at 3000 rpm for 10 min. The supernatant was carefully poured into an aluminum dish of known weight before drying at 105°C for 10 h. The sediment collected and weighed. Swelling power was calculated using the equation as given below.

$$\text{Swelling power} = \frac{\text{Weight of sediment}}{\text{Weight of flour - weight of dried solids in supernatant}}$$

Pasting properties of rice flours

A rapid visco-analyser was employed to evaluate the pasting characteristics of rice flour samples according to the AACC 76-21 method. About 3 gm of rice flour was weighed and poured into distilled water in aluminium RVA canister the amount of water prescribed by the amount of moisture present in the flour. The content was quickly stirred using a plastic paddle for 10 times before insertion into Rapid Visco-Analyzer. The temperature profile consisted of equilibrating the flour suspension at 500 ˚C for 1 min, then heated to 950 ˚C within 3 min 42 s at 12.20˚C/min, and held at 950 ˚C for 2 min 30 s. It was subsequently cooled to 500 C within 3 min 48 s at 11.80 C/min, and held at 500 C for 2 min. The rotation speed was maintained at 160 rpm. The pasting characteristics: peak viscosity (PV), trough (T), breakdown (BD), final viscosity (FV), and setback from trough (SB) were determined from Newport Scientifics Thermo Cline for Windows software.

Cooking characteristics of rice grains

Cooking time was determined by boiling 2g of whole rice grain in 20 ml distilled water, according to prescribed time and temperature removing a few kernels at different time intervals during cooking and pressing them between two glass plates until no white core was left. Optimum cooking time was taken as the established cooking time plus two addition minutes (Bhattacharya and Sowbhagya, 1971). Elongation ratio was determined by using mm scale. Ten cooked grains were placed either length-wise (with their respective ends, germ or distal) on a flat plane surface along a millimeter scale. Cumulative length was noted and averaged. The measurements were repeated three times in each sample. The elongation ratio was computed as given below

$$\text{Elongation ratio} = \frac{\text{length of cooked grains}}{\text{length of uncooked grains}}$$

Water uptake ratio was determined by cooking 2 g of rice grain from each treatment in 20 mL distilled water for a minimum cooking time in a boiling water bath and draining the superficial water then weighed accurately. The water uptake ratio was calculated as the ratio of final cooked weight to uncooked weight. The amount of total solid loss in cooking water was determined by cooking 2 g rice 20 mL of distilled water for 20 min. The gruel solid was calculated by taking the difference in weight. To determine the volume expansion ratio, 15 mL of water was taken in 50 mL graduated centrifuge tubes and 5 g of rice sample was added. Then initially increase in volume after adding 5 g of rice was measured (Y) and soaked for 10 min. Increase of volume before cooking was noted (Y-15). Rice samples were cooked for 20 min on a water bath and placed on bloating paper. Then all the 5 g of cooked rice were placed in 50 mL water taken in 100 mL measuring cylinder and increase volume of cooked rice in 50 mL of water was measured (X). The elongation ratio was computed as following

$$\text{volume expantion ratio} = \frac{\text{length of cooked grains}}{\text{length of uncooked grains}}$$

Textural profile analysis of cooked rice

TPA was conducted using the TA-XT-plus Texture Analyzer (Stable Micro Systems, UK). Five grains were placed in a single layer and compressed using a 2-in.-diameter stainless steel cylinder. Pre-test speed was 1 mm/sec, and post-test speeds were 10 mm/sec. Samples were compressed 95%, held for 1 second, released and compressed again to complete the two-cycle compression test.

Statistical analysis

The data were analyzed using ‘OPSTAT’ statistical software. ANOVA was applied in a completely randomized model. The values were represented as mean $\pm$SD. The mean were compared at 5% level of significance.

Results and discussion

Physical quality characteristics of rice grains

The measured values for the different physical quality characteristics of the rice grains of various varieties are as given in Table 1. The varieties having L/B ratio below 2.5 are common, those having L/B ratio of 2.5 to 3.0 as fine and those having L/B ratio of 3.0 and above are super fine. Among the studied varieties, the value of L/B ratio for the grains of all the studied varieties was more than 3.0 suggesting that these are superfine varieties with long slender grains. However, the L/B ratio of basmati varieties grains was significantly higher than non-basmati grains ($p \leq 0.05$). Since kernel type and dimension are of importance to the millers and processors, these characteristics are considered in the breeding of a new variety. 1000-kernel weight and hectoliter weight varied from 14.96 to 21.60g and 9.57 to 10.63 kg respectively. The highest thousand-kernel weight was observed in PP-1509 which was significantly higher ($p \leq 0.05$) among all the cultivars and the lowest value was observed in PB-1401. These values of thousand-kernel weight observed in the present study are in agreement with those reported by Yadav *et al*. (2007) in Indian rice cultivars. The bulk density and particle density of various rice cultivars varied from 0.79 to 0.91g/ml and 4 to 9 g/ml respectively. The highest bulk density was recorded for HKR-127 while P-2511 was recorded for least value for bulk density. Bhattacharya *et al*. (1972) observed that bulk density is related to the kernel shape i.e L/B ratio, the more round the kernel greater the bulk density. Wide variations (25.24 to 83.33%) were observed in the chalkiness index of different cultivars. The chalkiness of different cultivars of rice was in the order of PB-1>PP-1509>HKR-47>P-2511>PB-1401>HKR-47. Although chalkiness cannot be seen after cooking, it is an important physical property that determines the market price of rice. The higher chalkiness of rice kernels could be due to long storage period (Shilpa *et al.*, 2010). The values of sphericity and porosity ranged from 44 to 57% and 79 to 89% respectively. The sphericity of HKR-127 was higher among all of the cultivar HKR-127 revealed the highest porosity. Knowing the grain's bulk density, particle density, and porosity can be useful in sizing grain hoppers and storage facilities; they can affect the rate of heat and mass transfer of moisture during aeration and drying processes (Nelson, 1980; Matouk *et al.,* 2004; Kheiralipour *et al.,* 2008). Cereal-grain kernel densities have also been of interest in breakage susceptibility and hardness studies (Chang, 1988). The hardness of rice kernels varied from 64.6 to 213.7 N. P-2511 showed the highest hardness among all the cultivars and lowest was observed for HKR-127 grains. Arrangement of starch granules within the endosperm and the protein content of the rice endosperm might affect the hardness of the kernels. Kernel hardness is used to describe whether the kernel is physically hard or soft based on the basis of texture of the endosperm. An increase in kernel hardness results in an increase in energy input during milling, cooking, flour granularity, damaged starch and water absorption properties (Pomeranz and Williams, 1990).

Table 1. Physical Quality characteristics of rice grains

Cultivars	1000 Kernel weight (g)	Length/ breadth ratio	Bulk density (g/ml)	Chalkiness index (%)	Hectoliter weight (kg)	Porosity (%)	Particle density (g/ml)	Sphericity (%)	Hardness (N)
HKR-47	18.03±0.03	3.48±0.01	0.91±0.01	45.33±1.50	10.38±0.04	85	9	55	155.6±4.5
HKR-127	17.96±0.03	3.36±0.07	0.92±0.00	25.24±1.24	10.63±0.08	89	9	57	141.7±4.8
PP-1509	21.60±0.06	4.25±0.02	0.81±0.02	55.59±1.58	9.57±0.03	79	4	49	64.6±2.9
P-2511	20.47±0.14	3.53±0.05	0.79±0.01	39.54±0.36	9.75±0.01	80	4	45	175.0±3.5
PB-1401	14.96±0.03	4.32±0.03	0.80±0.01	29.30±2.51	10.05±0.09	83	5	44	213.7±5.7
PB-1	15.33±0.03	4.16±0.01	0.82±0.01	80.19±1.51	9.66±0.06	86	6	44	177.0±4.1
CD	0.22	0.07	0.01	4.97	0.03	-	-	-	8.8

The values are mean±SD of three independent determinations (P<0.05).CD=Critical difference.

Chemical composition of the flour

The chemical composition of rice flour milled from different cultivars is shown in Table 2. The moisture content of different cultivars varied from 10.50 to 12.09% being suitable for storage purpose. Yadav *et al.* (2007) reported moisture content varying from 11.64 to 12.72 % for different Indian rice cultivars. Significant differences in the ash content of the different varieties were observed ($p \leq 0.05$) and it varied from 0.30 to 0.60 %. The ash content of the basmati varieties was significantly higher than non- basmati varieties ($p \leq 0.05$). Protein content of different cultivars ranged from 5.28 to 8.87 %. The order for the protein content of different cultivars was PP-1509>P-2511>PB-1401>HKR-127>HKR-47>PB-1. Fat content of different rice cultivars varied from 0.43 to 0.80%. HKR-47 had highest fat content and PP-1509 contained lowest fat content. The amylose content of different rice cultivars ranged from 5.19 to 23.10% and the basmati varieties showed significantly higher amylsoe content as compared to non-basmati varieties ($p \leq 0.05$). The highest amylose content was observed in PP-1509 (Basmati) and lowest in HKR-127 (Non-

Basmati) variety. Rice can be grouped based on their amylose content into waxy (0-2%) very low (3-9%), intermediate (20-25%) and high above 25% amylose content amylose containing cultivars (Cruz and Khush, 2000). Our results indicated that PP-1509 and P-2511, PB-1 and PB-1401 cultivars had intermediate amylose content and HKR-47 and HKR-127 were grouped as low amylose containing cultivars. Amylose Content (AC) is considered the single most important character for predicting rice cooking and processing behavior (Juliano 1979; Webb, 1985).

Table 2. Chemical composition of rice grains

Cultivars	**Moisture (%)**	**Protein (%)**	**Fat (%)**	**Ash (%)**	**Amylose (%)**
HKR-47	12.04±0.05	5.43±0.56	0.80±0.01	0.27±0.03	6.29±0.02
HKR-127	12.09±0.07	5.45±0.21	0.76±0.09	0.30±0.00	5.19±0.23
P P-1509	10.50±0.06	8.87±0.13	0.43±0.02	0.60±0.01	23.10±1.80
P-2511	10.52±0.01	8.32±0.85	0.51±0.00	0.51±0.01	21.90±0.27
PB-1401	11.11±0.08	6.88±0.23	0.65±0.01	0.44±0.01	18.50±0.06
PB-1	11.62±0.01	5.28±0.42	0.65±0.02	0.41±0.02	18.81±0.38
CD	0.02	1.20	0.04	0.008	1.63

The values are mean±SD of three independent determinations ($P<0.05$), CD= Critical difference

Functional properties

The results of the various functional properties are elaborated in Table 3.

Alkali spreading value and gelatinization temperature

Estimate of the gelatinization temperature is indexed by the alkali digestibility test (Little et al., 1958). The alkali spreading value has been used to measure gelatinization temperature of rice and hence has been used for many years to categorize cooked rice properties (Patil *et al.*, 2012). The degree of spreading value of individual milled rice kernels in a weak alkali solution (1.7% KOH) is very closely correlated with gelatinization temperature. Rice with low gelatinization temperature disintegrates completely, whereas rice with intermediate gelatinization temperature shows only partial disintegration. Rice with high gelatinization temperature remains largely unaffected in the alkali solution. The gelatinization temperature of rice varieties may be classified as low (55 to 69^{o}C), intermediate (70 to 74^{o}C) and high (> 74^{0}C) (Cruz and Khush, 2000). The ASV of all rice cultivars ranged from level 1-7. The alkaline spreading values were observed in order of HKR-47>HKR-127>PP-1509>PB-1401>P-2511>PB-1. Based upon alkali spreading values, the result of the present study indicated that basmati rice cultivars had high gelatinization temperature in comparison with non-basmati cultivars. Among basmati cultivars P-2511 exhibited the highest value of gelatinization temperature (70˚C).

Table 3. Functional properties of rice flours

Cultivars	WAI	WSI	SP	GT (˚C)	ASV
HKR-47	5.12 ± 0.09	7.66± 0.33	5.05±0.06	55	7
HKR-127	7.26 ± 0.05	2.33 ± 0.33	7.25±0.06	54	7
PP-1509	4.50 ± 0.01	4.66 ± 0.33	4.46±0.02	64	3
P-2511	6.16 ± 0.02	3.66± 0.33	6.13±0.01	70	2
PB-1401	5.41± 0.02	2.33± 0.33	5.40±0.03	60	3
PB-1	5.90 ± 0.02	2.00± 0.33	5.89±0.05	60	2
CD	0.09	1.038	0.119	-	-

WAI=Water absorption index, WSI=Water solubility index, SP=Swelling power, GT=Gelatinization temperature, ASV=Alkali spreading value.
The values are means±SD of three independent determinations (P<0.05).
CD=Critical difference

Water absorption index (WAI) and water solubility index (WSI)

The water absorption index and water solubility index varied from 4.50 to 7.26 g/g and 2.00 to 7.66 % respectively. The highest WAI was observed in HKR-127 and the lowest value was observed in PP-1509. The order for the WSI of different cultivars was HKR-47>PP-1509>P-2511>PB-1401>HKR-127 and PB-1. Water solubility index provide evidence of the magnitude of the interaction between starch chains within both the amorphous and crystalline domains (Singh *et al.*, 2007).

Swelling power

The swelling power varied from 5.05 to 7.25 g/g. The highest swelling power was observed in HKR-127 and lowest was in PP -1509. Swelling power of starch is attributed to the strength and character of the micellar network within the starch granule. As the temperature was increased, the starch granules were vibrated more vigorously, breaking intermolecular bonds and allowing hydrogen-bonding sites to engage more water molecules (Iranna *et al.*, 2012).

Pasting properties of rice flour

The values for various pasting parameters of different rice cultivars are given in Table 4. Rice flours from different cultivars showed different behavior in regard to their pasting characteristics including peak, hot paste and cold paste viscosities. PV and HPV of different flour samples varied from 620 to 2588 cP and 549 to 1853 cP respectively. The highest PV was observed in HKR-47 and lowest was in P-2511. Peak viscosity is an indicator of ease with which the starch granule are disintegrated and often correlated with final product quality (Thomas and Atwell, 1999). The maximum HPV was observed in HKR-47 and minimum was observed in PB-1401. The breakdown which is measure of structural disintegration of starch during cooking was observed to be highest (735 cP) in HKR-47 and lowest (60 cP) was observed in P-2511. The final viscosity also called as cold paste viscosity (CPV), which is the change in the viscosity after holding cooked starch at 50°C ranged from 3990 (HKR-47) to 1055 (PB-1401). Final viscosity is commonly used to define the quality of particular starch based flour, since it indicates the ability of the flour to form a viscous paste after cooking and cooling. It also gives a measure of the resistance of paste to shear force during stirring (Adebowale *et al*., 2008). The difference in breakdown is related to difference in the rigidity of swollen granules (Rani and Bhattacharya, 1995). Setback, which is a measure of retrogradation tendency of the starch, was observed to be highest in HKR-127 (2174 cP) and lowest was observed in PB-1401 (506 cP). Amylose is believed to have a marked influence on the breakdown viscosity (a measure of susceptibility of cooked starch granule to disintegration) and the setback viscosity (which is measure of recrystallization of gelatinized starch during cooling) (Lee *et al*., 1995). High amylose content has also been suggested as the major factor contributing to the non-existence of a peak, a high stability during heating, and a high setback during cooling (Lii and Chang, 1981; Jin *et al*., 1994). The pasting temperature of the basmati cultivars was observed to be higher than no-basmati varieties with PP-1509 and PB-1401 showing the highest pasting temperatures. The temperature at the onset of this rise in viscosity is known as the pasting temperature. The pasting temperature provides an indication of the minimum temperature required to cook for a given rice sample.

Table 4. Pasting properties of rice flours

Cultivars	PV	HPV	BD	CPV	SB	Peak time	Pasting temperature
HKR-47	2580	1853	735	3990	2145	5.49	81.5
HKR-127	2325	1676	649	3850	2174	5.33	84.3
P P-1509	620	555	65	1783	1228	7	95.2
P-2511	636	576	60	1821	1245	7	94.8
PB-1401	705	549	156	1055	506	7	95.3
PB-1	785	785	167	1407	789	7	94.5

PV=Peak viscosity, HPV=Hot paste viscosity, BD=Breakdown, CPV=Cold paste viscosity, SB=Set back, Pasting viscosities values are in RVU

Cooking characteristics of the milled rice grains

Cooking time

The cooking time of different cultivars varied from 17 to 25 min as shown in Table 5. Basmati rice grains revealed higher cooking time in comparison with non-basmati varieties. Among the various rice cultivars, PP-1509 had the highest cooking time while lowest was observed in HKR-47 and HKR-127. The variation in cooking time could be traced to its gelatinization temperature since gelatinization temperature positively determines the cooking time of rice (Patil *et al*., 2012). Gelatinization temperature and cooking time of milled rice are positively correlated (Juliano *et al.,* 1964*).* Rice with high GT takes longer time to cook than do low-GT types. On the contrary Bhattacharya and Sowbhagya (1971) observed that water uptake and cooking time are strongly influenced by size and shape of rice grain and only marginally by GT.

Gruel solid loss

The solid loss of cooked rice grains ranged from 2.12 to 6.23 % (Table 5). The highest solid loss was observed in HKR-127 which was significantly higher ($p \leq 0.05$) among all cultivars while the lowest was observed in PP-1509.

Solids released by rice into cooking water have also been considered as a cooking quality attributes (Julino, 1985). Solids in cooking water may be correlated with amylose content and may be related to stickiness of cooked rice. Patil *et al*. (2012) concluded that non basmati cultivars showed highest solid loss as compare to basmati cultivars.

Water uptake ratio

The water uptake ratio ranged from 2.40 to 3.26 g/g. PB-1401 showed the highest water uptake ratio while P-2511 showed the lowest value. It has been reported in previous study that cell wall of basmati cultivars was more compact as compared to non-basmati cultivars (Patil *et al.*, 2012). The extent of water absorbed by rice during cooking is considered and economic quality as it gives some estimate of the volume increase during cooking.

Volume expansion ratio and elongation ratio

Significant differences were observed in the elongation ration of different rice varieties upon cooking ($p \leq 0.05$). The highest elongation ratio was observed in PB-1401 and lowest in HKR-127. Length wise expansion without increase in girth is considered a highly desirable trait in some high quality rice such as basmati rice of India and Pakistan. This characteristic which is unique for basmati types is being incorporated into improved germplasm through conventional methods which resulted in the development of several high yielding basmati varieties (Shobha Rani *et al*., 2001).The volume expansion ratio and elongation ratio ranged from 1.19-1.35 ml and 1.54 to 3.21 mm respectively in all the cultivars. In the present study it was found that highest volume expansion ratio was in PP-1509 and P-2511 and lowest was observed in HKR-47.

Table 5. Cooking quality characteristics of rice grains

Cultivars	Cooking time(min)	Solid loss (%)	Water uptake ratio(g/g)	Elongation ratio	Volume expansion ratio
HKR-47	17.5±0.8	6.20±0.07	3.26±0.06	1.60±0.02	1.19±0.03
HKR-127	17.0±0.7	6.23±0.02	3.10±0.07	1.54±0.01	1.20±0.01
P P-1509	25.5±0.2	2.12±0.04	2.65±0.05	2.67±0.03	1.35±0.00
P-2511	24.8±0.6	2.15±0.02	2.40±0.02	1.80±0.01	1.35±0.04
PB-1401	22.3±0.7	3.82±0.03	3.21±0.03	1.71±0.02	1.26±0.02
PB-1	21.0±0.3	3.22±0.04	2.81±0.02	1.83±0.02	1.26±0.01
CD	0.5	0.04	0.09	0.08	0.01

The values are mean ± SD of three independent determinations ($P<0.05$).
CD=Critical difference.

Texture profile analysis (TPA) of cooked rice

The TPA of cooked rice was determined using the compression method and the results pertaining to textural properties are presented in Table 6.

Table 6. Textural profile analysis of cooked rice

Cultivars	**Hardness (g)**	**Adhesiveness (g.sec)**	**Springiness**	**Cohesiveness**	**Gumminess (g)**	**Chewiness (g)**	**Resilience**
HKR-47	1734.51±25.28	734.94±9.2	0.024±0.002	0.570±0.005	988.5±18.95	24.00±1.06	1.18±0.17
HKR-127	1662.20±21.80	374.70±16.0	0.019±0.001	0.439±0.061	768.49±10.6	15.62±6.72	1.25±0.28
P P-1509	1996.08±31.7	343.54±13.0	0.026±0.001	0.562±0.025	1073.8±10.93	28.053±0.54	1.21±0.12
P-2511	2333.31±18.8	338.20±14.7	0.030±0.001	0.450±0.006	1054.3±15.3	32.21±6.02	0.76±0.04
PB-1401	1419.25±3.85	281.08±13.0	0.022±0.001	0.506±0.02	719.07±16.5	15.36 ±0.09	1.25±0.20
PB-1	3417.15±25.9	240.22±10.2	0.038±0.001	0.592±0.02	2022.6±17.1	76.50±5.35	1.39±0.07
CD	592.06	199.60	0.004	0.098	406.76	13.43	0.05

. The values are mean ±SD of three independent determinations ($P<0.05$), CD=Critical difference.

The maximum force required during the first cycle of compression was hardness. Hardness of the cooked rice cultivars varied from 1419.76 to 3417.56 g. The maximum hardness was observed in PB-1 which was significantly higher ($p\leq0.05$) among all cultivars while P-1401 had the minimum hardness. The adhesiveness was the maximum negative force observed during first compression cycle. The adhesiveness of cooked rice ranged from -240.22 to-734.94 g/sec. The highest adhesiveness was measured in HKR-47 which was significantly higher ($p\leq0.05$) than all other cultivars. Springiness measure the recovered height between two cycles and it was measured highest in case of PB-1 (0.038) while lowest was observed in HKR-127. The cohesiveness is the ratio of positive area during the second cycle of compression to that of the first cycle. It determines the behavior of intermolecular attraction within the product. Maximum cohesiveness was observed in PB-1 while the minimum was observed in HKR-127. The gumminess of cooked rice cultivars varied from 719.070 to 2022.68 g. Resilience defines the elastic recovery of the sample from deformation and it was observed maximum in PB- 1 (1.39) while minimum was observed in P-2511 (0.76).

Conclusion

Varietal differences were observed in the studied cultivars of rice in relation to their physicochemical, functional, pasting, cooking and textural quality attributes. The grains of all the cultivars were observed to be fine grains. Among the studied varieties HKR-47 and HKR-127 rice cultivars showed good physical characteristics (maximum hulling, HR recovery, L/B ratio). The chemical properties (Amylose content, alkali spreading value, gel consistency) were excellent in basmati cultivars. The best cooking quality (appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation) was observed in the rice varieties PP-1509, P-2511, PB-1 and PB-1401.

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