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Physical properties and food value of rice varieties of Western Himalaya

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Six rice varieties namely *Bhrigu Dhan*, *Begami*, *Desi Dhan*, *Paddy Karad*, *Sukara Dhan* and *Lal Dhan* grown in the westeren Himalaya, as a dehulled rice grain, were evaluated with the aim of establishing their specific food value. Length, breadth, length/breadth ratio, thousand -kernel weight, density, and bulk density of all varieties were in the range of 7.80-8.70 (mm), 3.12-3.68 (mm), 2.15-2.74,13.79-28.66 (g), 0.10-1.25 (g/mL) and 0.477-0.657 (g/mL), respectively. Maximum length (8.70 mm), 1000 kernel weight (28.66 g) and bulk density (1.25g/mL) were observed for *Bhrigu Dhan.* Moisture content, crude fat, crude fibre and ash, were in the range of 11.21 to 12.92, 2.35 to 3.26, 2.22 to 2.69 and 1.60 to 1.79 per cent, respectively on dry weight basis. The highest and lowest value for crude protein was recorded in *Desi Dhan* (12.00%) and *Bhrigu Dhan* (7.66 %), respectively; and total carbohydrates were observed highest in *Bhrigu Dhan* (86.88%) and lowest in *Desi Dhan* (82.44%). The starch content ranged between 81.63 to 88.56%. The total sugar content was highest in *Sukara Dhan* (1.40%) followed by *Desi Dhan* (1.35%), *Lal Dhan* (1.32%), *Paddy Karad* (1.29%), *Begami* (1.25%) and minimum was in *Bhrigu Dhan* (1.05%), respectively. The highest content of free fatty acid was present in *Begami* (0.377%) and minimum in *Sukara Dhan* (0.293%) whereas, the maximum amount of free amino acid was present in *Bhrigu Dhan* (0.443% as glycine) and minimum was present in *Begami* (0.333% as glycine). *Begami* had highest content of iron and zinc (8.95 and 9.77 mg/100gm). However maximum values for phosphorus and copper were observed for *Sukara Dhan* 311.05 and 3.020 mg/100 g respectively. The maximum content of magnesium was observed in *Paddy Karad* 137.33 mg/100 g and manganese in *Bhrigu Dhan* 3.49 mg/100 g. The highest total phenolic content observed in *Lal Dhan* (297.45 mg GAE/100 g) and lowest in *Begami* (231.66 mg GAE/100 g). The amylose content of red rice varieties varied from 23.56 to 26.55%. Highest amylose value was recorded in *Lal Dhan* (26.55%) and lowest in *Sukara Dhan* (23.56%). The data for the sensory evaluation of cooked red rice revealed that the appearance score was highest in variety *Lal Dhan*, and *Paddy Karad*.

Keywords: Anti-nutritional factors, Cooking quality, Flavonoid content, Rheological properties**,** Sensory evaluation, Total phenols.

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Introduction

Rice is the seed of the monocot plant of the genus *Oryza*, which belongs to the grass family Poaceae (formally Graminae) that includes twenty wild species and two cultivated ones, *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice). *O. sativa* is the most commonly grown species throughout the world today. Rice has been considered the best staple food among all cereals and is the staple food for over 3 billion people, constituting over half of the world's population[1]. Minerals like calcium, magnesium, phosphorus are present along with some traces of iron, copper, zinc and manganese[2]. There are many types of rice grown around the world and they exhibit a diverse array of properties. It is well-known fact that different rice varieties exhibit compositional variation for protein, lipid, starch content (amylose and amylopectin) and other minerals and vitamins. These compositional differences contribute to the diversity of chemical and physical properties of rice such as viscosity, starch gelatinization and water absorption[3]. These properties influence the eating and cooking quality of rice and have a considerable effect on quality characteristics of end products such as bread, noodles and other extruded products made from rice flour. Moreover, the chemical and nutritional quality of rice grain varies considerably and this may be attributed to genetic factors, environmental influences, and fertilizer treatments, degree of milling and storage conditions[4]. Coloured rice posses unique colour and flavour, therefore they are used as an

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ingredient in many dishes[5]. Positive health effects of the pigments present in the bran layer of rice have been reported. A commonly found anthocyanin in coloured rice is procyanidins, which is reported to possess a free radical scavenging activity[6]. Despite its great importance, this cereal is classified on the base of its industrial and commercial parameters, and not on its nutritional value, which is the most important parameter to compose a balanced diet[7]. The specific colour of rice is formed by deposits of anthocyanins in different layers of the pericarp, seed coat and aleurone[8]. The phenolic compounds have been found as a major active component for antioxidation[9-12]**.** For pigmented rice, the main substance of phenolic compounds has been reported as anthocyanins[9-11]. Elucidating the physicochemical properties of red rice varieties would facilitate the understanding of its potential uses and applications (cooking properties, processing uses, functional ability etc.) as a new food ingredient. Therefore, to address the gap of knowledge on red rice varieties of western Himalaya, the aim of present investigation was to search for such beneficial varieties, suggesting the use of colour parameters as a practical indicator of some key nutritional characteristics.

Material and Methods

Raw material and sample preparation

The grains of red rice cultivars viz. *Bhrigu Dhan*, *Begami* (AC-19146), *Kangra Desi Dhan* (Kangra) and *Paddy Karad* (Local) Chamba were procured from Rice and Wheat Research Center Malan, *Sukaradhan Chamba* (IC-3131180) from Department of Seed Science and Technology, College of Agriculture, CSK HPKV, Palampur and *Lal Dhan* from Dodra Kavar location of District Shimla. Paddy of each variety were dehulled with a stake sheller to obtain red kernel rice. Dry mature grains of selected Red Rice cultivars were analyzed and results were calculated on dry matter basis.

Physical properties

Ten grains of each rice cultivar were taken randomly for measuring length and width using micrometer (Vernier calliper). The thousand grains weight was recorded in g/1000 kernels by counting grains and weighing on electronic balance. The colour and shape of the grains were observed from their physical appearance through visual perception. Bulk density of the shelled kernels of rice was determined by using mass/volume relationship[13] and the density (g/mL) was determined by the kerosene oil displacement method[14] and measured by dividing the weight of kernels (g) with volume displaced (mL).

Chemical analysis

Moisture content, crude protein, crude fat, ash, crude fibre, acidity, sugars, and minerals were estimated by using standard analytical procedures[15]. The content of the per cent available carbohydrates was estimated by method given by Raghuramulu *et al.*[16]. Dietary fibre constituents, acid detergent fibre, and free amino acids were estimated using the method prescribed by Van Soestand Lie[17,18] whereas pH, starch and free fatty acid were determined by method[19,20]. Flavonoids were estimated using the method given by Boham and Kocipia[21].

Anti-nutritional factors

Phytic acid and tannin were estimated according to procedure given by Haugh and Lantzch[22,23] whereas alkali spreading value was estimated according to the procedure adopted by Little *et al.*[24].

Cooking quality

For determining minimum cooking time, the dehulled hard rice (2 g) of each cultivar were taken in 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. Water uptake ratio was determined by method given by Bhatacharya and Sowbhagya[25]. Elongation ratio was determined by using millimetre scale. Ten cooked grains were placed lengthwise on a flat plain surface along a millimetre scale. Elongation ratio was determined by dividing the cumulative length of 10 kernels by length of 10 mentioned raw kernels. The milled rice was randomly selected from each treatment.

For calculating solid loss in gruel, 2 g of sample was cooked in 20 mL distilled water for minimum cooking time in boiling water bath. The gruel was transferred after several washings to 50 mL volumetric flask and made the volume with distilled water. The leached solid solution, 10 mL of each treatment was kept for drying in three Petri plates (70 ^{o}C) till it got completely dried.

The solids were weighed and per cent solid loss in gruel was calculated by using the following formula

Solid loss in Gruel (%)

$$= \frac{\text{Wt. of petridish and sample after drying (g)} - \text{Wt. of empty petridish (g)} \times \text{Volume made}}{\text{Weight of sample (g)} \times \text{aliquot taken}}$$

The cooking coefficient of rice was calculated by using following formula:

Cooking coefficient

$$= \frac{\text{Length of cooked rice} - \text{Length of raw rice}}{\text{Breadth of cooked rice} - \text{Breadth of raw rice}}$$

Rheological properties

The amylose content in each rice sample was determined by using spectrophotometrical techniques according to modified method[26]. The rheological properties of red rice samples were measured by using the Rapid Visco Analyser (Newport Scientific)[27].

Sensory evaluation

The cooked rice samples were evaluated for appearance, cohesiveness, tenderness on chewing and touching, taste, aroma, elongation, and overall acceptability of different red rice varieties. To 5 g of rice samples 15 mL of water were added and soaked for 10 min. Rice samples were cooked in water bath for 15 min and scored as per panel test performance[28].

Statistical analysis

Each parameter was measured in three replications and data obtained from the studies were subjected to Analysis of Variance (ANOVA) using statistical package WINDOWSTAT 8.0 The obtained data were interpreted[29] and compared at 5% level of significance ($P \leq 0.05$).

Results and Discussion

Physical properties

The physical properties of rice varieties are shown in Table 1. The colour of '*Sukara Dhan* and *Begami'* was light reddish brown, '*Bhrigu Dhan* and *Desi Dhan'* was reddish brown, while '*Paddy Karad* and *Lal Dhan'* was dark reddish brown. The differences in grain colour depends on the form of anthocyanins and different rice varieties. Size and shape are the important characteristics for the consumer acceptability that dictates the marketability and commercial viability of rice[30]. All the red rice varieties had medium sized grain, with their breadth ranged from 3.12 to 3.71 mm. The grain length of red rice varieties ranging from 7.20 to 8.70 mm. The maximum grain length was recorded in *Bhrigu Dhan* (8.70 mm). A non-significant difference was observed in the grain length of '*Paddy Karad*', '*Desi Dhan*', '*Sukara Dhan*' and '*Lal Dhan*' varieties. All varieties tested were long grain. Grain length of white and brown varieties ranged from 6.66 to 7.04 mm[31]. The grain length ranged from 6.63 to 6.93 mm in two red rice and one brown rice genotype[32]. The slight variation in the length of red rice grain may be due to varietal difference.

The grain breadth of red rice ranged between 3.12 to 3.71 mm. However, the values of red rice varieties viz. '*Lal Dhan*, *Paddy Karad* and *Bhrigu Dhan*', '*Bhrigu Dhan* and *Begami*' and '*Begami*, *Desi Dhan* and *Sukara Dhan*' varied critically non-significantly. Grain breadth ranged between 2.13 mm to 3.24 mm in two red rice varieties and one brown rice variety[32] and also of *Offada* and *Alasoosm* varieties of rice as 2.53 mm to 3.00 mm has been reported[31].

The shape of the grain is generally expressed as the ratio between the length and breadth. A non-significant difference was observed for length/breadth ratio between the red rice varieties. The length-breadth ratio was maximum of *Lal Dhan* (2.74) and minimum of *Desi Dhan* (2.15)**.** Length-breadth ratio has been observed from 2.12 to 2.62 in white variety (*Offada*) and 2.22-2.56 in brown variety (*Alasoom*)[31], while in different varieties of rice (viz; Himdhan,

Table 1 — Physical characteristics of red rice grown in Himachal Pradesh

Parameter	*Bhrigu Dhan*	*Begami*	*Desi Dhan*	*Paddy Karad*	*Sukara Dhan*	*Lal Dhan*	CD ($P \leq 0.05$)
Colour	Reddish brown	Light reddish brown	Reddish brown	Dark reddish brown	Light reddish brown	Dark reddish brown	-
Shape	Medium extra long	Medium extra long	Medium extra long	Medium extra long	Medium extra long	Medium extra long	-
Length (mm)	8.70	8.69	7.88	7.80	8.31	8.58	0.83
Breadth (mm)	3.32	3.47	3.68	3.16	3.71	3.12	NS
L/B ratio	2.63	2.55	2.15	2.47	2.25	2.74	NS
1000 kernel weight (g)	28.66	13.79	20.70	23.52	18.48	23.13	0.83
Density (g/mL)	1.25	1.25	1.11	1.11	0.10	1.16	0.058
Bulk Density (g/mL)	0.557	0.560	0.537	0.487	0.477	0.657	0.024

*Values are of dehulled rice Grain

China-988, Himalaya-741, Himalaya-799, Himalaya-2216 and T-23) length-breadth ratio ranged from 2.43 to 3.98[33]. The slight variation in result may be to the due to genetic factor and environmental influences.

The 1000-kernel weight of red rice ranged from 18.48 to 28.66 g. The highest grain weight was recorded in *Bhrigu Dhan* (28.66 g). The 1000 kernel weight of '*Lal Dhan* and *Paddy Karad*' varied non-significantly. Weight of basmati rice (HBC-19 and Bas-370) has been observed 15.18-17.03 g[34], while for white rice (HBC-19 and Bas-370) 14.82 to 21.02 g has been observed[33]. The results for the density of red rice varieties ranged from 0.997 to 1.250 g/mL. The maximum density was recorded in variety *Begami* and *Bhrigu Dhan* (1.250 g/mL) and minimum in case of *Sukara Dhan* (0.997 g/mL). The results for all red rice varieties varied non-significantly. Density of brown rice of Himachal Pradesh ranged from 1.27 to 1.39 g/mL[33], whereas density from 0.79 to 0.82 g/mL has been observed in different varieties of rice[35]. The maximum bulk density was in *Lal Dhan* (0.657 g/mL), followed by *Begami* (0.560 g/mL) and minimum in *Sukara Dhan* (0.477g/mL). However, the values of bulk density of '*Paddy Karad* and *Sukara Dhan*' and '*Bhrigu Dhan*, *Desi Dhan* and *Begami*' varied critically non-significant. Higher bulk density in brown rice varieties of Himachal Pradesh has been reported in the range of 0.85 to 0.94 g/mL[32].

Chemical analysis

The results of chemical analysis (Table 2) showed that the values for moisture content, crude protein, crude fat, crude fibre, ash and total carbohydrate in selected red rice varieties were between 11.21 to 12.92, 7.66 to 12.00, 2.35 to 3.26, 2.22 to 2.69, 1.60 to 1.79 and 82.44 to 86.88%, respectively**.** The differences in the moisture content of different red rice varieties could be due to genetic factor, environmental influences or fertilizer treatments. Similar results have been observed for moisture content of brown rice and milled rice with the level of moisture content ranged from 12.40 to 13.80 per cent in red and black varieties[36]. The maximum crude protein content was reported in *Desi Dhan* (12.00%) followed by *Paddy Karad* (11.07%), *Begami* (10.63%), *Sukara Dhan* (10.12%), *Lal Dhan* (8.55%) and minimum in *Bhrigu Dhan* (7.66%). Protein content from 7.16 to 10.36% has been reported earlier in the Homkradunga, Kamyan, and Sangyod rice varieties[37]. It is clear from Table 2 that crude fat content among six red rice varieties was in the range of 2.35 to 3.26%. Slightly lower values of fat content in M202 among different temperature of dehusked pigmented rice grain has been observed[38]. However, fat content value of 3.27% in brown rice (Irri-6, Irri-9, Sarshar and DR-83) has also been observed in Pakistan[39].

Among the six red rice varieties the crude fibre content was lowest in *Begami* (2.22%). and highest in *Sukara Dhan* (2.69%). The fiber content value in different brown rice varieties has been reported between 2.17 to 2.57%[40]. The maximum ash content was present in *Begami* (1.79%) and *Paddy Karad* (1.79%) and minimum was present in *Bhrigu Dhan* (1.60%). However, the values of ash content of '*Sukara Dhan* and *Lal Dhan*' and '*Begami* and *Paddy Karad*' varied critically non-significant.

Table 2 — Chemical composition of different varieties of red rice

Parameters	*Bhrigu Dhan*	*Begami*	*Desi Dhan*	*Paddy Karad*	*Sukara Dhan*	*Lal Dhan*	CD ($P \leq 0.05$)
Moisture (%)	12.63	12.92	12.63	11.21	12.67	11.86	0.36
Crude protein (%)	7.66	10.63	12.00	11.07	10.12	8.55	0.38
Crude fat (%)	3.26	3.13	3.08	2.35	2.67	3.21	0.29
Crude fibre (%)	2.30	2.22	2.40	2.37	2.69	2.57	0.19
Ash (%)	1.60	1.79	1.65	1.79	1.78	1.78	NS
Total carbohydrate (%)	86.88	83.36	82.44	85.65	84.26	86.35	0.80
Reducing sugars (% glucose)	0.713	0.873	0.380	1.010	0.697	0.983	0.284
Non reducing sugars (% sucrose	0.350	0.373	1.02	0.297	0.580	0.337	0.284
Total sugars % (glucose)	1.06	1.25	1.40	1.29	1.35	1.32	0.066
Starch %	82.70	81.63	85.76	83.94	88.56	83.01	0.88
Amylose %	25.06	26.42	25.33	24.64	23.56	26.55	0.42
Neutral detergent fiber NDF (%)	26.01	33.06	34.23	36.51	26.36	35.23	1.14
Acid detergent fiber ADF (%)	10.23	11.63	12.32	14.27	10.93	13.41	0.49
Hemicellulose (%)	15.77	21.43	21.86	22.25	15.28	21.82	1.18
FFA (% oleic acid)	0.363	0.377	0.293	0.347	0.333	0.373	0.043
FAA (% glycine)	0.443	0.333	0.410	0.373	0.393	0.423	0.011

Similar results were obtained for Red Rice (CWR, SRR, TBR)[36].

The highest carbohydrate was present in *Bhrigu Dhan* (86.88%), followed by *Lal Dhan* (86.35%), *Paddy Karad* (85.65%), *Sukara Dhan* (84.26%), *Begami* (83.36%) and *Desi Dhan* (82.44%). However, the values of the total carbohydrates of '*Lal Dhan* and *Paddy Karad*' and '*Lal Dhan* and *Bhrigu Dhan*' varied critically non-significant. Carbohydrate value of 81.69 per cent in Red Rice, 79.21% in brown rice, 76.91% in black and 77.99% in white rice variety has been observed[41] which are in agreement with the result obtained in the present study. Reducing sugars (glucose), non reducing sugars (sucrose), total sugar (glucose) starch and amylose, were in the range of 0.380 to 1.010, 0.297 to 1.02, 1.06 to 1.40, 81.63 to 88.56 and 23.56 to 26.55%, respectively (Table 2). The highest value for reducing sugar was reported in *Paddy Karad* (1.010%), followed by *Lal Dhan* (0.983%), *Begami* (0.873%), *Bhrigu Dhan* (0.713%), *Sukara Dhan* (0.697%) and *Desi Dhan* (0.380%). Slightly lower values for reducing sugars in brown rice and milled rice (Irri-6, Irri-9, Sarshar and DR-83) has been reported[42] with the values between 0.40 to 0.42% for brown rice and 0.20 to 0.31% for milled rice. The value for non reducing sugars ranged from 0.297 to 1.02%. The maximum content of non reducing sugars was found in *Desi Dhan* (1.02%) and lowest in *Paddy Karad* (0.297%). However, the values for non reducing sugars of '*Paddy Karad, Lal Dhan, Bhrigu Dhan Begami* and *Sukara Dhan*' and '*Sukara Dhan* and *Desi Dhan*' varied critically non-significant.

The total sugar content was highest in *Desi Dhan* (1.40%) followed by *Sukara Dhan* (1.35%), *Lal Dhan* (1.32%), *Paddy Karad* (1.29%), *Begami* (1.25%) and minimum in *Bhrigu Dhan* (1.05%). However, non-significant results were obtained when red rice varieties were compared with each other. Further, Table 2 shows that starch content was maximum in *Sukara Dhan* (88.56%) and minimum in *Begami* (81.63%). However, the values of starch content of '*Bhrigu Dhan* and *Lal Dhan*' were at par. Slightly lower values for starch content have been observed earlier which varied from 74.28 and 76.95% for red and 73.24 to 76.84% for for white rice varieties[41]. Amylose, the linear component of starch imparts definite characteristics to starch and hence is an important criterion in starch quality. Among the six red varieties of rice, the amylose content was lowest in *Sukara Dhan* (23.56%) and highest in *Lal Dhan* (26.55%) and comparable to earlier study[42] where amylose content in red rice varied from 21.8 to 25.0% while in red rice crosses, it varied from 15.1 to 25.5%. The values of neutral detergent fibre (NDF) ranged between 26.01 to 36.51%. However, the values of NDF of '*Bhrigu Dhan* and *Sukara Dhan*' and '*Lal Dhan* and *Desi Dhan*' varied non-significantly.

Acid detergent fibre ADF content ranged from 10.23 to 14.27% in different red rice varieties showing highest value of ADF in *Paddy Karad* (14.27%), followed by *Lal Dhan* (13.41%), *Desi Dhan* (12.32%), *Begami* (11.63%), *Sukara Dhan* (10.93%) and lowest value in *Bhrigu Dhan* (10.23%). However, the value of free amino acid varied non-significantly when compared with each other. The highest value of free fatty acid was present in *Begami* (0.377%) and minimum in *Desi Dhan* (0.293%). However, the values of free fatty acid for *Desi Dhan, Sukara Dhan* and *Paddy Karad* were found at par when when compared with each other. Free fatty acid values varied from 0.29 to 0.49 per cent in brown rice varieties (Himdhan, China-988, Himalaya-741, Himalaya-799, Himalaya-2216 and T-23), which are in agreement with the present findings[33]. The maximum amount of free amino acid was present in *Bhrigu Dhan* (0.443% as glycine) and minimum was present in *Begami* (0.333% as glycine). Slightly higher values of free amino acid have been reported[33] as compared to the results obtained in the present study The hemicellulose content for red rice varieties viz. *Bhrigu Dhan, Lal Dhan, Desi Dhan, Sukara Dhan, Paddy Karad* and *Begami* was observed 15.77, 21.82, 21.86, 15.28, 22.25, and 21.43%, respectively.

Mineral content

The results pertaining to mineral contents on the basis of varietal differences during the study are presented in Table 3. The highest phosphorus content was found in *Sukara Dhan* (311.05 mg/100 g). Phosphorous is one of the non carbohydrate constitutes in the starch, which significantly affects its functional properties. Slightly higher phosphorus content in the brown rice varieties (Himdhan, China-988, Himalaya-741, Himalaya-799, Himalaya-2216 and T-23) of Himachal Pradesh has been observed[33]. Among the six red rice varieties, the value of iron content was highest in *Begami Dhan* (8.95 mg/100 g) and lowest in *Paddy Karad* (5.00 mg/100 g). Very low values for iron content in brown rice have been

Table 3 — Mineral profile, anti-nutritional factors and antioxidants of different varieties of red rice

Parameters	*Bhrigu Dhan*	*Begami*	*Desi Dhan*	*Paddy Karad*	*Sukara Dhan*	*Lal Dhan*	CD ($P \leq 0.05$)
Phosphorus (mg/100 g)	245.64	274.71	255.81	302.33	311.05	284.88	0.91
Iron (mg/100 g)	5.56	8.95	5.69	5.00	5.35	7.33	0.16
Zinc (mg/100 g)	5.12	9.77	2.90	4.07	4.53	4.69	0.85
Copper (mg/100 g)	0.470	0.350	0.580	1.05	3.020	0.580	0.16
Manganese (mg/100 g)	3.49	0.930	0.580	0.350	3.14	2.33	0.18
Magnesium (mg/100 g)	112.79	127.21	99.65	137.33	125.35	130.69	0.14
Tannins (mg GAE /100 g)	60.94	72.02	71.02	76.37	74.69	70.34	4.36
Phytic Acid (mg/100 g)	234.20	226.41	244.07	257.54	250.35	254.09	0.63
Total Phenols (Mg GAE/100 g)	229.36	231.66	273.68	296.91	292.59	297.45	5.24
Flavonoids (%)	46.19	48.31	46.38	46.57	48.23	45.05	NS

reported in KS-282, IRRI-6, Basmati 2000 and Super Basmati[43]. The zinc content of different red rice varieties was found in the range of 2.90 to 9.77 mg/100 g. The present results differed with the earlier findings[43] of slightly lower values for zinc content in brown rice.

The highest copper content was found in *Sukara Dhan* (3.020 mg/100 g) and lowest in *Begami* (0.350 mg/100 g). The reason for such variation in copper content may be due to the varietal difference and agro climatic condition. Copper content in between 0.58 to 0.92 mg/100 g has been observed in different rice varieties (DR-83, Sarshar, Irri-9, Irri-6) grown in different regions in Pakistan[39].

The manganese content of different red rice varieties ranges from 0.350 to 3.49 mg/100 g. The highest content was observed in *Bhrigu Dhan* (3.49 mg/100 g) and lowest in *Paddy Karad* (0.350 mg/100 g). Manganese content ranging from 1.57 to 2.33 mg/100 g has been observed in different rice varieties from different regions in Pakistan[39]. The highest amount of magnesium content was observed in *Paddy Karad* (137.33 mg/100 g) and lowest in *Desi Dhan* (99.65 mg/100 g).

Antioxidant properties

The results pertaining to antioxidant properties during the study are presented in Table 3. Among six red rice varieties the highest total phenol content was observed in *Lal Dhan* (297.45 mg/100 g) and lowest in *Bhrigu Dhan* (229.36 mg/100 g).

Slightly higher total phenolic content in red and black rice varieties with values ranging from 79.18 to 691 mg/100 g for red rice and 336.69 to 665.16 mg/100 g for black rice varieties have been observed earlier[36]. The flavonoid content ranged from 45.05 to 48.31 mg/100 g. The highest content was in *Begami* (48.31 mg/100 g) and lowest in *Lal Dhan* (45.05 mg/100 g). Flavonoid content of different red rice varieties of Himachal Pradesh have been observed from 10.44 to 23.39 mg/100 g[44]. The variation in result may be due to genetic makeup, varietal differences and agro-climatic conditions.

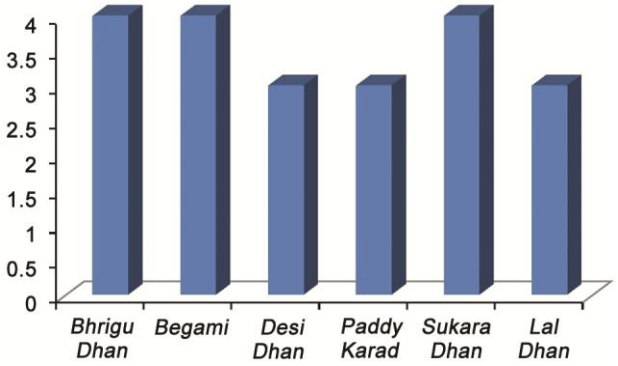

Fig. 1 — Alkali spreading value of different Red Rice varieties

Anti-nutritional factors

Values in respect of tannins in the red rice are presented in Table 3. The maximum content was in *Paddy Karad* (76.37 mg/100g), followed by *Sukara Dhan* (74.69 mg/100g), *Begami* (72.02 mg/100g), *Desi Dhan* (71.02 mg/100g), *Lal Dhan* (70.34 mg/100g) and *Bhrigu Dhan* (60.94 mg/100g). However, slightly lower values for tannins have been observed in 17 rice accessions[45]. The highest phytic acid content was observed in *Paddy Karad* (257.54 mg/100g) and the lowest value was in *Lal Dhan* (254.09 mg/100g). The IRRI-6, KS-282, Basmati 2000 and Super Basmati varieties of rice recorded slightly higher values of phytic acid content in milled and brown rice[46]. Data in Table 3 gives the phytate phosphorus content of various red rice varieties and the maximum content were observed in *Sukara Dhan* (87.66 mg/100g) and minimum in *Bhrigu Dhan* (71.75 mg/100g). However, the values of phytic acid of '*Bhrigu Dhan* and *Desi Dhan*' were at par.

Alkali spreading value

In the present study, degradation response of alkali reaction was clearly noticed after 23 h. (Fig. 1) and the alkali spreading value ranged from 3.0 to 4.0 for the tested red rice varieties. Alkali spreading value from 2 to 5 has been observed for long, medium, and short grain of rice grown under Andhra Pradesh regions[47] where latter showed lower spreading values than long grain.

Rheological properties

The results for rheological properties are shown in Table 4. The red rice varieties were evaluated for paste temperature, peak viscosity, hold viscosity, final viscosity, breakdown and setback. The highest paste temperature was observed in *Begami* (92.30 ^{o}C) followed by *Sukara Dhan* (91.80 ^{o}C), *Paddy Karad* (90.50 ^{o}C), *Desi Dhan* (88.70 ^{o}C), *Lal Dhan* (88.17 ^{o}C) and *Bhrigu Dhan* (86.83 ^{o}C). The maximum peak viscosity was in *Bhrigu Dhan* (2045.33 cP) and the minimum was in *Begami* (602.00 cP). The values of peak viscosity for other varieties were (1734.67 cP) *Lal Dhan)* 1623.00 cP *(Desi Dhan)*, 1564.00 cP (*Paddy Karad*), 838.00 cP *(Sukara Dhan* and 602.00 cP *(Begami*).

The hold viscosity has been observed between 1299.00 cP to 509.00 cP with highest in variety *Desi Dhan* (1299.00 cP), followed by *Bhrigu Dhan* (1182.33 cP), *Lal Dhan* (1116.00 cP), *Paddy Karad* (1064.00 cP), *Sukara Dhan* (630.00 cP) and *Begami* (509.00 cP).

The highest final viscosity value was observed in red rice variety *Desi Dhan* (2869.00 cP), followed by *Bhrigu Dhan* (2577.00 cP), *Lal Dhan* (2386.33 cP), *Paddy Karad* (2206.67 cP), *Sukara Dhan* (1535.00 cP) and the minimum was found in *Begami* (1265.00 cP). The value for the breakdown ranged from 859.00 cP to 93.00 cP. The maximum was observed in red rice variety *Bhrigu Dhan* (859.00 cP), followed by *Lal Dhan* (631.00 cP), *Desi Dhan* (324.00 cP), *Paddy Karad* (287.00 cP), *Sukara Dhan* (208.00 cP) and *Begami* (93.00 cP). The highest setback was observed in *Desi Dhan* (1570.00 cP), followed by *Bhrigu Dhan* (1357.67 cP), *Lal Dhan* (1280.67 cP), *Paddy Karad* (1043.00 cP), *Sukara Dhan* (905.00 cP) and *Begami* (756.00 cP). Slightly lower values for pasting properties of red and black rice varieties have been reported earlier[36]. The pasting temperature of all varieties ranged between 56.2 to 79.0 ^{o}C, peak viscosity 365 to 872 BU, final viscosity 334 to 1199 BU, breakdown 7 to 416 BU and setback 183 to 801 BU.

Cooking quality of rice

Cooking quality of different varieties of red rice is presented in Table 5. The maximum cooking time of 32.41 min was observed in variety *Bhrigu Dhan* and minimum cooking time was observed in *Desi Dhan* (28.36 min). However, the values of minimum cooking time of '*Begami, Sukara Dhan and Lal Dhan* were found at par with each other. The results are in line with earlier findings[31]. The water uptake ratio was maximum in variety of *Bhrigu Dhan* (2.59). The water uptake ratio of rice variety varied between 1.87 to 2.59. However, the value of uptake ratio of *Paddy Karad and Sukara* were found at par. Similar results have been reported earlier[39]. Who analyzed water uptake ratio for brown rice, milled and polished rice and values were as 1.71, 2.51, and 2.65. Among the different rice varieties the elongation ratio was significantly higher in *Lal Dhan* (1.28), followed by *Bhrigu Dhan* (1.23), *Desi Dhan* (1.15), *Paddy Karad*

Table 4 — Pasting properties of different varieties of red rice

Parameters	*Bhrigu Dhan*	*Begami*	*Desi Dhan*	*Paddy Karad*	*Sukara Dhan*	*Lal Dhan*	CD ($P \leq 0.05$)
Paste temp. (^{o}C)	86.83	92.30	88.70	90.50	91.80	88.17	0.91
Peak viscosity (cP)	2045.33	602.00	1623.00	1564.00	838.00	1734.67	0.16
Hold viscosity (cP)	1182.33	509.00	1299.00	1064.00	630.00	1116.00	0.85
Final viscosity (cP)	2577.00	1265.00	2869.00	2206.67	1535.00	2386.33	0.16
Breakdown (cP)	859.00	93.00	324.00	287.00	208.00	631.00	0.18
Setback (cP)	1357.67	756.00	1570.00	1043.00	905.00	1280.67	0.14

Table 5 — Cooking quality of different varieties of red rice

Parameters	*Bhrigu Dhan*	*Begami*	*Desi Dhan*	*Paddy Karad*	*Sukara Dhan*	*Lal Dhan*	CD ($P \leq 0.05$)
Cooking time (min)	32.41	30.19	28.36	31.84	30.25	30.32	0.29
Water uptake ratio	2.59	2.24	2.11	1.87	1.91	2.34	0.17
Solid gruel loss (%)	0.019	0.590	0.310	0.967	0.110	0.011	0.60
Cooking coefficient	1.30	1.40	0.899	1.34	1.75	3.60	0.26
Elongation ratio	1.23	1.13	1.15	1.14	1.12	1.28	0.053

(1.14), *Begami* (1.13) and the minimum was in *Sukara Dhan* (1.12). The results were similar[48] to the findings, where elongation ratio of traditional rice varieties of Goa varied from 1.60 to 1.00. The solid gruel loss in different rice varieties varied significantly. Higher solid losses were observed in the *Paddy Karad* (0.967 %), followed by *Begami* (0.590%), *Desi Dhan* (0.310%), *Sukara Dhan* (0.110%), *Bhrigu Dhan* (0.019%) and *Lal Dhan* (0.011%) (Table 5). Solid gruel loss in brown rice and brown parboiled rice has been reported as 1.49 and 0.31% respectively[49]. The values for cooking coefficient ranged from 0.899 to 3.60. The maximum value for cooking coefficient was observed in *Lal Dhan* (3.60), followed by *Sukara Dhan* (1.75), *Begami* (1.40), *Paddy Karad* (1.34), *Bhrigu Dhan* (1.30) and *Desi Dhan* (0.89).

Correlation of pasting properties in relation to cooking quality

Red Rice revealed that the paste temperature was strongly correlated with solid gruel loss. While peak viscosity, hold viscosity and breakdown was strongly correlated with cooking time, water uptake ratio, cooking coefficient and elongation ratio. However, final viscosity and setback was strongly correlated with water uptake ratio and elongation ratio. Fig. 2 indicates the correlation of pasting properties in relation to the cooking quality of red rice varieties.

Sensory evaluation of cooked rice

The samples were evaluated for appearance, cohesiveness, tenderness on chewing and touching, taste, aroma, elongation and overall acceptability of different Red Rice varieties (Table 6). The appearance score was highest in *Lal Dhan* (4.60) followed by *Paddy Karad* (4.40), *Bhrigu Dhan* (3.90), *Begami* (3.20), *Desi Dhan* (3.00) and *Sukara Dhan* (2.80). Variety *Lal Dhan* and *Paddy Karad* were dark reddish brown in colour while other varieties were observed to be reddish brown and light reddish brown in colour. For cohesiveness, *Paddy Karad* (5.00) was well separated and other varieties scored from 'partially separated' to 'well separated'. Only *Bhrigu Dhan* was slightly separated (3.30). The tenderness score on touching and chewing of cooked rice of different varieties were in between moderately hard to moderately soft. Only *Bhrigu Dhan* had soft texture on touching and chewing. The score of cooked rice for taste indicated that all varieties had desirable to good taste. The scores ranged between 3.20 to 3.60. Only *Bhrigu Dhan* reported lowest scores for taste (2.90) and showed undesirable taste when compared with scores. When compared for aroma, all red rice varieties were observed to be mildly scented. For elongation, *Desi Dhan* showed moderate elongation and all other varieties showed good elongation. When overall acceptability of red rice varieties was compared with each other, all varieties were observed to have good acceptability. Among three varities of rice viz. *Jaha, Monoharsali and Prosadbhog Jaha*, a scented variety scored highest aroma but was inferior in term of non-cohesiveness and integrity whereas. *Monoharsali* had the highest overall scores for appearance, non-cohesiveness and integrity of kernels[50].

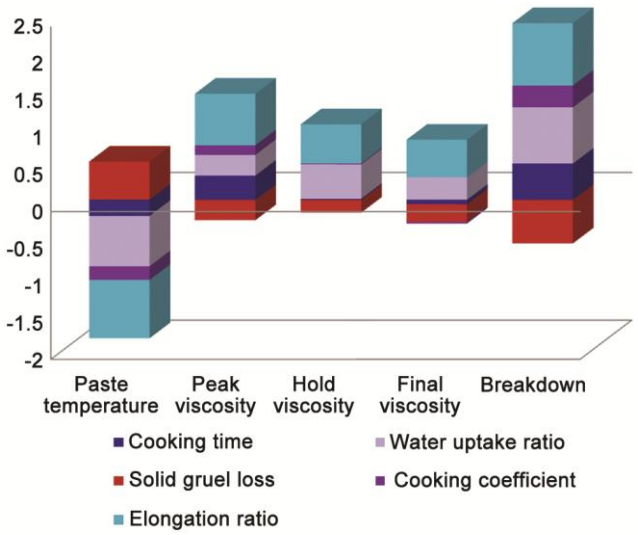

Fig. 2 — Correlation of pasting properties in relation to cooking quality of red rice varieties

Table 6 — Sensory evaluation of cooked red rice

Parameters	*Bhrigu Dhan*	*Begami*	*Desi Dhan*	*Paddy Karad*	*Sukara Dhan*	*Lal Dhan*
Appearance	3.90	3.20	3.00	4.40	2.80	4.60
Cohesiveness	3.30	4.60	4.60	5.00	4.80	4.70
Tenderness on chewing	4.40	2.70	2.60	2.70	2.80	3.60
Tenderness on touching	3.90	2.40	2.30	2.30	2.40	3.10
Taste	2.90	3.60	3.40	3.30	3.20	3.50
Aroma	2.40	2.00	2.00	1.70	2.10	2.00
Elongation	2.60	2.80	3.00	2.80	2.60	2.80
Overall acceptability	2.00	1.60	1.70	1.60	1.80	2.00

Conclusion

Total phenol were determined maximum in *Lal Dhan* (297.45 mg GAE/100g) and lowest in *Begami* (231.66 mg GAE/100g) whereas, flavonoids ranged from 45.05 to 48.31 per cent, respectively From the result obtained, it has been observed that red rice varieties are rich sources of antioxidants (total phenols and flavonoids), minerals (iron and zinc), and other nutrients. The profile of rheological properties of red rice as assessed in the present study and its suitability are of great significance for the research and development personals and for food processing sector for preparation of various specialty foods.

Conflict of interest

The authors declare that there is no conflict of interest.

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