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Physico-chemical characteristics and nutritional quality analysis of aromatic rice (*Oryza sativa* L.) genotypes

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Abstract

Aromatic rice constitutes a small but an important sub-group of rice. These are rated best in quality and fetch much higher price than high quality non-aromatic rice in international market. In spite of their importance, pace of improvement of this group of rice has been rather slow. Quality rice are characterized by not only aroma but also by several other traits like grain length and width, elongation after cooking, amylose content, gelatinization temperature etc. Grain quality in rice is very difficult to define with precision as preferences for quality vary from country to country and region to region in a country. The concept of quality varies according to the ways of preparations for which the grains are to be used. Although some of the quality characteristics desired by grower, miller and consumer may be the same, yet each may place different emphasis on various quality characteristics of rice. Physico-chemical characteristics and nutritional quality of 32 genotypes of aromatic rice (*Oryza sativa* L.) were analysed. A total of ten quality parameters related to grain were estimated and three nutritional estimation were also carried out using standard protocols. Maximum variations among the genotypes were observed for amylose content (AC), kernel length (KL), gel consistency (GC), carbohydrate content (CC) and protein content (PC). AC ranged from 2.97% to 20.60%, GC from 20.31 mm to 86.49 mm, CC from 29.83% to 82.18% and PC from 2.35% to 11.69%. In terms of nutritional quality analysis, Ja-Pnah (82.18%) followed by IC-465275 (81.55%) recorded the highest carbohydrate content. CT3-D-4 (11.69%) recorded the highest protein content whereas IC 137342 (0.99%) recorded the highest fat content. The promising genotypes identified in this study by emphasizing upon genotypes for various grain quality and nutritional traits can be utilized according to the choice of the breeder in further improvement of aromatic rice.

Key words: Aromatic rice, grain quality, nutritional quality, gelatinization temperature, amylose

Introduction

The *Oryza sativa* is divided into three sub-species, namely*, indica, japonica* and *javanica*. Rice is a "Global Grain", cultivated widely across the world and is the major staple food for billions of people. It is the staple food for half of the world's population and occupies almost one-fifth of the total land area covered under cereals. It is one of the very few crop species endowed with rich genetic diversity which account for 100,000 landraces and improved cultivars (Meti et al. 2007).

India has the largest area and is ranked second in rice production among the rice growing countries. According to United States Department of Agriculture (USDA), Foreign Agriculture Service (FAS), in 2016-17 India's forecasted rice production is 105 million ton with 44 million ha area while in 2015-16 India's rice production was 103.5 million ton with 43.46 million ha area. However, its share for export in international market is less than five percent for which low grain quality characteristics may be one of the factors. Rice grain quality is a major factor from consumer as well as marketing point of view. Grain quality has always been an important consideration in rice variety selection and development. Based on the survey of 11 major rice growing countries, Juliano and Duff (1991) concluded that grain quality is second only to yield as the major breeding objective.

Aromatic rice is one of the major types of Asian rice. It is short to long grained rice known for its nut-like aroma and taste. Aromatic rice constitutes a small but an important sub-group of rice (Singh et al. 2000). These are rated best in quality and fetch much higher price than high quality non-aromatic rice in international

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market. In spite of their importance, pace of improvement of this group of rice has been rather slow. In addition to other problems related to their cross-compatibility with high yielding non-aromatic rice and high dependence of expression of quality traits on environmental factors, lack of information on various aspects of aromatic rice too have contributed towards the slow pace of improvement.

The grain quality attributes of rice that determine its acceptability by the end user can be grouped into two main categories, (i) grain appearance and (ii) cooking and eating qualities (Juliano and Villareal, 1993). The appearance quality is determined by grain length, breadth, length-breadth ratio, and translucency of the endosperm. The cooking and eating quality traits include volume expansion, fluffiness, cooked kernel elongation, firmness/stickiness (related to amylose content), gelatinization temperature (also measured as alkali spreading value), mouth feel and a pleasant aroma. Each of these traits is determined by the physico-chemical properties of the rice grain which in turn are genetically controlled with some modulation of expression by the growth environment. The study was conducted to characterize some aromatic rice genotypes using grain quality traits to identify different rice genotypes for better grain quality characteristics.

Materials and methods

The experimental materials comprised of 32 rice genotypes including three checks *viz*., Bahadur (non-aromatic), Ja-Pnah (aromatic) and Chakhao Poireiton (aromatic)which were collected from ICAR-NBPGR Shillong, Manipur, Meghalaya and Mizoram. The materials were grown in completely randomized block design in three replications during *kharif* 2017. Of the thirteen characters studied, ten characters identified were physico-chemical characters (Hulling percentage, Kernel length, Kernel breadth, Kernel length: breadth ratio, Alkali spreading value, Gelatinization temperature, Gel consistency, Amylose content, Aroma and Water uptake ratio) and three were nutritional composition (Carbohydrate content, Protein content and Fat content).

Physico-chemical characters

Hulling percentage was calculated as follows:

$$\text{Hulling percentage (\%)} = \frac{\text{Weight of the dehusked kernel (g)}}{\text{Weight of paddy (100 g)}} \times 100$$

Ten grains were taken randomly after removing hull and average kernel length and breadth were recorded in millimeters (mm) using vernier calipers. Standards for evaluation of grain length and shape of breeding materials vary among countries and marketing areas. The classification of the grain for routine breeding evaluation was followed as per the guidelines of SES (IRRI, 2002)

Amylose content, aroma and gelatinization temperature (GT) through alkali spreading value (ASV)

The simplified procedure of Juliano (1971) was used for the amylose content analysis.

The amylose content is expressed as - Amylose (percent) = R x 76.92ss

An organoleptic test was used for detection of aroma of the samples under study. To 5 g of rice, 15 ml of water was added, soaked for 10 minutes and cooked for 15 minutes, transferred into a Petri dish and placed in a refrigerator for 20 minutes. Then the cooked rice sample was smelled by a random panel and then categorized into very strongly scented (VSS), strongly scented (SS), mild scented (MS), very mild scented (VMS) and non scented (NS) depending upon the intensity.

Gelatinization temperature through alkali spreading value and clearing scale was determined as per procedure described by Little et al. (1958).

Gel consistency (GC)

The method of determining gel consistency is briefly mentioned as follow; 100 mg of flour quadruplicates was taken in culture tubes. 0.2 ml of ethanol was added followed by 2 ml of 0.2N Potassium Hydroxide (KOH). The solution was then mixed on a vortex mixer. The culture tubes were then kept in water bath at 90-100^{o}C for 8 minutes after putting one glass tube marble on each test tube. After removing the culture tubes from water bath, they were cooled for 5 minutes. The solution was mixed again on a vortex mixer. The culture tubes were then placed in low temperature bath at 0-2^{o}C for 20 minutes and were removed from ice bath and laid horizontally for one hour over graph paper. The length of the gel from the inside bottom of the test tube to the gel front was then measured as gel consistency of the sample.

Water uptake ratio (WUR)

WUR was determined by cooking 2.0 g of whole rice kernels from each treatment in 20 ml distilled water for about 10 minutes in a boiling water bath and draining the superficial water from the cooked rice. The weight of the cooked samples was then accurately weighed and then the WUR was calculated as the ratio of final cooked weight to uncooked weight i.e.

$$\text{Water Uptake Ratio} = \frac{\text{Weight of cooked rice}}{\text{Weight of uncooked rice sample}}$$

Nutritional quality analysis

Protein estimation by Lowry's method

Protein content (PC) can be estimated by different methods as described by Lowry and can also be estimated by determining the total nitrogen content. No method is 100% sensitive. Hydrolyzing the protein and estimating the amino acids alone will give the exact quantification. The method developed by (Lowry et al. 1951) is sensitive enough to give a moderately constant value and hence largely followed. Protein content of enzyme extracts is usually determined by this method. The method is based on the blue colour developed by the reduction of the phosphomolybdic phosphotungstic components in the Folin-Cioealteau reagent by the amino acids tyrosine and tryptophan present in the protein plus the colour developed by the burette reaction of the protein with the alkaline cupric tartarate.

Carbohydrate estimation by phenol - Sulphuric Acid method

The carbohydrate content (CC) can be measured by hydrolyzing the polysaccharides into simple sugars by acid hydrolysis and estimating the resultant monosaccharides. Phenol - Sulphuric acid method was used for calculating the amount of total Carbohydrate. The method is as follows; 100 mg of the sample was weighed into a boiling tube. It was Hydrolyzed by keeping it in a boiling water bath for three hours with 5 ml of 2.5N HCl and cooled to room temperature. Then the sample was neutralized with Solid Sodium carbonate until the effervescence ceases. The volume was made up to 100 ml and centrifuged. 0.1 and 0.2 ml of the sample solution was taken in two separate test tubes. The volume was made up to 1 ml in each tube. 5 ml of 96% sulphuric acid was added to each tube and shaken well. After 10 minutes, the contents in the tubes were placed in water bath at 25-30^{o}C for 20 minutes. The colour was read at 490 nm. Amount of total carbohydrate present in the sample solution was calculated using the standard calibration graph.

Estimation of fats (FC)

A small quantity of free fatty acids is usually present in oils along with the triglycerides. The free fatty acid content is known as acid number/acid value. It increases during storage. The keeping quality of oil

Table 1. Aromatic rice genotypes along with check varieties

S. No.	Genotype code	Genotypes	Source
1	R1	IC-89071	ICAR-NBPGR, Shillong
2	R2	IC-137342	-do-
3	R3	IC-137401	-do-
4	R4	IC-323776	-do-
5	R5	IC-323781	-do-
6	R6	IC-326284	-do-
7	R7	IC-342353	-do-
8	R8	IC-342368	-do-
9	R9	IC-342369	-do-
10	R10	IC-351517	-do-
11	R11	IC-394788	-do-
12	R12	IC-464363	-do-
13	R13	IC-464661	-do-
14	R14	IC-464684	-do-
15	R15	IC-465275	-do-
16	R16	Tai Sanghan	Mizoram
17	R17	CT3-D-1	Manipur
18	R18	CT3-D-2	-do-
19	R19	CT3-D-4	-do-
20	R20	CT3-D-6	-do-
21	R21	CT3-D-7	-do-
22	R22	CT3-D-9	-do-
23	R23	CT3-D-10	-do-
24	R24	CT3-D-11	-do-
25	R25	CT3-D-12	-do-
26	R26	Mantup Chakhao	-do-
27	R27	Kaunglauny Chakhao	-do-
28	R28	Faisenbuman Chakhao	-do-
29	R29	Bahadur (check)	Meghalaya
30	R30	Ja-Pnah (check)	-do-
31	R31	Chakhao Poireiton (check)	Manipur
32	R32	Chakhao Amubi	-do-

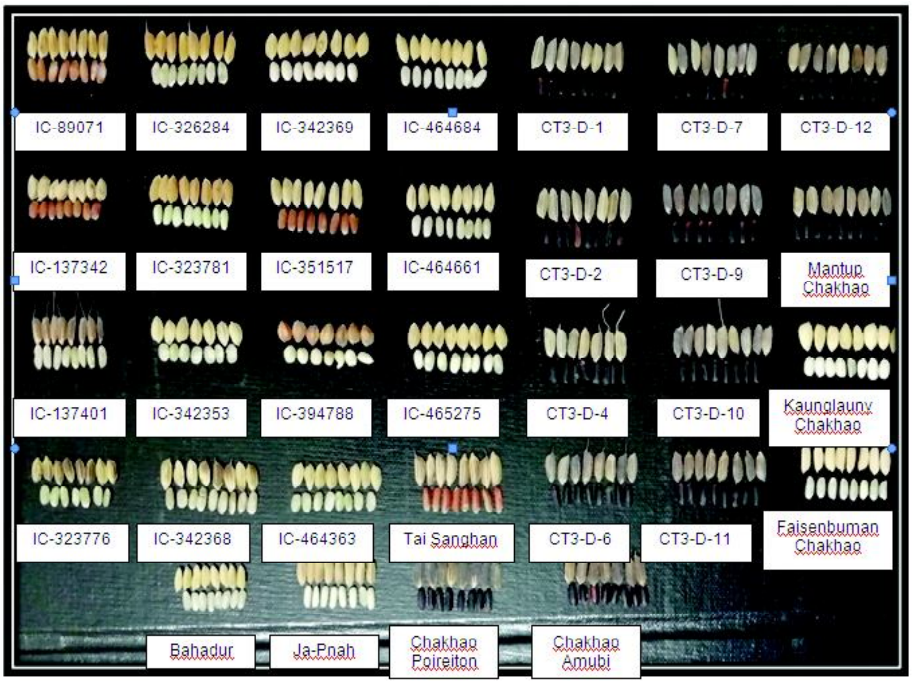

Fig. 1. Differences in kernel size and shape

therefore relies upon the free fatty acids.

The free fatty acid is estimated by titrating it against KOH in the presence of phenolphthalein indicator. The acid number is defined as the mg KOH required to neutralize the free fatty acids present in 1 g of sample.

Results and discussion

The present investigation was carried out for grain quality characterization of 32 aromatic rice genotypes. A total of ten quality parameters related to grain were estimated and three nutritional estimation were also carried out using standard protocols. Maximum variations among the genotypes were observed for amylose content (AC), kernel length (KL), gel consistency (GC), carbohydrate content (CC) and protein content (PC). AC ranged from 2.97% to 20.60%, GC from 20.31 mm to 86.49 mm, CC from 29.83% to 82.18% and PC from 2.35% to 11.69%. In terms of nutritional quality analysis, Ja-Pnah (82.18%) followed by IC-465275 (81.55%) recorded the highest carbohydrate content. The other genotypes which were statistically at par with Ja-Pnah were IC-394788 (74.76%), IC-351517 (76.70%), IC-342368 (76.80%), Tai Sanghan (77.01%), Chakhao Amubi (77.38%), IC-464363 (77.53%), Faisenbuman Chakhao (78.01%), IC-342353 (78.93%), IC-464661 (79.66%) and IC-464684 (79.95%). CT3-D-4 (11.69%) recorded the highest protein content %) which was statistically at par with Chakhao Poireiton (10.80%), CT3-D-6 (10.19%) and CT3-D-10 (10.51%) whereas IC-137342 (0.99%) recorded the highest fat content. Highest GCV was recorded for AC followed by PC suggesting selection based on the trait would be effective. Different cultivars were considered to be the best performers which can be further tapped as parents in any breeding programme for desirable traits depending upon the choice of the breeder (Table 2). Gaikwad et al. (2018) reported that the traits, kernel length and breadth and their ratio can be improved through interspecific hybridization in rice. They also observed a high magnitude of heterosis for these traits.

Among different quality traits aroma is considered most important. Popcorn like aroma component '2-acetyl-1-pyrroline' has been reported as an important flavour component of several aromatic varieties. Among the 32 genotypes under study, aroma was detected in all 32 but differs in their intensity from very strong, strong, mild and very mild scented. Chakhao Poireiton and IC-394788 were the two genotypes which were very strongly scented. Aroma can make rice highly desired by consumers (Yau and Liu, 1999). Pusa Basmati variety Pusa Basmati No. 1, released from IARI, has a mild aroma. Pusa Basmati variety, Pusa Basmati 1121, has a strong aroma from which other Basmati varieties like Pusa Basmati 6 and Pusa Basmati 1509 has been developed having strong aroma. (Singh et al. 2018).

The hulling percentage varied from 81.87% (Faisenbuman Chakhao) to 71.33% (IC-464684) with an average of 77.36%. Among the checks, Bahadur (80.40%) recorded a higher hulling percentage which was statistically at par with the highest hulling percentage under study suggesting that it performed better than the other checks. The other genotypes having statistically at par values with Faisenbuman

Table 2. Outstanding genotypes under study based on mean performance

S.No.	Characters	Outstanding genotype under study based on mean performance
1	Aroma	Chakhao Poireiton and IC-394788 (Based on intensity of aroma)
2	Kernel length (mm)	Tai Sanghan, CT3-D-2, CT3-D-1, CT3-D-4, CT3-D-6, CT3-D-10, Ja-Pnah and Chakhao Poireiton
3	Kernel breadth (mm)	IC-394788, IC-342353 and Kaunglauny Chakhao
4	Kernel length: breadth ratio	Ja-Pnah
5	Hulling percentage (%)	Faisenbuman Chakhao, Bahadur, CT3-D-6, CT3-D-10, CT3-D-4, CT3-D-2, IC-89071, IC-465275, Tai Sanghan, IC-323776, IC-326284, IC-137342, IC-351517 and Kaunglauny Chakhao
6	Water uptake ratio	IC-465275, IC-342369 and IC-323781
7	Amylose content (%)	Chakhao Poireiton, Bahadur, IC-89071 and IC-137342
8	Gel consistency (mm)	IC-351517, Bahadur, Mantup Chakhao and IC-394788
9	Carbohydrate content (%)	Ja-Pnah, IC-394788, IC-351517, IC-342368, Tai Sanghan, Chakhao Amubi, IC-464363, Faisenbuman Chakhao, IC-342353, IC-464661 and IC-464684
10	Protein content (%)	CT3-D-4, Chakhao Poireiton, CT3-D-6 and CT3-D-10
11	Fat content (%)	IC-137342

Chakhao were CT3-D-6 (77.93%), CT3-D-10 (78.03%), CT3-D-4 (78.10%), CT3-D-2 (78.13%), IC-89071 (78.20%), IC-465275 (78.93%), Tai Sanghan (79.53%), IC-323776 (79.73%), IC-326284 (79.80%), IC-137342 (80.13%), IC-351517 (80.40%) and Kaunglauny Chakhao (81.07%). More than 80% value of hulling percentage is preferred since as the hulling percentage increases the head rice recovery also increased as reported by Rita and Sarawgi (2008). Bajpai and Singh (2010) also reported similar findings during their study when the results revealed the hulling percentage ranging from 78.6% (3047) to 81.6% (3227).

Grain size and shape are the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production. Some ethnic groups prefer short bold grains, some have a preference for medium long grains, and long slender grains are highly prized by others. In general, long grains are preferred in the Indian subcontinent, but in Southeast Asia the demand is for medium to medium long rice. The investigation carried out in this study revealed the length of the kernel which ranged from 6.33 mm to 10.90 mm. Among the checks, Ja-Pnah (10.07 mm) is the longest. Ja-Pnah and Chakhao Poireiton was statistically at par with Tai Sanghan among the 3 checks. Other genotypes which were statistically at par with Tai Sanghan were CT3-D-2 (9.80), CT3-D-1 (9.90), CT3-D-4 (9.97), CT3-D-6 (10.20) and CT3-D-10 (10.23). The study revealed that three genotypes of rice namely Tai Sanghan, CT3-D-6 and CT3-D-10 were having longer kernel length than the highest check, Ja-Pnah. The mean was recorded as 8.68 mm. Bajpai and Singh (2010) also revealed similar kind of observations with respect to kernel length ranging from 9.3 mm (3219) to 11.0 mm (3051). Similarly the kernel breadth ranged from 2.13 mm to 3.50 mm with an average of 2.63 mm. The highest kernel breadth was observed in IC-394788 (3.50 mm) which was statistically at par with IC-342353 (3.17 mm) and Kaunglauny Chakhao (3.13 mm). In terms of kernel breadth, most cultivars recorded higher kernel breadth than the checks. The findings of kernel breadth were in accordance with the study of Dutta et al. (1998). The lowest kernel length: breadth ratio was observed in IC-394788 (1.81) and the highest ratio was observed in Ja-Pnah (4.64). Shilpa and Krishnan (2010) reported similar findings for kernel length: breadth ratio during their evaluation of 22 traditionally cultivated rice varieties of Goa. Singh et al. (2018) also reported similar findings for Pusa Basmati 1121 which has extra-long slender grains with a milled rice kernel length averaging 9.00 mm, a breadth of 1.90 mm and a length:breadth ratio of 4.74

Alkali spreading value is used as an inverse indicator of gelatinization temperature of milled rice starch granules. Rice with low gelatinization temperature disintegrate completely in a weak alkali solution (1.7% KOH), whereas rice with intermediate gelatinization temperature show only partial disintegration. Rice with high gelatinization temperature remains largely unaffected in the alkali solution. The

ASV and GT score of the 32 genotypes under study are represent in Table 3. Bhonsle and Krishnan (2010) reported similar findings. Higher the value of GT, the longer time it takes to cook rice. CT3-D-2, CT3-D-10, IC-323781, IC-394788, IC-464684 and CT3-D-1 recorded intermediate GT implying that they are highly preferred, supported by findings of Bansal et al. (2006).

The water uptake ratio ranged from 1.99 to 3.30. IC-465275 (3.30) reported the highest water uptake ratio which was statistically at par with IC-342369 (3.10) and IC-323781 (3.17) and Kaunglauny Chakhao (1.99) recorded the lowest. The three checks *viz*., Bahadur, Ja-Pnah and Chakhao Poireiton recorded water uptake ratio of 2.01, 2.54 and 2.08, respectively. The results observed were comparable with the findings of Oko and Dambaba (2012) where the water uptake ratio varied from 1.13-3.35.

Low amylose rice cooks moist and sticky. Intermediate amylose rice cooks moist and tender and do not become hard upon cooling. Intermediate amylose rice is the preferred type in most of the rice growing areas of the world, except where low-amylose *japonicas* are grown. In the present study, the amylose content ranged from 20.60% in Chakhao Poireiton to 2.97% in IC-323781. The amylose content was detected maximum in Chakhao Poireiton (20.60%) which was statistically at par with IC-323776 (20.48%), IC-89071 (18.83%) and IC-137342 (19.66%). Majority of the genotypes under study reported low amylose content (10-20%). Bahadur and Ja-Pnah recorded AC of 18.54% and 8.58% respectively. Similar kind of observation was revealed by Thongbam et al. (2012) when the study revealed that majority of the cultivars had low amylose contents (<20%).

The gel consistency (GC) was measured into soft, medium and hard. The gel consistency ranged from 20.31 mm (IC-464363) to 86.49 mm (IC-351517) with an average of 58.71 mm. The highest gel consistency was recorded in IC-351517 (86.49 mm) which was statistically at par with Bahadur (82.43 mm), Mantup Chakhao (80.19 mm) as well as IC-394788 (81.77 mm). Rice with soft gel consistency cook tender, and remain soft even upon cooling. Cooked rice with hard gel consistency hardens faster than those with soft one. The three checks recorded the gel consistency of 82.43 mm (Bahadur), 69.01 mm (Ja-Pnah) and 40.73 mm (Chakhao Poireiton). Bhonsle and Krishnan (2010) concluded that 65-70 mm of gel consistency is categorized as soft. Rice with soft GC is preferred by most rice consumers. The identified genotypes in the present study with highmean value of the traits can be used in breeding to improve rice genotypes. The quality traits thrugh conventional breeding takes longer time, therefore, marker assites breeding is suggested to be an integral part of breeding to improve both physic-chemical and other quality characters (Singh et al. 2019).

Mean per se performance of 32 rice cultivars for 3 nutritional quality characters

Rice is the main source of carbohydrates for more than 1/3rd of the people in the world. The mean carbohydrate in the thirty two samples studied was 64.15%. Ja-Pnah recorded highest carbohydrate content of 82.18% which was statistically at par with IC-394788 (74.76%), IC-351517 (76.70%), IC-342368 (76.80%), Tai Sanghan (77.01%), Chakhao Amubi (77.38%), IC-464363 (77.53%), Faisenbuman Chakhao (78.01%), IC-342353 (78.93%), IC-464661 (79.66%), IC-464684 (79.95%) and IC-465275 (81.55%). Graphical representation of kernel length and breadth, carbohydrate content (CC), fat content (FC) and protein content has been given in Figs. 2, 3, & 4. The cultivar CT3-D-6 had lowest carbohydrates of 29.83%. In Table 3 the checks performed better than the other cultivars having values more than the average indicating the better acclimatization of these checks in the area under study. Thongbam et al. (2012) reported similar findings by revealing that eleven cultivars possessed higher carbohydrate content (>76%) and 6 cultivars found to have >60% of carbohydrate content. The above observations were also in conformity with the findings of Nadiger and Kasturiba (2015) and Thongbam et al. (2010). In this study, some cultivars recorded carbohydrate content lesser than 35% deviating from the average due to influence of genetic component or possibly the effects of the environment. Eleven cultivars recorded carbohydrate content lesser than the average value. The correlation amongst the quality characteristics evaluated is presented in Table 4.

The nutritional quality of rice depends on the protein content and rice is the poor sources of protein among cereals. But the quality of protein depends on the composition of amino acids. The rice protein is superior because of its unique composition of essential amino acids. The protein content ranged from 2.35% to 11.69% in the samples studied. Analyzing the protein in local germplasm will help the nutritionist to assess the protein intake and deficiency of protein in the people of rice consuming countries. In the present investigation, the thirty two varieties had an average

Table 3. Mean performances of 32 rice genotypes of characters under study

S.No.	Genotypes	KL (mm)	KB (mm)	K L:B	Hulling (%)	GC (mm)	ASV	GT	WUR	AC (%)	CC (%)	FC (%)	PC (%)
1	IC-89071	8.87	2.43	3.65	78.20	71.84	1	7	2.43	18.83	52.59	0.77	3.95
2	IC-137342	6.97	2.43	2.87	80.13	70.52	3	5	2.21	19.66	62.90	0.99**	4.09
3	IC-137401	8.27	2.57	3.22	77.67	74.35	3	5	2.32	5.36	61.91	0.74	5.53
4	IC-323776	8.00	2.5	3.20	79.73	53.10	6	1	2.48	20.48	71.27	0.79	4.99
5	IC-323781	7.97	2.6	3.07	75.67	69.14	5	3	3.17	2.97*	34.73	0.69	3.82
6	IC-326284	8.57	2.53	3.39	79.80	40.89	6	1	2.60	15.72	71.36	0.54	4.87
7	IC-342353	7.47	3.17	2.36	74.60	40.91	6	1	2.26	12.35	78.93	0.52	4.91
8	IC-342368	9.27	2.93	3.16	74.93	59.90	6	1	2.40	13.48	76.80	0.43	4.22
9	IC-342369	7.63	3.03	2.52	75.63	50.86	6	1	3.10	5.31	71.93	0.49	5.27
10	IC-351517	8.93	2.53	3.53	80.40	86.49**	3	5	2.28	15.72	76.70	0.65	2.35*
11	IC-394788	6.33*	3.5**	1.81*	74.47	81.77	5	3	2.81	4.28	74.76	0.44	5.36
12	IC-464363	8.50	2.47	3.44	73.47	20.31*	6	1	2.41	13.47	77.53	0.44	4.46
13	IC-464661	8.10	2.73	2.97	77.80	41.95	6	1	2.50	13.51	79.66	0.41	4.47
14	IC-464684	7.80	2.57	3.04	71.33*	53.44	5	3	2.27	13.39	79.95	0.54	3.78
15	IC-465275	6.73	2.73	2.47	78.93	45.73	6	1	3.30**	4.27	81.55	0.59	5.76
16	Tai Sanghan	10.90**	2.47	4.41	79.53	74.58	2	7	2.31	5.41	77.01	0.73	5.30
17	CT3-D-1	9.90	2.4	4.13	77.67	68.17	5	3	2.30	14.38	56.15	0.55	5.86
18	CT3-D-2	9.80	2.53	3.87	78.13	40.42	4	3	2.07	14.17	64.74	0.52	8.60
19	CT3-D-4	9.97	2.53	3.94	78.10	67.97	2	7	2.03	11.76	34.48	0.57	11.69**
20	CT3-D-6	10.20	2.6	3.92	77.93	74.23	2	7	2.33	14.00	29.83*	0.54	10.19
21	CT3-D-7	9.53	2.37	4.02	76.07	72.70	3	5	2.11	15.70	46.35	0.55	8.05
22	CT3-D-9	9.13	2.5	3.65	77.27	65.53	2	7	2.11	14.18	30.53	0.60	8.99
23	CT3-D-10	10.23	2.53	4.04	78.03	29.10	4	3	2.09	11.97	44.91	0.56	10.51
24	CT3-D-11	8.60	2.57	3.35	76.13	47.84	3	5	2.37	15.14	70.65	0.62	9.13
25	CT3-D-12	8.83	2.73	3.23	76.80	52.76	3	5	2.05	14.99	33.70	0.48	8.97
26	Mantup Chakhao	8.27	2.63	3.14	76.00	80.19	3	5	2.34	6.20	65.54	0.59	4.81
27	Kaunglauny Chakhao	7.77	3.13	2.48	81.07	58.97	3	5	1.99*	9.47	65.04	0.53	6.20
28	Faisenbuman Chakhao	9.27	2.57	3.61	81.87**	49.55	1	7	2.16	16.65	78.01	0.72	5.43
29	Bahadur	7.83	2.13*	3.68	80.40	82.43	2	7	2.01	18.54	74.29	0.39*	4.79
30	Ja-Pnah	10.07	2.17	4.64**	77.73	69.01	2	7	2.54	8.58	82.18**	0.59	3.89
31	Chakhao Poireiton	9.70	2.67	3.63	74.13	40.73	3	5	2.08	20.60**	69.55	0.83	10.80
32	Chakhao Amubi	8.44	2.83	2.98	75.60	43.40	3	5	2.32	9.33	77.38	0.60	3.97
	Mean	8.68	2.63		77.36	58.71			2.37	12.5	64.15	0.59	6.41
	SE(m) ±	0.64	0.16		1.39	9.67			0.19	2.91	9.67	0.08	1.42
	CD (0.05)	1.23	0.41		3.98	7.09			0.41	3.48	7.52	0.05	2.15

**Maximum; *Minimum, KL = kernel length; KB = kernel breadth; KL: B = kernel length uptake ratio; GC = Gel consistency; ASV = Alkali spreading value; GT = Geletinization temperature; AC = Amylose content; CC = Carbohydrate content; FC = Fat content and PC = Protein content

Table 4. Correlation coefficients among 10 traits for the 32 rice genotypes

	Character	1	2	3	4	5	6	7	8	9	10
1	Hulling percentage (%)	1.000									
2	Kernel Length (mm)	0.137	1.000								
3	Kernel Breadth (mm)	-0.314	-0.496**	1.000							
4	Kernel Length: Breadth ratio	0.242	0.901**	-0.804**	1.000						
5	Gel Consistency (mm)	0.251	0.000	-0.142	0.116	1.000					
6	Water Uptake Ratio	-0.167	-0.468**	0.279	-0.433*	-0.022	1.000				
7	Amylose Content (%)	0.207	0.201	-0.411*	0.300	-0.148	-0.578**	1.000			
8	Carbohydrate Content (%)	-0.042	-0.339	0.172	-0.283	-0.222	0.220	-0.060	1.000		
9	Fat Content (%)	0.283	0.049	-0.282	0.134	0.170	-0.043	0.235	-0.071	1.000	
10	Protein Content (%)	-0.032	0.467**	-0.040	0.313	-0.197	-0.406*	0.174	-0.610**	-0.042	1.000

*Values in bold are different from 0 with a significance level alpha= 5%

**Values in bold are different from 0 with a significance level alpha= 1%

Table value of r = 0.349 at 5% and r = 0.449 at 1

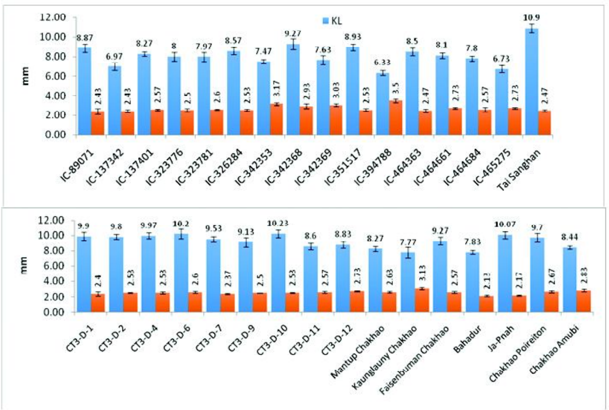

Fig. 2. Graphical representation of kernel length and breadth

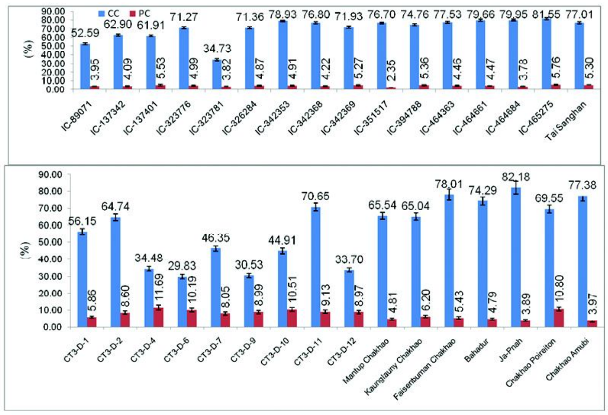

Fig. 3. Graphical representation of CC and PC

Fig. 4. Graphical representation of FC

of 6.41% protein, CT3-D-4 cultivar (11.69%) recorded highest protein content which was statistically at par with Chakhao Poireiton (10.80%), CT3-D-6 (10.19%) and CT3-D-10 (10.51%) and IC-351517 (2.35%) was lowest protein among the samples. Among the checks, only Chakhao Poireiton (10.80%) recorded high protein content. Similar findings were also reported by Shilpa and Krishnan, (2010) and Banerjee et al. (2011). Banerjee et al. (2011) estimated protein content of milled grains and it ranged from 4.91% to 12.08% with the mean of 6.63% much similar to the present investigation.

The fat content of the thirty two samples ranged from 0.39% to 0.99% with mean value of 0.59%. IC-137342 (0.99%) recorded the highest fat content and Bahadur (0.39%) recorded the lowest among the samples under study. Among the checks, only Chakhao Poireiton (0.83%) recorded fat content value which is higher than the average. It could however, be concluded that the fat content reported in this present investigation were of narrow range. The present findings were in conformity with the findings of Thongbam et al. (2010) when they reported the total fat content ranging from 0.5% (Changsanal) to 1.91% in the study.

Correlation among the 10 traits for 32 rice genotypes

Pearson's correlation studies for the various quantitative traits revealed both negative and positive correlation. Also, no correlation was observed between gel consistency and kernel length. The association of kernel breadth with kernel length and also between water uptake ratio and kernel length was negative and highly significant. Also, positive and highly significant correlation was observed between kernel length: breadth ratio and kernel length as well as between protein content and kernel length. Negative and significant correlation was observed between amylose content and kernel breadth whereas negative and highly significant correlation was observed between kernel length: breadth ratio and kernel breadth. Negative and significant correlation was observed between water uptake ratio and kernel length: breadth ratio. The correlation between amylose content with water uptake ratio was found to be negative and highly significant whereas the association of protein content with water uptake ratio was negative and significant. Protein content and carbohydrate content was negatively correlated and highly significant (Table 4). There was no significant correlation between carbohydrate and amylose, hence these findings were also in conformity with the findings of Thongbam et al. (2011).

Authors' contribution

Conceptualization of research (NSK, WR); Designing of the experiments (WR, NSK, WT, MR, VKK); Contribution of experimental materials (WR, NSK); Execution of field/lab experiments and data collection (WR); Analysis of data and interpretation (WR, NSK); Preparation of the manuscript (WR, NSK).

Declaration

The authors declare no conflict of interest.

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