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Evaluation of Physical and Cooking Property Based Grain Quality Traits in Popular Rice (*Oryza sativa* L) Cultivars of Bangladesh

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Abstract: Rice grain is consumed as main staple food in many areas of the world. Therefore, grain physical and cooking properties are very important for consumers as well as producers. A study was conducted with 21 rice cultivars comprising 10 from Aman season, 10 from Boro season and one from Aus season to evaluate the pattern of variation and performances based on grain quality traits. All the physical and cooking quality traits considered differed significantly among the cultivars ($P<0.01$). Performance range of quality parameters were found as 6.18 to 9.91 mm for rough rice length, 1.16 to 3.31 mm for rough rice breadth, 4.21 to 7.27 mm for brown rice length, 1.50 to 2.59 mm for brown rice breadth, 3.08 to 6.69 mm for milled rice length (L_1), 1.05 to 2.61 mm for milled rice breadth (B_1), 5.59 to 9.77 mm for cooked rice length (L_2), 2.50 to 3.81 mm for cooked rice breadth (B_2), 1.26 to 1.72 for grain elongation ratio (L_2/L_1), 2.05 to 5.04 for grain length and breadth ratio before cooking (L_1/B_1), 2.01 to 3.72 for grain length and breadth ratio after cooking (L_2/B_2). Milling outturn %, and head rice recovery (%) were ranged between 65 to 82.52% and 36.60 to 71.03 % respectively, which indicate the grading category that is suitable for selection. Only one rice cultivar (BRRI Dhan50) was found as 100% translucent. The lower percentage of grain chalkiness is desirable which is useful for grain quality improvement in rice breeding programs. Based on the standards followed for quality rice production, BRRI Dhan50 was found to have most of the desirable grain quality traits, followed by BRRI Dhan67, BRRI Dhan38 and Binadhan-16. The comparative information about physical and cooking qualities of rice might be used as reference to develop high grain quality rice cultivars in future.
Keywords: Rice cultivars, grain quality, physical properties, cooking properties.

INTRODUCTION

Rice is mainly eaten as whole cooked grains by humans [1], therefore, grain quality is as important as yield. Grain quality not only contributes to yield but also attributed to rice marketing and trade facility [2]. Consequently, consumer's preference for grain quality has become the major objectives for rice breeding.

Rice grain quality is a combination of several physical properties. Physical quality properties such as size, kernel shape, and length-breadth ratio are important features while assessing grain quality [3]. The length of the hulled grain is simply a measure of the rough rice kernel in its greatest dimension while the breadth of the hulled grain is the measure of the rough rice kernel breadth in its maximum dimension. The length and breadth of the seed rice are variable, sometimes even within a genotype, because of the variation in the length of the awn and the pedicel [4]. Grain elongation ratio is one of the important parameters for cooked rice. Some genotypes expand more in size than others upon cooking. Length-breadth elongation without a corresponding increase in girth is considered a highly desirable rice grain quality trait [5]. The size and shape are stable varietal properties that can be used to identify a genotype [6]. Rice genotypes are classified as short, medium, or long grain by rough rice kernel dimension ratio [7]. Since kernel type and dimension are of importance to the millers and processors, these traits are considered in the breeding selection program. During cooking, rice grains absorb water, and increases in length, breadth and volume [8]. Therefore, changes of rice grain after cooking are important issues to consider.

Furthermore, milling quality is considered as one of the most important aspects of rice grain quality [9]. The actual head rice percentage in a sample of milled rice depends on genotypic traits, production factors, harvesting and the drying milling process [10]. The consumer prefers rice with a translucent endosperm and pays a premium price for it, even though opacity

disappears during cooking and does not alter eating quality. Similar, greater the chalkiness, lower the market acceptability. The chalky areas are not as hard as the translucent areas and the grains with chalkiness are more prone to breakage during milling [11].

From the above discussion, it is evident that rice grain quality is not only an important aspect to consider but also a complex system to manage. A detail evaluation of the popular rice cultivars for their grain quality traits has, thereafter has, undertaken to enable the relevant researchers to gather information about potential parents to be used for grain quality improvements.

MATERIALS AND METHODS

The experiment has been conducted at Grain Quality and Nutrition Division (GQN) Lab at Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. A total 21 rice genotypes, collected from BRRI, BINA (Bangladesh Institute of Nuclear Agriculture), and BAU (Bangladesh Agricultural University, Mymensingh) were used in this study (Table 1), The experiment was conducted following Completely Randomized Design (CRD) with three replications.

Table-1: List of rice genotypes used in the study

SL. NO.	Genotypes	Sources
1	BR26	Bangladesh Rice Reasearch Inistitute (BRRI)
2	BRRI Dhan29	
3	BRRI Dhan35	
4	BRRI Dhan38	
5	BRRI Dhan46	
6	BRRI Dhan49	
7	BRRI Dhan50	
8	BRRI Dhan59	
9	BRRI Dhan61	
10	BRRI Dhan64	
11	BRRI Dhan66	
12	BRRI Dhan67	
13	BRRI Dhan69	
14	BRRI Dhan72	
15	BRRI Hybrid Dhan2	
16	BRRI Hybrid Dhan4	
17	Kallizira	Bangladesh Agricultural University, Mymensingh
18	Tulsi mala	
19	Binadhan-11	Bangladesh Institute of Nuclear Agriculture (BINA)
20	Binadhan-13	
21	Binadhan-16	

The data were collected following the standard evaluation system prescribed by IRRI [12, 13]. The traits evaluated were rough rice length, rough rice breadth, brown rice length, brown rice breadth, milled rice length, milled rice breadth, cooked rice length, cooked rice breadth, grain elongation ratio (L_2/L_1), length-breadth ratio before cooking (L_1/B_1), length-breadth ratio after cooking (L_2/B_2).

MS Office Excel® software was used for managing data on spreadsheet. Analysis of variance was performed using MSTAT-C statistical program. Multiple mean comparisons were made with Fisher's least significant difference (LSD).

RESULTS AND DISCUSSION

The analysis of variance revealed highly significant differences among the genotypes for all the 11 quality traits indicating the existence of the significant amount of variability among the genotypes studied.

The physical properties of the rice samples are shown in Table 2. The length of the rough rice ranged between 6.18 to 9.91 mm with BRRI Dhan50 having the highest value and Kalizira having the lowest value. The breadth of the rough rice ranges between 1.16 to 3.31 mm with BRRI Dhan64 has the highest and BRRI Dhan50 has the lowest value. Similarly, length and breadth of brown, milled and cooked rice were ranged between 4.21 to 7.27 mm, 1.50 to 2.59 mm, 3.08 to 6.79 mm, 1.05 to 2.61 mm, 5.59 to 9.77 mm, 2.50 to 3.81 mm. BRRI Dhan72 and Binadhan-16 demonstrated maximum length as brown and milled rice, and BRRI Dhan67 had maximum as cooked rice. BRRI Dhan50 had lowest breadth of grain in brown, milled and cooked conditions.

Table-2: Mean performances of 21 rice genotypes based on 11 grain quality traits

SL No.	Genotype	RRL	RRB	BRL	BRB	MRL	MRB	CRL	CRB	L2/L1	L1/B1	L2/B2
1.	BR26	9.01 E	2.17K	6.49C	2.05 M	6.06C D	1.93N	8.83E	2.62N	1.45F	3.13C D	3.36C
2	BRRI Dhan29	8.85F	2.37H	6.37C-E	2.11K	6.02C D	2.10K	8.32H	3.16G	1.38G	2.86EF	2.63K
3	BRRI Dhan35	7.90 P	2.75E	5.67J	2.33G	5.56F-G	2.23H	8.22I	3.34F	1.47E F	2.49H-J	2.38O
4	BRRI Dhan38	8.54 K	2.06L	5.68J	1.93O	5.66EF	1.74Q	8.97D	2.60O	1.58C	2.76F G	3.44B
5	BRRI Dhan46	7.98 O	2.96C	5.81I J	2.55C	5.23H	2.46D	9.03C D	3.70B	1.72A	2.88D-F	2.44N
6	BRRI Dhan49	8.34 M	2.28I	6.13FG	2.07L	3.08K	1.98 M	7.87J	2.75L	1.37G	2.13K L	2.85H
7	BRRI Dhan50	9.91 A	1.16M	6.44C D	1.50Q	6.36B	1.05S	9.44B	2.54Q	1.48E	5.04A	3.71A
8	BRRI Dhan59	8.14 N	2.62F	5.91HI	2.40E	5.67EF	2.23H	8.89E	3.56C	1.56C	2.54G-I	2.43N
9	BRRI Dhan61	8.69 I	2.42H	6.07G H	2.18I	5.68EF	2.12I	8.60F	2.96J	1.51D	2.67F-H	2.90G
10	BRRI Dhan64	7.93P	3.31A	5.83IJ	2.70A	5.36G H	2.61A	8.51G	3.81A	1.56C	2.05L	2.23P
11	BRRI Dhan66	8.82 G	2.70E	6.27EF	2.42E	5.83D E	2.29F	9.08C	3.07H	1.56C	2.53G-I	2.95F
12	BRRI Dhan67	8.63J	2.48G	6.41C D	2.15J	6.13B C	2.01L	9.77A	2.62N	1.58C	3.05C-E	3.72A
13	BRRI Dhan69	8.48 L	2.82D	5.77IJ	2.46D	5.37G H	2.25G	7.67K	3.46E	1.52D	2.38I-K	2.21P
14	BRRI Dhan72	9.61 C	2.63F	7.27A	2.35F	6.69A	2.44E	9.06C	2.96J	1.34H	2.74F-H	3.05E
15	BRRI Hybrid Dhan2	7.99 O	2.82D	6.11G	2.58B	5.37G H	2.49C	7.18L	3.55D	1.34H	2.16K L	2.01Q
16	BRRI Hybrid Dhan4	9.11 D	2.20J K	6.84B	2.29H	6.24B C	1.82O	7.63K	2.70 M	1.26I	3.43B	2.82I
17	Kallizira	6.18S	2.06L	4.21M	1.89P	3.89J	1.73R	6.63M	2.60O	1.70B	2.24J-L	2.54L
18	Tulsi mala	6.26 R	2.25IJ	4.57L	1.98N	4.13IJ	1.80P	6.48N	2.59P	1.57C	2.29I-L	2.50 M
19	Binadhan -11	8.74 H	3.04B	6.31D E	2.59B	5.48F-H	2.51B	8.26HI	3.03I	1.50D	2.18K L	2.72J
20	Binadhan -13	6.45 Q	2.29I	4.87K	2.13J	4.22I	2.01L	5.59O	2.50R	1.32H	2.09L	2.23P
21	Binadhan -16	9.71 B	2.49G	7.15A	2.20I	6.79A	2.11J	9.05C	2.90K	1.33H	3.22B C	3.11D
CV(%)		0.48	4.33	4.22	1.25	7.59	0.56	1.33	0.61	2.23	15.55	1.53
Max		29.14	9.11	21.81	7.77	20.37	7.40	29.31	11.45	5.18	15.14	11.85
Min		18.54	3.47	12.63	4.50	9.24	3.15	16.79	7.52	3.78	6.16	6.06
Mean		8.35	2.47	6.01	2.23	5.47	2.09	8.25	3.01	1.48	2.71	2.77
Lsd (.05)		0.029	0.07	0.16	0.02	0.27	0.01	0.07	0.01	0.02	0.05	0.03

Legend, RRL=Rough rice length; **RRB**=Rough rice breadth; **BRL**=Brown rice length; **BRB**=Brown rice breadth; **MRL**=Milled rice length ; **MRB**=Milled rice breadth ;**CRL**=Cooked rice length ; **CRB** =Cooked rice breadth ; $\mathbf{L_2/L_1}$= Grain elongation ratio; $\mathbf{L_1/B_1}$= Length breadth ratio before cooking; $\mathbf{L_2/B_2}$= Length breadth ratio after cooking;
Note: Genotypes with same letters are statistically similar, and with different letters are statistically different.

The grain elongation ratio during cooking was ranged between 1.26 to 1.72. In the present investigation, the highest grain elongation ratio was found BRRI Dhan46 and it differed quite significantly with others ($P<0.01$). Grain elongation ratio is one of the important parameters for cooked rice. Some varieties expand more in size than others upon cooking. During cooking, rice kernels absorb water and increase in volume through an increase in length and breadth [14]. Length/breadth elongation without a corresponding increase in girth is considered a highly desirable rice grain quality trait [5].

The length/breadth ratio after cooking of the rice genotypes was found, ranged between 2.01 to 3.72. Higher grain length and breadth ratio is considered as preferable by consumers [15, 16]. In the present observation, the highest grain length and breadth ratio was found in BRRI Dhan67. In Bangladesh, high-income group people prefer long slender grains whereas the low-income people prefer the short bold grains because of its high volume expansion ratio [17].

Considering the data from Table 2, a rank table (Table 3) of genotypes was constructed based on the score derived from the mean performances of the genotypes used in the study. Considering all traits from Table 2, BRRI Dhan50 was found as a best-ranked performer considering the concept of popular quality features of rice grain.

Table-3: Ranking of the genotypes based on mean performances of 11 grain quality traits

SL NO	Genotype	RRL	RRB	BRL	BRB	MRL	MRB	CRL	CRB	L2/L1	L1/B1	L2/B2	Total	Rank
1.	BR26	5	3	3	15	3.5	6	5	5	6	3.5	3	58	5
2	BRRI Dhan29	6	6	4	7	3.5	9	8	12	7	5.5	11	79	8
3	BRRI Dhan35	16	9	10	11	6.5	12	9	13	5.5	9	15	116	17
4	BRRI Dhan38	11	2	10	3	5.5	3	4	4	3	6.5	2	54	3
5	BRRI Dhan46	15	11	9.5	15	9	16	3.5	17	1	5	14	116	17
6	BRRI Dhan49	13	5	6.5	6	11	7	10	7	7	11.5	8	92	12
7	BRRI Dhan50	1	1	3.5	1	2	1	2	2	5	1	1	20.5	1
8	BRRI Dhan59	14	8	8.5	13	5.5	12	5	16	3	8	14	107	14
9	BRRI Dhan61	9	6	7.5	9	5.5	11	6	9	4	7	7	81	9
10	BRRI Dhan64	16	13	9.5	17	7.5	19	7	18	3	12	16	138	20
11	BRRI Dhan66	7	9	5.5	13	4.5	14	3	11	3	8	6	84	10
12	BRRI Dhan67	10	7	3.5	8	2.5	8	1	5	3	4	1	53	2
13	BRRI Dhan69	12	10	9.5	14	7.5	13	11	14	4	10	16	121	18
14	BRRI Dhan72	3	8	1	12	1	15	3	9	8	7	5	72	7
15	BRRI Hybrid Dhan2	15	10	7	16	7.5	17	12	15	8	11.5	17	136	19
16	BRRI Hybrid Dhan4	4	3.5	2	10	2.5	5	11	6	9	2	9	64	6
17	Kallizira	19	2	13	2	10	2	13	4	2	11	12	90	11
18	Tulsi mala	18	4.5	10	4	9.5	4	14	3	3	10.5	13	93.5	13
19	Binadhan-11	8	12	4.5	16	7	18	8.5	10	4	11.5	10	109.5	15
20	Binadhan-13	17	5	11	8	9	8	15	1	8	12	16	110	16
21	Binadhan-	2	7	1	9	1	10	3	8	8	2.5	4	55.5	4

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The rice genotypes were further evaluated for length/breadth ratio according to ISO classified scale [13, 16]. In the present investigation, the length/breadth ratio before cooking of the rice genotypes ranged between 2.05 to 5.04. BRRI Dhan50 was the highest performer (Table 4). The rice genotypes, in the present study, were classified as slender (>3.00), medium (2.10-3.00) and bold (1.01-2.00) [16]. The shapes determined were slender for the long genotypes, medium for the medium genotypes and bold for the small genotypes sample (Table 4). The shape of the rice grain influences its volume and weight. In slender genotypes of rice occupy more volume than round genotypes [16].

Milling quality is the measure of rough rice performance during milling process. It is the total quantity of head rice and broken grain recovered from the unit quantity of milling process [18]. Milling outturn% and head rice recovery was graded according to Rice Technical Working Group [19]. In general, premium quality with long grain is expected during the milling [16, 20]. Premium quality with a high percentage of milling outturn is considered as the best performer which is presented in Table 4. Majority of genotypes performed premium quality except BR26, BRRI Hybrid Dhan4 and Tulsi mala (Table 5).

Table-4: Classification of rice grain according to ISO classified scale

Scale	Shape	L/B ratio	Genotypes
1	Slender	≥ 3.00	BR26, BRRI Dhan29, BRRI Dhan38, BRRI Dhan50, BRRI Dhan67, BRRI Hybrid Dhan4, Binadhan-16
3	Medium	2.10 – 3.00	BRRI Dhan66, BRRI Dhan69, BRRI Dhan72, Kalizira, Tulsi mala, Binadhan-11, Binadhan-13
5	Bold	1.1 – 2.00	BRRI Dhan35, BRRI Dhan46, BRRI Dhan49, BRRI Dhan59, BRRI Dhan61, BRRI Dhan64, BRRI Hybrid Dhan2
9	Round	≤ 1.00	None

Table-5: Performances of 21 rice genotypes for milling properties

Serial no.	Genotype	Milling outturn (%)		Head rice recovery (%)	
1	BR26	69.60	Grade 1	60.20	Grade 3
2	BRRI Dhan29	71.00	Premium	62.03	Grade 3
3	BRRI Dhan35	71.75	Premium	69.51	Grade 1
4	BRRI Dhan38	82.52	Premium	69.79	Grade 1
5	BRRI Dhan46	75.00	Premium	64.75	Grade 3
6	BRRI Dhan49	74.86	Premium	62.12	Grade 3
7	BRRI Dhan50	69.78	Premium	59.63	Grade 3
8	BRRI Dhan59	74.70	Premium	65.98	Grade 1
9	BRRI Dhan61	71.65	Premium	68.98	Grade 1
10	BRRI Dhan64	73.40	Premium	71.03	Premium
11	BRRI Dhan66	70.75	Premium	65.58	Grade 1
12	BRRI Dhan67	71.87	Premium	59.78	Grade 3
13	BRRI Dhan69	72.00	Premium	61.22	Grade 3
14	BRRI Dhan72	74.65	Premium	61.50	Grade 3
15	BRRI Hybrid Dhan2	70.10	Premium	66.51	Grade 1
16	BRRI Hybrid Dhan4	65.00	Grade 1	36.60	Grade 3
17	Kallizira	70.16	Premium	60.00	Grade 3
18	Tulsi mala	67.55	Grade1	67.50	Grade 1
19	Binadhan-11	73.33	Premium	57.91	Grade 3
20	Binadhan-13	71.805	Premium	61.68	Grade 3
21	Binadhan-16	70.53	Premium	67.68	Grade 1

Head rice yield is one of the most important criteria for measuring milled rice quality, where, 75-80% whole kernel is considered as head rice [20]. The head rice recovery is the proportion of the whole grain in milled rice. It depends on varietal features as well as drying condition [18]. In the present investigation, head rice recovery varied between 36.60 to 71.03% (Table 5). The genotype with the highest percentage of head rice was BRRI Dhan64 as considered as premium and lowest was BRRI hybrid Dhan4 as grade-3.

The cultivars were further evaluated for grain translucency and chalkiness (Table 6). Translucency refers to the degree of crystallinity for the ability of light to pass through grain [13, 16]. It is a desirable trait and among the cultivars, BRRI Dhan50 was found with maximum translucency and no chalkiness. On the contrary, chalkiness signifies the white opaque portion in the grain. Chalkiness hampers the market value of grain, and makes the grain more prone to breakage [11]. Here, BRRI Dhan64 showed maximum chalkiness followed by BRRI Dhan61, and justified their poor preference status from producers and consumers.

Table-6: Determination of chalkiness of 21 rice genotypes

Serial no.	Genotype	Translucent (%)	Chalkiness (%)			
			W_b	W_c	O_p	Scale
1	BR26	75	-	10	15	9
2	BRRI Dhan29	55	-	-	45	9
3	BRRI Dhan35	45	35	-	20	9
4	BRRI Dhan38	70	-	20	10	9
5	BRRI Dhan46	40	35	-	25	9
6	BRRI Dhan49	90	5	5	-	5
7	BRRI Dhan50	100	-	-	-	-
8	BRRI Dhan59	40	20	-	40	9
9	BRRI Dhan61	25	45	-	30	9
10	BRRI Dhan64	10	35	5	50	9
11	BRRI Dhan66	55	25	5	15	9
12	BRRI Dhan67	40	15	10	35	9
13	BRRI Dhan69	65	10	-	25	9
14	BRRI Dhan72	90	5	5	-	5
15	BRRI Hybrid Dhan2	90	-	5	15	5
16	BRRI Hybrid Dhan4	45	20	-	35	9
17	Kallizira	70	-	10	20	9
18	Tulsi mala	65	15	-	20	9
19	Binadhan-11	80	-	-	20	5
20	Binadhan-13	55	15	-	-	5
21	Binadhan-16	85	-	-	15	5

Legends, W_b= White belly, **W_c** = White Core, and **O_p**= Opaque

CONCLUSIONS

The result of the analysis carried out on 21 different popular rice cultivars shows varietal significant differences for grain length, breadth, grain elongation ratio, length/breadth ratio before and after cooking, chalkiness, milling outturn% and head rice recovery %. Considering all the physical grain quality traits, the superior genotypes identified were, BRRI Dhan47, BRRI Dhan50, BRRI Dhan64, BRRI Dhan67, BRRI Dhan72, Binadhan-16, Binadhan-13. Traits like milling outturn% and head rice recovery% showed high desirable outcome; which significantly determines the milled and head rice yield. Therefore, these traits need top priority during selection. Among physical properties, traits like length, breadth, grain elongation ratio, length/breadth ratio before and after cooking can be used as selection indices for improving grain quality. The overall information generated herein can be utilized in rice genotypes improvement programs and in selecting suitable rice genotypes for commercial cultivation and further improvement through breeding.

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