Morphological, physicochemical and cooking properties of some Indian rice (*Oryza sativa* L.) cultivars

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Morphological, physicochemical and cooking properties of some Indian rice cultivars (four non-basmati, namely Jaya, P-44, HKR-120, Sharbati and two basmati, namely HBC-19 and Bas-370) were studied. Length and breadth of milled raw rice varied from 5.85 to 8.25 mm and 1.65 to 2.93 mm, respectively. HBC-19 had the highest length, whereas Jaya variety had smallest kernel with a length of 5.85mm. Different cultivars showed significant variations in their morphological, physico-chemical and cooking properties. Basmati cultivars showed a higher elongation ratio, a higher water uptake ratio and a lower solid loss in gruel, than the non-treated cultivars. Water uptake was observed to be correlated positively with L/B ratio ($r=0.837$, $p<0.05$) and hardness ($r=0.907$, $p<0.05$). The water uptake and elongation ratio of rice kernels were observed to show highly significant and positive correlation with amylose content, with a correlation coefficient of 0.922 and 0.941 respectively ($p<0.01$). The elongation ratio of cooked kernels showed a highly significant and positive correlation with L/B ratio ($r=0.945$, $p<0.01$) and hardness ($r=0.933$, $p<0.01$) of raw kernels. Cooking time also had a highly significant and positive correlation with hardness ($r=0.970$, $p<0.01$), water uptake ($r=0.939$, $p<0.01$) and amylose content ($r=0.917$, $p<0.01$).

Key words: physicochemical property, rice (*Oryza sativa* L.)

Introduction

Rice (*Oryza sativa* L.) is the staple food of the Indian population, consumed mainly in the form of whole grains. Rice has a great diversity in its genetic background, amylose content, grain shape, and cooking quality. Varietal properties such as grain size, shape, thousand-kernel weight, hardness and bulk density affect the grain quality. The cooking quality of rice is dependent to a large extent on the properties of starch, mainly amylose content

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(Juliano, 1985). On the basis of amylose content, milled rice is classified as waxy (0-2% amylose, dry basis), low (10-20%), intermediate (20-25%) and high (>25). During cooking, amylose leaches out of the starch granule and retrogrades or stales when cooled, whereas amylopectin remains in the gelatinized granule. Amylose content of milled rice has been found to be correlated positively with hardness values of cooked rice and negatively with stickiness values (Juliano et al., 1965; Perez and Juliano, 1979). Cooked rice with low amylose is soft and sticky, while rice with high amylose is firm and fluffy. The high levels of amylose cause rice to absorb more water and expand more during cooking, and the grains tend to cook dry, fluffy, and separate (Juliano, 1971). The morphological, physico-chemical, nutritional, milling, cooking, eating, and textural properties determine the overall assessment of a rice grain. The present investigation was to study morphological, physicochemical and cooking properties of some of the Indian rice cultivars.

Materials and methods

Six paddy cultivars i.e. four non-basmati (Jaya, a coarse variety, P- 44 and HKR- 120, the medium varieties, Sharbati, fine variety) and two basmati (HBC-19 and Bas-370) were procured from the Rice Research Centre of CCS Haryana Agricultural University, Hisar at Kaul (Kaithal) Haryana, India. Paddy samples were dehusked and polished uniformly utilizing the locally available milling facilities.

Morphological and physical properties of milled rice grain

Length and breadth of raw rice kernels of six cultivars were measured by using Vernier caliper. The measurements were repeated 10 times in each sample and thus an average of 10 grains was recorded. Ratio of length and breadth gave L/B ratio. The 1000 kernels from each cultivar were counted randomly in triplicate and weighed separately to determine 1000 kernel weight. Grain hardness was determined as force required to break a kernel using texture analyzer (TA.XT Plus, Stable Microsystems, U.K.) at a crosshead speed of 5 mm/s. Bulk density of kernels of milled rice was calculated as mass per unit volume.

Chemical properties of rice flour

The kernels were ground to flour in a milling machine (Navdeep flour mill) with sieve No.1. Moisture, ash, fat and protein contents were determined using the standard methods of analysis (AOAC, 1984). Starch content of rice flour was determined by using the method of Clegg (1956). Amylose content was determined by using the method of Williams et al. (1970).

Cooking properties of milled rice

The milled head rice (2 g) of each cultivar was taken in a 50 ml test tube and cooked with 20 ml distilled water in a boiling water bath. The minimum cooking time was determined by removing a few kernels at different time intervals during cooking and pressing between two glass plates till no white core was left. The cooked rice kerenls were drained and pressing the cooked samples in filter paper sheets sucked superficial water present on cooked rice. The cooked samples were weighed accurately and water uptake was determined. Solid loss in gruel was determined by drying an aliquot of cooking water in a petri dish at 110°C in a hot air oven until completely dry. Elongation and width ratios were determined by using millimeter scale. Ten cooked grains were placed either length-wise (with their respective ends, germ or distal) or breadth-wise (with their respective sides, dorsal, ventral touching each other), on a flat plane surface along a millimeter scale. Cumulative length and breadth were noted and averaged. The measurements were repeated three times in each sample.

Statistical analysis

The data were analyzed statistically by using one factor analysis of variance (ANOVA) in a completely randomized design by using Opstat. Pearson correlation coefficients (r) were calculated by using SPSS 11.0 statistical software.

Results and discussion

Morphological and physical properties of milled rice grain

The morphological and physical properties of milled rice are shown in Table 1. Significant differences in the grain dimensions were noted ($P \leq 0.05$). Length and breadth of milled raw rice varied 5.85 to 8.25 mm and 1.65 to 2.93 mm, respectively. HBC-19 had the highest length, whereas, Jaya variety had the smallest kernel with a length of 5.85 mm. The Jaya cultivar having L/B ratio less than 2.0 was categorized as short grain variety, HKR-120 and P-44 rice cultivars having L/B ratio less than 3.0 were termed as medium grain varieties and Sharbati, Bas-370 and HBC-19 having L/B ratio greater than 3.0

were categorized as long grain varieties (FAO/WHO, 1995). Significant variation in thousand-kernel weight was reported (P≤0.05), except between Sharbati and Bas-370. Sharbati cultivar had the lowest thousand-kernel weight i.e.14.82 g whereas Jaya showed the highest value for thousand-kernel weight (21.02g). There were significant differences in hardness between Jaya and Bas-370 and between Jaya and HBC-19 (P≤0.05). Kernels of Bas-370 and HBC-19 cultivars showed greater hardness as compared to that of other cultivars. Significance difference in bulk density was obtained between Jaya and other cultivars (P≤0.05). The bulk densities of various rice cultivars varied between 0.83 to 0.92g/ml, higher for coarse grains. Bhattacharya *et al.* (1972) observed that bulk density is related to the kernel shape i.e. L/B ratio, the more round the kernel, the greater the bulk density.

Table 1. Morphological and physical properties of milled rice from different rice cultivars.

Cultivar	Length* (mm)	Breadth* (mm)	L/B ratio	Thousand** kernel weight (g)	Hardness** (kg)	Bulk density** (g/ml)
Jaya	5.85±0.07	2.93±0.06	1.99	21.02±0.25	8.47±0.87	0.92±0.02
HKR120	6.78±0.06	2.35±0.03	2.88	19.67±0.09	10.89±1.16	0.87±0.01
P-44	7.45±0.03	2.56±0.06	2.91	17.13±0.14	11.34 ±0.84	0.86±0.01
Sharbati	7.89±0.05	1.87±0.04	4.22	14.82±0.04	11.19 ±1.19	0.86±0.01
Bas-370	7.25±0.03	1.65±0.06	4.39	15.18±0.08	14.18±0.79	0.84±0.03
HBC-19	8.25±0.06	1.91±0.05	4.32	17.03±0.09	15.77±1.10	0.83±0.01

*The values are mean ± SD of ten independent determinations at 5% level of significance.
**The values are mean ± SD of three independent determinations at 5% level of significance.

Chemical properties of rice flour

Table 2 depicts the chemical properties of different rice cultivars. The moisture content of different rice cultivars was found to range from 11.64 to 12.72%. The ash content and protein contents of different rice cultivars ranged from 0.31 to 0.67% and 5.46 to 7.02%, respectively. Jaya cultivar differed significantly in its ash content from other cultivars (P≤0.05). No significant difference in ash content was observed between P-44 and HBC-19. Jaya cultivar differed significantly from all others, except HKR-120 in its protein content (P≤0.05). No significant difference was observed in the fat contents of different non-basmati and basmati cultivars (P≤0.05). The starch content from different rice cultivars varied from 68.73 to70.24%, which the highest for Jaya and the lowest for Bas-370. No significant difference in the starch content of different cultivars was obtained (P≤0.05). The amylose content from different cultivars varied significantly and ranged between 2.25 to 22.21%. Jaya showed the lowest amylose content whereas HBC-19 showed the highest amylose content.

Table 2. Chemical properties of milled rice from different rice cultivars.

Cultivar	Moisture conten (%)	Protein content (%)	Ash (%)	Fat (%)	Starch content (%)	Amylose content (%)
Jaya	12.55±0.08	5.46±0.23	0.31±0.04	0.82±0.07	70.24±1.22	2.25±0.09
HKR120	12.15±0.04	5.59±0.12	0.40±0.05	0.78±0.08	69.43±1.47	4.32±0.08
P-44	12.72±0.05	6.26±0.27	0.67±0.05	0.72±0.04	70.10 ±0.69	5.97±0.09
Sharbati	11.64±0.06	6.52±0.12	0.41±0.04	0.66±0.08	69.88 ±1.32	7.10±0.07
Bas-370	11.85±0.05	7.02±0.16	0.44±0.06	0.65±0.08	68.73±0.71	20.58±0.06
HBC-19	11.90±0.03	6.94±0.14	0.67±0.05	0.54±0.06	69.25±1.21	22.21±0.02

The values are mean± SD of three independent determinations at 5% level of significance.

Cooking properties of milled rice

The cooking characteristics of various cultivars are presented in Table 3. The cooking time of milled rice from different cultivars varied from 16.5 to 18.3 min, which the highest for HBC-19 and the lowest for Jaya. No significant difference was observed in cooking time of different cultivars (P≤0.05). HBC-19 showed the highest water uptake of 4.63g/g while HKR-120 cultivar showed the least value of 2.89g/g. No significant difference in the water uptake of P-44 and Sharbati was observed (P≤0.05). Gruel solid losses of all the cultivars varied significantly (P≤0.05). Jaya showed the highest gruel solid losses (5.20%) and HBC-19 showed the lowest value of 2.51%. Vaingankar and Kulkarni (1986) observed that basmati rice gave thin gruel as compared to non-basmati rice. Hirannaiah *et al*. (2001) reported that during soaking, kernels of non-basmati rice suffer cracking, the cell contents become rather loose and leach out easily during cooking, resulting in a higher solid loss. It has been reported that cell walls of basmati are more compact as compared to those in non-basmati rice (Beerh and Srinivas, 1991).

No significant difference in the elongation ratio was observed between two basmati cultivars i.e. Bas-370 and HBC-19 (P≤0.05). Significant differences in the elongation ratios were observed between basmati and non-basmati cultivars (P≤0.05). HBC-19 showed the highest elongation ratio i.e. 1.89 and the lowest width ratio of 1.14, while reverse was observed for Jaya. This is supported by the earlier findings that basmati cultivars showed higher elongation ratio, volume expansion ratio and water uptake ratio (Khan and Ali, 1985).

Table 3. Cooking properties of milled rice from different rice cultivars.

Cultivar	Cooking time (min)	Water uptake (g/g)	Solid loss in gruel (%)	Elongation ratio	Width ratio
Jaya	16.50±0.40	3.05±0.04	5.20±0.05	1.52±0.06	1.57±0.06
HKR-120	17.03±0.61	2.89±0.03	4.89±0.03	1.58±0.06	1.56±0.02
P-44	17.40±0.23	3.54±0.06	3.82±0.06	1.66±0.02	1.46±0.06
Sharbati	17.53±0.43	3.73±0.33	3.21±0.07	1.75±0.04	1.39±0.04
Bas-370	18.00±0.46	4.14±0.05	2.85±0.06	1.88±0.05	1.20±0.05
HBC-19	18.30±0.63	4. 63±0.05	2.51±0.03	1.89±0.03	1.14±0.02

The values are mean± SD of three independent determinations at 5% level of significance.

Correlations among various physico-chemical and cooking properties

Pearson correlation coefficients for relationships among various physico-chemical and cooking properties of different rice cultivars have been shown in Table 4. Water uptake was positively correlated with L/B ratio ($r=0.837$, $p<0.05$) and hardness ($r=0.907$, $p<0.05$). Bhattacharya and Sowbhagya (1971) have also reported a strong positive correlation between water uptake and L/B ratio. Solid loss in gruel had a significant negative correlation with L/B ratio ($r= -0.938$, $p<0.01$) and water uptake (-0.954, $p<0.01$). Similar observations regarding the correlation of solid loss in gruel with L/B ratio and water uptake have been taken by Vaingankar and Kulkarni (1986). Elongation ratio had a highly significant and positive correlation with L/B ratio ($r=0.945$, $p<0.01$) and water uptake ($r=0.952$, $p<0.01$). The results of this study are in accordance with those reported earlier by Khan and Ali (1985). Cooking time was observed to have a highly significant and positive correlation with hardness ($r=0.970$, $p<0.01$) and water uptake ($r=0.939$, $p<0.01$). Amylose content had a highly significant positive correlation with water uptake ($r=0.922$, $p<0.01$) and elongation ratio ($r=0.941$, $p<0.01$). Inatsu et al. (1974) have also reported a positive correlation between amylose content and water uptake ratio.

Table 4. Pearson correlation coefficients between various physico-chemical and cooking properties of different rice cultivars

	L/B ratio	1000 kernel weight	Hardness	Bulk density	Cooking time	Water uptake	Solid loss	Elongation ratio	Width ratio
1000 kernel weight	-0.886*								
Hardness	-0.882*	-0.605							
Bulk density	0.837*	0.764	-0.929**						
Cooking time	0.916*	-0.769	0.970**	-0.959**					
Water uptake	0.837*	-0.688	0.907*	-0.806	0.939**				
Solid loss	-0.938**	0.866*	-0.884*	0.890*	-0.966**	-0.954**			
Elongation ratio	0.945**	-0.805	0.933**	-0.893*	0.974**	0.952**	-0.975**		
Width ratio	-0.876*	0.690	-0.945**	0.837*	-0.954**	-0.978**	0.943**	-0.981**	
Amylose	0.809	-0.569	0.956**	-0.812*	0.917**	0.922**	-0.860*	0.941**	-0.977**

* $p<0.05$; ** $p<0.01$.

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