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GRAIN QUALITY EVALUATION OF TRADITIONALLY CULTIVATED RICE VARIETIES OF GOA, INDIA

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Abstract

The physicochemical characteristics such as physical (hulling, head rice recovery (HR), broken rice (BR), grain classification, chalkiness), chemical (alkali spreading value, amylose content (AC), gel consistency (GC), aroma) and cooking characteristics (volume expansion, elongation ratio, water uptake) were studied for 22 traditionally cultivated rice varieties from Goa, in comparison with high yielding rice varieties Jaya, Jyoti and IR8. The hulling percentage ranged from 63-81% and HR recovery from 45-74%. Among the varieties Length/Breath ratio ranged from 1.5-3.5 and the AC ranged from 14-25%. The lowest percentage of chalkiness was recorded in variety Barik Kudi. Highest GC was recorded in variety Salsi and lowest in Khochro. The kernel elongation ratio ranged from 4.78-1.83 mm and water uptake ratio ranged from 160-390. Some of traditionally cultivated rice varieties are with excellent grain quality characteristics. The rice variety korgut which predominantly grown in khazan lands could be used in breeding programmes to develop high saline varieties.

Keywords: Amylose content, Grain quality, Physicochemical characteristics, Traditional rice varieties

Introduction

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population. About 90% of the world's rice is grown and consumed in Asia [1]. Rice is an economically important food crop with nutritional diversification and helps in poverty alleviation [2]. Rice is ranked as the world's number one human food crop [3].

Rice is the predominantly cultivated food crop of Goa occupying total cultivated area of 39% (52,442 ha) in the state. Grain quality of rice is determined by the factors such as grain appearance, nutritional valve, cooking and eating quality [4]. Specialty rice is a term used to distinguish cultivars of rice that have unique properties like flavor, color, nutrition and chemical composition [5].

The physicochemical characteristics include grain length (L), grain breadth (B), L/B ratio, hulling and milling percentage. The cooking qualities are AC, alkali spreading value, water uptake, volume expansion ratio and kernel elongation ratio. Grain quality is a very wide area encompassing diverse characters that are directly or indirectly related to exhibit one quality type [6]. Different cultivars showed significant variations in morphological, physicochemical and cooking properties [7]. The gelatinization temperature (GT), gel consistency (GC) and amylose content (AC) are major rice traits, which are directly related to cooking and eating quality [8]. On the other hand AC, amylopectin structure and protein composition explained the difference in cooking quality of rice [9].

The cooking quality of rice was determined on the basis of physicochemical properties and AC [10]. Cooked rice is composite food consist of different biopolymers, including starch and proteins along with moisture as plasticizer [11]. GT is responsible for cooking time, water absorption and the temperature at which starch irreversibly loses its crystalline order during cooking. The GC is responsible for softness and the AC for texture of cooked rice [12]. Today, the consumers prefer to eat unpolished rice especially traditional rice because of the nutrient value in the bran and their reputation for nutritional excellence. Therefore the demands for brown and parboiled rice are increasing among the populations [13]. In the present study we have evaluated the rice grain quality characteristics (physical, chemical and cooking) of traditionally cultivated rice varieties of Goa in comparison with conventionally breeded rice varieties.

Materials and Methods

Plant materials

The field survey was carried out at different parts of Goa, for the collection of rice varieties. The rice seeds were dried and stored at 4°C for grain quality studies.

Physical traits

Brown rice (BR) yield

Hundred grams of rough rice seeds were de-hulled using a standard dehusker and the average whole-grain BR yield was determined [14].

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Head rice recovery (HR)

Hundred grams of de-hulled rice grains that had no visible breakage and ¾ size grains were used to determine the head rice recovery. The percentage of HR and broken rice were calculated using the standard formula [14].

Grain classification

De-husked brown rice was used for computing the grain shape and size. Minimum of 10 full grains per replication were measured using dial micrometer and L/B ratio was calculated. Based on the L/B ratio, grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB) [14].

Chalkiness of endosperm

The degree of chalkiness was determined using milled rice by observing under stereo-zoom microscope. Based on the observation the chalkiness of the endosperm was classified into white belly, white centre and white back [14].

Chalk index determination

Ten de-husked rice grains were placed on light box and visually identified the grain with more than 50% of chalkiness, weighed and percentage of chalkiness was calculated [14].

Chemical traits

Alkali Spreading and Clearing test

Six milled rice were taken in Petri plates and 10 mL of potassium hydroxide (19.54 g of potassium hydroxide dissolve in one liter) was added to the sample. Samples were kept undisturbed for 23 hours in an incubator at 27-30°C [15].

Amylose content (AC)

Hundred mg of rice flour was placed in 100 mL volumetric flasks and added 1 mL of 95% v/v ethanol. Then 9 mL of 40 g NaOH dissolved in one liter was added and heated in a boiling water bath for 10 min. Samples were diluted to 100 mL with distilled water. Later, 5 mL of sample suspension was added to 50 mL of distilled water in a 100 mL of flask and 1 mL of acetic acid (57.75 mL in one liter water) was added to acidify the sample along with 1.5 mL of iodine solution (0.2 percent w/v iodine in 2% potassium iodide). Distilled water was added to make the volume of 100 mL and the suspension was mixed well and kept for 20 min. As a control, NaOH solution was used for the calibration of spectrophotometer and samples were measured at 620 nm. Samples with known values of high, medium and low AC were used to draw the standard AC curve. The AC of different varieties was calculated in comparison with standard graph [16&17].

Gel consistency (GC)

Milled rice was ground to a fine powder using mortar & pestle and sieved with 1 mm sieve. 100 mg of rice flour was taken in long test tube (2×19.5 cm) and added 0.2 mL of ethanol containing 0.25% thymol blue and 2.0 mL of 2.8 g of KOH in 250 mL distilled water was added and mixed well using vortex mixture, kept in boiling water bath for 8 min, cooled for 5 min, mixed and kept in ice bath for 20 min. Later tubes were removed, laid horizontally for one hour and measurements were made using graph paper. The degree of disintegration and the transparency of paste dissolved out of the kernels were evaluated using a 7 point scale [8&18].

Aroma

To 5 g of rice 15 ml of water was added, soaked for 10 min and cooked for 15 min, transferred into a Petri dish and placed in refrigerator for 20 min. Then the cooked rice was smelled by a random panel: strongly scented (SS); mild scented (MS); non-scented (NS) [19].

Cooking characteristics

Volume expansion ratio and elongation 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. Ten cooked rice kernels were selected (intact at both ends) and length of the kernels measured using graph paper for computing the kernel length after cooking (KLAC). Then all the 5 g of cooked rice were placed in 50 mL water taken in 100 mL measuring cylinder and increase in volume of cooked rice in 50 mL of water was measured (X). Later, the volume raise was recorded (X-50). Then volume expansion ratio and elongation ratio were calculated [20].

Water uptake

2 g of samples were taken in graduated test tubes with 10 mL of water and soaked for 30 min. Boiled for 45 min at 77 to 80°C in a constant temperature water bath. 2-3 test tubes were kept with 10 mL of water as control in the water bath without rice grains. Immediately the tubes were placed in a beaker containing cold water for cooling. The supernatant were poured into graduated cylinder after cooling and note the water level. Water uptake was calculated using the following formula: Water uptake = 100 /2 g × actual water absorbed [21].

Organoleptic test

5 g rice samples were taken in a test tube, 15 mL of water added and soaked for 10 min. Rice samples were cooked in water bath for 15 min and transferred into a Petri dish and scored as per panel test performance [21].

Statistical analysis

Experiments were carried out using three replicates. The data was statistically analyzed using WASP-Web Agri Stat Package 2.0.

Results and Discussion

During this study we have collected 22 traditionally cultivated rice varieties which are unique in their morphological characters of shape, size and color. Most of these traditional rice varieties are found only in Goa region and cultivated in small patches. Out of 22 rice varieties collected, some of the varieties such as Bello, Chudi, Dodga, Khochro and Ner cultivation are becoming rare, if these varieties are not preserved, they may become extinct in due course of time since high yielding rice varieties such as Jaya and Jyoti are predominantly cultivated in the state of Goa. The only rice variety Korgut is still popularly cultivated in khazan lands of Goa due to its high salinity tolerance. Due to the introduction of high yielding rice varieties, the local germplasm and their genetic diversity are being eroded. The collection, documentation, characterization of germplasm is important for utilizing the appropriate attribute based donors in breeding programmes and essential for protecting the unique rice varieties [22].

Physical characteristics

The de-hulling of rice is one of the important post harvest processes. If the hulling percentage is high, then the recovery of rice is also increased. The hulling percentage for 22 traditionally cultivated rice varieties were compared with high yielding varieties Jaya, Jyoti and IR8 (Table 1). Among traditionally cultivated rice varieties, hulling percentage ranged from 63 to 81%. The highest hulling percentage (80.8%) was observed in variety Vadlo kenal and lowest in Dodga (63.1%), whereas Jaya recorded 80.5% and Jyoti (78.3%). The eighty percent or more are the desirable hulling characteristics for rice [22]. The head rice recovery (HR) indicates that weight of whole grains obtained after industrial processing. For quality evaluation, HR recovery is one of the most important characters and more than 65% of HR recovery is desirable. HR is the proportion of the intact grain in the milled rice. HR value ranged from 45-74% in all the rice varieties evaluated during this study. The rice varieties Khochro and Novan showed highest head rice recovery among the traditional rice varieties and lowest in Vadlo Kenal (44.5%), but it is not significant with the variety Barik Kudi (44.9%). HR in Jyoti recorded above 68%. When compared to conventionally breeded rice varieties, the traditional rice varieties recorded higher HR value and showed significant differences (Table 1). It was reported that the quality rice variety should have HR value at least 70%. HR value depends on the grain type, chalkiness, cultivation practices and drying condition [23]. In high yielding rice varieties, the percentage of broken rice (BR) grains ranged from 5.3 to 36.3. Among the traditional rice varieties, lowest breakage was recorded in variety Novan and highest in variety Vadlo Kenal. However, no significant differences were observed for the varieties Revati and Khoncho. In high yielding varieties the BR grains ranged from 10.2-23.16%.

Among the rice varieties studied, the L/B ratio ranged from 1.5-3.5. The traditional rice variety Tamde Jyoti recorded the highest L/B ratio and lowest in Novan. The L/B ratio in high yielding varieties ranged from 2.10 to 3.31 (Table 1). The grain size and shape of most high yielding rice varieties is short to medium bold with translucent appearance [24]. To gain and maintain the optimum milling rice grain quality, rice must be harvested at proper moisture content and should be dried carefully up to 14% moisture level [23]. During this investigation, rice grains were classified into four different categories, eight varieties belongs to short bold, four varieties as long slender, eight varieties as long bold and five varieties as medium slender grains (Table 1).

Chalkiness in endosperm was classified into white belly, white centre and white back based on the position and orientation of chalkiness. The rice varieties having minimum amount of chalkiness is consider as good quality grains in comparison with chalky once which decrease the rice grain quality. In variety Dhave the chalkiness is occasionally present whereas in variety Barik Kudi the chalkiness is very occasionally present. The varieties such as Damgo, Kendal and Khochro recorded 100% chalkiness and least amount was observed in variety Barik Kudi (Table 2). When compared to traditional rice varieties, in high yielding varieties the chalkiness found to be less and ranged from 24.1-85%. Among the varieties studied, white belly type of chalkiness was found to be dominant and it is recorded in eighteen rice varieties. White centre type of chalkiness was observed in varieties such as Barik Kudi, Dodga, Irtal, Kalo Novan, Ner, IR8 and Jaya. Grain shape and endosperm opacity are major attributes that determine the appearance quality. The greater amount of chalkiness in the grain indicates that it is more prone to grain breakage during milling, which results in lower HR recovery [25].

Table 1. The hulling percentage, HR recovery, brown rice, L/B ratio and Grain classification of traditionally cultivated and high yielding rice varieties

Sl. No.	Varieties	Mean Hulling (%)	Mean Head rice recovery	Mean Broken rice	Mean L/B ratio	Grain Classification
1	Annapurna	74.16±0.75f	51.5±0.46l	22.6±1.17efgh	2.38±0fghi	LB
2	Atthavis	77.23±0.05bcde	52.6±1.16jkl	24.6±1.21de	2.70±0de	LB
3	Barik Kudi	77.03±1.26bcde	44.9±1.51n	32.0±0.72b	3.43±0ab	LS
4	Bello	73.26±0.96fg	47.1±0.75m	26.1±0.30cd	2.86±0.05cd	MS
5	Chudi	76.36±1.15de	54.8±0.60i	21.5±1.75fgh	2.70±0.1de	LB
6	Damgo	77.43±1.36bcde	67.0±0.40c	10.3±1.74jkl	2.26±0.20ghi	LB
7	Dhave	72.40±0.75g	59.6±0.40g	14.5±2.39i	2.46±0.20efgh	MS
8	Dodga	63.16±1.05i	62.2±1.10f	11.9±1.70jk	2.26±0.15ghi	SB
9	Irtal	65.50±1.31h	57.7±0.55h	7.7±1.44mn	2.40±0.26efghi	SB
10	Kala Novan	78.13±0.90bc	51.2±0.95l	26.9±1.61c	2.51±0.17efgh	SB
11	Karz	76.10±1.66e	63.9±0.62e	12.2±2.00jk	2.65±0.18def	MS
12	Kenal	74.36±0.96f	65.4±1.30d	8.9±2.26lm	2.24±0.09hi	LB
13	Kendal	77.23±1.25bcde	68.3±1.00bc	8.9±1.17lm	2.42±0.24efgh	LB
14	Khochro	77.40±1.01bcde	71.8±0.51a	5.6±1.21nop	2.56±0.29defg	SB
15	Korgut	77.86±0.58bcd	68.2±0.65c	9.6±0.81lm	2.40±0.10efghi	SB
16	Mangala	74.30±0.95f	53.3±1.06j	20.9±2.00gh	2.69±0.10de	LB
17	Ner	73.30±1fg	63.4±0.64ef	9.9±1.63klm	2.66±0.25def	MS
18	Novan	78.40±1.08b	73.0±0.47a	5.3±1.19op	1.59±0.19ghi	SB
19	Revati	77.33±1.10bcde	69.7±0.55b	7.6±0.55mnop	2.33±0.35ghi	SB
20	Salsi	72.30±0.9g	51.8±0.51kl	20.5±1.03h	2.66±0.20def	MS
21	Tamde Jyoti	76.73±0.47cde	53.2±0.95jk	23.5±1.13ef	3.51±0.08a	LS
22	Vadlo Kenal	80.86±0.35a	44.5±2.13n	36.3±1.79a	2.40±0.26efghi	LB
23	IR8	76.26±0.20e	63.8±0.58e	12.4±0.6ij	2.10±0.09i	SB
24	Jyoti	78.36±0.321b	68.1±0.1c	10.2±0.25jkl	3.31±0.27ab	LS
25	Jaya	80.50±0.4a	57.3±0.11h	23.1±0.41efg	3.12±0.06bc	LS

Superscript letters (a-n) indicate significant differences ($p \leq 0.05$) among different rice varieties in hulling, head rice recovery, broken rice and L/B ratio. Means with same letter within column are not significantly different ($p \leq 0.05$). SB, short bold; LB, long bold; LS, long slender; MS, medium slender

Chemical characters

The alkali spreading value and GT were calculated for all the rice varieties examined (Table 3). The alkali spreading value was calculated as low, intermediate and high. The low alkali spreading value was detected in varieties viz. Annapurna, Damgo, Kendal, Khochro, Tamde Jyoti, Vadlo Kendal, Karz, IR8, Jyoti and Jaya. The intermediate (>74°C) alkali spreading value was recorded in Atthavis, Bello, Chudi, Dhave, Dodga, Irtal, Kalo Novan, Mangala, Ner and Revati. Rice varieties such as Novan, Jaya and Salsi showed high alkali spreading value. The low-intermediate alkali spreading values was recorded in varieties Barik-Kudi and Korgut. Rice with low GT disintegrates completely in 1.7 percent KOH solution, whereas rice with intermediate GT showed partial disintegration. Rice with high GT remains largely unaffected in alkali solution. In addition, the disintegration of rice starch granules is affected by the fine structure of amylopectin [26]. If the alkali spreading value is low, the GT is high (>74°C). If the alkali spreading is intermediate, the GT is intermediate (70-74°C). If the alkali spreading value is low intermediate then the GT is high intermediate. The different range of drying also affects the GC [27].

Table 2. Chalkiness of endosperm of traditionally cultivated and high yielding rice varieties

Sl. No.	Varieties	Frequency	Kernel area (Extent)	Type	Chalkiness (%)
1	Annapurna	P	Long (more than 20 %)	WB	84.03±1.60d
2	Atthavis	P	Long (more than 20 %)	WB	65.40±2.53g
3	Barik Kudi	VOP	Small (less than 10 %)	WC	10.23±0.87m
4	Bello	P	Long (more than 20 %)	WB	76.60±1.21f
5	Chudi	P	Long (more than 20 %)	WB	55.23±2.62i
6	Damgo	P	Long (more than 20 %)	WB	100±0.00a
7	Dhave	OC	Medium (11 % to 20 %)	WB	88.40±0.98c
8	Dodga	P	Long (more than 20 %)	WC	84.40±1.01d
9	Irtal	P	Long (more than 20 %)	WC	87.43±1.05c
10	Kala Novan	P	Long (more than 20 %)	WC	33.30±0.90k
11	Karz	P	Long (more than 20 %)	WB	57.40±1.31h
12	Kenal	P	Long (more than 20 %)	WB	87.56±1.51c
13	Kendal	P	Long (more than 20 %)	WB	100±0.00a
14	Khochro	P	Long (more than 20 %)	WB	100±0.00a
15	Korgut	P	Long (more than 20 %)	WB	87.86±0.65c
16	Mangala	P	Long (more than 20 %)	WB	67.40±0.87g
17	Ner	P	Long (more than 20 %)	WC	38.46±1.16j
18	Novan	P	Long (more than 20 %)	WB	91.63±0.66b
19	Revati	P	Long (more than 20 %)	WB	76.50±0.65f
20	Salsi	P	Long (more than 20 %)	WB	93.06±2.67b
21	Tamde Jyoti	P	Long (more than 20 %)	WB	80.73±0.45e
22	Vadlo Kenal	P	Long (more than 20 %)	WB	88.56±0.41c
23	IR8	P	Long (more than 20 %)	WB	81.80±1.15e
24	Jyoti	P	Long (more than 20 %)	WB	85.00±0.75d
25	Jaya	P	Long (more than 20 %)	WC	24.10±1.47l

Superscript letters (a-m) indicate significant differences ($p \leq 0.05$) among different rice varieties in percentage of chalkiness. Means with same letter within column are not significantly different ($p \leq 0.05$). WB, white belly; WC, white centre; VOP, very occasionally present; OC, occasionally present; P, present

Amylose content (AC) is considered to be the single most important characteristic for predicting rice cooking and processing behaviors. The percentage of AC in the present study ranged from 14-25% (Table 3). The variety Mangala showed lowest AC (13.6%), while highest AC was recorded in variety Kalo Novan (23.7%). In high yielding varieties the AC ranged from 17.86-24.75%. Most consumers prefer rice with intermediate AC ranged between 20-25% [28]. The AC in rice ranges between 20.7-21.4% and difference in brightness of the grain is probably due to the higher AC [29].

The GT of the rice samples have been classified as high to intermediate which means the temperature required for normal cooking time is 75-79°C. While the GC of the rice samples is 65-70 mm and categorized as soft, this means the tendency of cooked rice to be soft on cooling. The GC is measured into soft, medium and hard. Among the traditional rice varieties, the length of the blue gel was highest in Salsi (93 mm) but no significant difference with Dodga (91.3 mm) and lowest in Khochro (34.6 mm). In high yielding rice varieties the GC ranged from 44- 64% (Table 3).

Table 3. The alkali spreading value (ASV), gelatinization temperature (GT), amylose content (AC), gel consistency (GC) and aroma in traditionally cultivated and high yielding rice varieties

Sl. No.	Varieties	ASV	GT	Amylose (%)	Length of blue gel (mm)	GC	Aroma
1	Annapurna	L	H>74 °C	16.9±0.62fgh	70.3±1.52d	Soft	Mild scent
2	Atthavis	I	I (70-74 °C)	14.8±0.52ijk	84.6±2.51b	Soft	No scent
3	Barik Kudi	LI	HI	14.0±0.87k	62±1efg	Soft	Mild scent
4	Bello	I	I (70-74 °C)	16.0±1.28hij	55.3±1.52h	Medium	No scent
5	Chudi	I	I (70-74 °C)	18.6±1.21bcdef	60.3±0.57g	Medium	No scent
6	Damgo	L	H >74°C	17.2±0.69efgh	75.3±3.51c	Soft	No scent
7	Dhave	I	I (70-74 °C)	17.9±0.61cdefgh	50.6±1.15i	Medium	No scent
8	Dodga	I	I (70-74 °C)	16.7±1.09fghi	91.3±2.30a	Medium	No scent
9	Irtal	I	I (70-74 °C)	16.4±1.09ghij	61±1fg	Soft	No scent
10	Kala Novan	I	I (70-74 °C)	23.7±0.76a	60.3±0.57g	Medium	No scent
11	Karz	L	HI	20.4±0.84b	46±3.6j	Medium	No scent
12	Kenal	L	H >74 °C	16.9±0.75fgh	65±3e	Soft	No scent
13	Kendal	L	H >74 °C	19.9±0.33bc	85±2b	Soft	No scent
14	Khochro	L	H >74 °C	14.6±0.37jk	34.6±0.57k	Hard	No scent
15	Korgut	LI	HI	17.5±1.40defgh	64.6±2.51e	Soft	No scent
16	Mangala	I	I (70-74 °C)	13.6±1.13k	64.6±0.57e	Soft	No scent
17	Ner	I	I (70-74 °C)	19.3±1.31bcd	82±1b	Soft	No scent
18	Novan	H	L (55-69 °C)	17.1±0.84efgh	54.3±4.04h	Medium	No scent
19	Revati	I	I (70-74 °C)	19.0±1.29bcde	83.3±1.52b	Soft	No scent
20	Salsi	H	L (55-69 °C)	18.3±0.35cdef	93±1a	Soft	Mild scent
21	Tamde Jyoti	L	H >74 °C	16.8±0.57fgh	71±1d	Soft	Optimal
22	Vadlo Kenal	L	H >74 °C	16.7±0.93fghi	64.3±2.08ef	Soft	No scent
23	IR8	L	H >74 °C	17.8±0.59defgh	62.6±2.51efg	Soft	Mild scent
24	Jyoti	L	H >74 °C	24.7±4.12a	64.0±4ef	Soft	Mild scent
25	Jaya	H	L (55-69 °C)	23.3±0.88a	44.6±2.51j	Soft	Mild scent

Superscript letters (a-k) indicate significant differences ($p \leq 0.05$) among different rice varieties in AC and length of blue gel in mm. Means with same letter within the column are not significantly different ($p \leq 0.05$)
L, Low; I, Intermediate; LI, Low-intermediate; H, High; HI, High-intermediate

Aroma is another important trait in rice and the aromatic rice has high demand in the market. It was observed in the present study that few native varieties are having aroma, for which these varieties are preferred for consumption by local people. Among the rice varieties examined, Annapurna, Barik Kudi, Salsi, Tamde Jyoti, IR8, Jyoti and Jaya showed the presence of mild aroma (Table 3). It was reported that in basmati rice 2-acetyl-1-pyrroline (2-AP) is the major aroma compound responsible for the fragrance and quantity of 2-AP varies with varieties and climatic conditions [30]. Also reported that the epidermal papillae of lower epidermis of leaf of *Pandanus amaryllifolius* contain similar aroma compounds as present in basmati rice, traditionally it has used during cooking of non-scented rice to get the smell of basmati [31].

Cooking characteristics

The volume expansion ratio ranged from 2-4 mm in traditional rice varieties, while in high yielding varieties 2.0-3.4 mm. Variety Jaya showed 3.4 mm and IR8 with 2.0 mm. The positive correlation of AC with water uptake, volume expansion ratio and alkali spreading value indicates that high amylose rice varieties will absorb more water at low GT and will produce a greater volume of cooked material [32].

Kernel elongation ratio was found to be not related with either AC or alkali spreading value. Kernel length after cooking ranged from 1.8-4.7 mm in traditionally cultivated rice and 2.0-3.4 mm in high yielding rice varieties. Minimum kernel length after cooking was calculated in variety Novan and maximum in variety Bello. Kernel elongation in traditional rice varieties ranged from 1.0-1.6 and high yielding varieties from 1.0-1.1. Highest kernel elongation

ratio was observed in variety Bello and lowest in Mangala (Table 4).

Fig. 1 Water uptake in traditionally cultivated and high yielding rice varieties

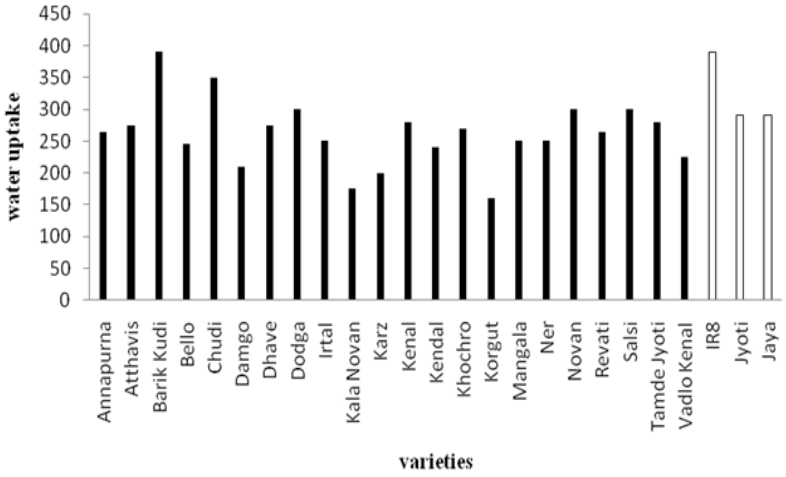

Table 4. The volume expansion ratio, kernel length after cooking (KLAC), kernel elongation ratio (ER) and water uptake in traditionally cultivated and high yielding rice varieties

Sl. No.	Varieties	Volume Expansion	KLAC (mm)	Elongation ratio
1	Annapurna	3.03±0.05d	3.07±0.06defg	1.29±0.02c
2	Atthavis	2.03±0.05fg	2.89±0.04fgh	1.07±0.01fghi
3	Barik Kudi	4.00±0b	3.91±0.07b	1.13±0.02defghi
4	Bello	3.10±0.1d	4.78±0.16a	1.66±0.07a
5	Chudi	2.60±0.1e	3.34±0.03cd	1.23±0.03cd
6	Damgo	2.20±0.1fg	2.76±0.05hi	1.22±0.13cde
7	Dhave	2.00±0g	2.93±0.08fgh	1.19±0.10cdef
8	Dodga	3.03±0.05d	2.50±0.20ij	1.10±0.06efghi
9	Irtal	3.50±0.1c	2.33±0.05jk	1.05±0.06ghi
10	Kala Novan	3.43±0.28c	3.81±0.11b	1.51±0.06b
11	Karz	2.10±0.1fg	3.16±0.10def	1.19±0.11cdef
12	Kenal	4.03±0.05ab	2.92±0.04fgh	1.30±0.04c
13	Kendal	2.03±0.05fg	2.84±0.03gh	1.17±0.10cdefg
14	Khochro	4.06±0.05ab	2.56±0.11ij	1.10±0.04efghi
15	Korgut	2.70±0.1e	2.38±0.33j	1.10±0.10efghi
16	Mangala	4.23±0.15a	2.74±0.15hi	1.03±0.02hi
17	Ner	2.23±0.20f	2.89±0.08fgh	1.08±0.12fghi
18	Novan	4.03±0.05ab	1.83±0.03l	1.16±0.15efghi
19	Revati	2.03±0.05fg	2.50±0.2ij	1.13±0.04defghi
20	Salsi	3.03±0.05d	3.31±0.07cde	1.24±0.11cd
21	Tamde Jyoti	3.50±0c	3.94±0.05b	1.12±0.02defghi
22	Vadlo Kenal	2.16±0.28fg	3.04±0.62efg	1.05±0ghi
23	IR8	2.03±0.05fg	2.45±0.04j	1.19±0.02cdef
24	Jyoti	2.63±0.05e	2.08±0.02kl	1.01±0.04i
25	Jaya	3.46±0.32c	3.48±0.02c	1.14±0.02defghi

Superscript letters (a-1) indicate significant differences ($p \leq 0.05$) among different rice varieties in volume expansion, KLAC, ER and water uptake in ml. Means with same letter within column are not significantly different ($p \leq 0.05$).

In high yielding varieties, water uptake ratio ranged from 290-390 and in traditional rice varieties 160-390. Rice variety IR8 recorded the highest water uptake and among traditional rice varieties the minimum water uptake was noted in Korgut and maximum in Barik Kudi (Fig. 1). When the AC of a variety increases, cooking time is also increase. The Organoleptic test were conducted for appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation and overall acceptability for traditional and high yielding rice varieties (Table 5). The excellent overall acceptability was recorded in the varieties Korgut and Tamde Jyoti. The good overall acceptability was observed in rice varieties viz. Annapurna, Dhave, Kenal, Kendal, Vadlo Kenal, Jyoti and Jaya.

Table 5. Organoleptic test of traditionally cultivated and high yielding rice varieties

Q	Characteristics	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y
A	Appearance																									
5	White							+																		
4	Creamish white/ brown	+	+		+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
3	Red streaks																									
2	White with brown streaks			+																						+
1	White with black streaks																									
B	Cohesiveness																									
5	Well separated	+	+	+	+	+	+	+	+		+	+	+	+	+	+		+	+				+		+	
4	Partially separated									+							+			+	+	+		+		+
3	Slightly separated																									
2	Moderately separated																									
1	Very sticky																									
C	Tenderness on touching																									
5	Soft																									+
4	Moderately soft							+														+	+			
3	Moderately hard		+			+			+	+	+		+	+				+	+	+	+					
2	Hard	+		+	+		+					+			+	+	+							+	+	
1	Very soft																									
D	Tenderness on chewing																									
5	Soft																					+	+			+
4	Moderately soft																	+	+	+	+					
3	Moderately hard	+		+	+	+		+	+	+			+	+		+	+							+	+	
2	Hard		+				+				+	+			+											
1	Very soft																									
E	Taste																									
5	-																									
4	Good																					+	+			
3	Desirable	+			+		+	+				+	+	+		+		+	+	+	+			+		+
2	Tasteless		+	+		+			+	+	+				+		+								+	
1	undesirable																									
F	Aroma																									
5	Strong																									
4	Optimal																					+				
3	Mild																									
2	Other than basmati (mild)	+		+																	+			+	+	+
1	No scent		+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+			
G	Elongation																									
5	-																									
4	Excellent																									
3	Good						+	+				+				+						+			+	
2	Moderate	+	+	+	+	+			+	+	+		+	+	+		+	+	+	+	+		+	+		+
1	none																									
H	Overall acceptability																									
5	-																									
4	Excellent															+						+				
3	Good	+						+					+	+									+		+	+
2	Acceptable		+	+	+	+	+		+	+	+	+			+		+	+	+	+	+			+		
1	undesirable																									

a, Annapurna; b, Atthavis; c, Barik Kudi; d, Bello; e, Chudi; f, Damgo; g, Dhave; h, Dodga; i, Irtal; j, Kala Novan; k, Karz; l, Kenal; m, Kendal; n, Khochro; o, Korgut; p, Mangala; q, Ner; r, Novan; s, Revati; t, Salsi; u,Tamde Jyoti; v, Vadlo Kenal; w, IR8; x, Jyoti; y, Jaya and Q, quality.

The study revealed that the traditionally cultivated rice varieties Vadlo Kenal, Novan and Tamde Jyoti with maximum hulling percentage, HR recovery and L/B ratio. Maximum AC, alkali spreading value and gel consistency was recorded in traditionally cultivated rice varieties Salsi, Barik Kudi, and Kala Novan. The cooking characteristics indicated that the traditionally cultivated rice varieties Korgut and Tamde Jyoti are with excellent grain quality and varieties such as Annapurna, Dhave, Kenal, Kendal, Vadlo Kenal in category of good cooking quality.

Conclusions

In the present study physical, chemical and cooking characteristics were evaluated for 22 traditionally cultivated and three high yielding rice varieties. Among the varieties studied traditionally cultivated rice varieties such as Vadlo Kenal, Novan and Tamde Jyoti showed good physical characteristics (maximum hulling, HR recovery, L/B ratio). The chemical properties (AC, alkali spreading value, gel consistency) were excellent in varieties Salsi, Barik Kudi, and Kala Novan. The best cooking quality (appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation) was observed in the rice varieties Korgut, Tamde Jyoti, Annapurna, Dhave, Kenal, Kendal and Vadlo Kenal. The study revealed that some of the traditional rice varieties are with high grain quality characteristics, which could be used in rice breeding programmes and biotechnological research for further improvement of rice. The Korgut is another traditionally cultivated rice variety showed high grain quality characteristics with high salinity tolerance and could also be used for rice breeding.

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