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Evaluation of Some Popular Rice Varieties of Bangladesh for Physical and Cooking Quality Properties

Md. Abdul Wahed Khan[1,4], Mahbuba Sultana Priti[2], Md. Sohel Rana[1,4], Md. Nuruzzaman[1], Muhammad Javidul Haque Bhuiyan[3] and Sharif-Ar-Raffi[1*]

[1]Department of Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh-2202; [2]Soil Science Division, Bangladesh Institute of Nuclear Agriculture (BINA), BAU Campus, Mymensingh-2202; [3]Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh-2202; [4]Department of Agricultural Extension (DAE), Khamarari, Dhaka-1215.

***Corresponding author:** Sharif-Ar-Raffi; E-mail: saraffi@bau.edu.bd

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ABSTRACT

Rice is the primary staple meal in many parts of the world. Therefore, both consumers and producers must pay close attention to the physical and cooking characteristics of grains. The present study was conducted to evaluate the physical and cooking quality characters in twenty popular Bangladeshi boro rice genotypes along with one *japonica* rice genotype. A high degree of significant variation was observed for all the characters studied. Genotypes BRRI dhan55, BR16, BRRI dhan57, BINA dhan-6 and BINA dhan-14 has the maximum length of grain before cooking (L_1). BRRI dhan36, BRRI dhan57, BRRI dhan55 and BINA dhan-6 were the best performer in terms of grain length after cooking (L_2). BRRI dhan57 and BRRI hybrid dhan1 were best for width of grain before cooking (W_1). BRRI dhan57, BRRI dhan29 and BRRI dhan36 were exhibited minimum width of grain after cooking (W_2). Yukihikari, BRRI hybrid dhan3 and BRRI dhan36 were best for grain elongation ratio. Highest grain length/width ratio before cooking (L_1/W_1) was observed in genotype BRRI dhan57, BRRI hybrid dhan1 and BINA dhan-14. The highest grain length/width ratio after cooking (L_2/W_2) was recorded in genotype BRRI dhan57 and BRRI dhan36. Best genotype for percent water uptake (WU %) after cooking was BRRI dhan28 (180%). The best genotypes for solid in cooking water (SCW) were BRRI dhan36 (0.897%), BRRI dhan28 (0.956%), Yukihikari (1.043%) and BRRI dhan29 (1.048%), respectively. The prominent performer genotypes for CT were BRRI dhan58 (18.38 minutes) followed by BR 14 (19.12 minutes), BRRI dhan28 (20.00 minutes) and BRRI dhan57 (19.82 minutes). Best genotypes for amylase content (AC) BRRI dhan28 (24.93%), BRRI dhan55 (24.91%), BRRI dhan59 (24.90%). Most of the rice genotypes had found low cooking time (GT) except BRRI dhan57, BRRI dhan59, Yukihikari which shows intermediate gelatinization temperature (GT). The comparative information about physical and cooking qualities of rice might be used as reference to develop high grain quality rice cultivars in future.

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INTRODUCTION

Rice is ranked as the world's number one human food crop (Itani et al., 2002) for nearly half of the world's population (Sellamuthu et al., 2011). Worldwide, rice is cultivated on an area of 164.9 million hectors with an annual production of 502.9 million tons (FAO, 2020). About 90% of the world's rice is grown and consumed in Asia (Tyagi et al., 2004). Rice is one of the most important sources of calories consumed by 3 billion Asians. It is the only cereal crop cooked and consumed mainly as whole grains, and quality considerations are much more important than for any other food crop (Hossain et al., 2009). However, as rice is often processed into food or feed, grain quality is just as crucial for rice as yield. As a result, along with yield improvement, another goal of rice breeding has been for grain quality attributes to meet up the conscious consumer preferences. The quality of rice grain is a outcome of various physical characteristics and cooking qualities. The physical characteristics include grain length (L), grain width (W), L/W ratio, hulling and milling percentage. The cooking qualities are amylose content, alkali spreading value, water uptake, volume expansion ratio and kernel elongation ratio (Cruz and Khush, 2000). Different cultivars showed significant variations in morphological, physicochemical and cooking properties (Yadav et al., 2007). It has been reported that due to variations in the length of the awn and pedicel, the length and breadth of the seed rice can vary, sometimes even within a genotype (Ntakirutimana et al., 2019). One of the crucial factors for cooked rice is the grain elongation ratio. When cooked, some genotypes grow larger than others. It is thought that length-breadth elongation without an equal rise in girth is a very desirable rice grain quality feature. Rice grains expand in length, breadth, and volume as a result of water absorption during cooking (Little et al., 1958). Changes in the rice grain after cooking are crucial to consider. Eating quality refers to the customers' sensory perception of the cooked rice's glossiness, flavor, and stickiness. These characteristics, which are influenced by cooking time, volume expansion ratio, and gelatinization, show the chemical response that happens to the rice grain while it is cooked. The gelatinization temperature (GT), gel consistency (GC) and amylose content (AC) are major rice traits, which are directly related to cooking and eating quality (Little et al., 1958).

On the other hand, amylose content, amylopectin structure and protein composition explained the difference in cooking quality of rice (Lisle et al., 2000). The cooking quality of rice was determined on the basis of physicochemical properties and amylose content (Sujatha et al., 2004). 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 (Sabouri, 2009.) As a primary food source, there is a constant desire for higher-quality rice, which varies depending on the cultivar and the location and is judged on its suitability for cooking and eating. Bangladesh has a wide range of rice landraces and introduced rice varieties; therefore, differences of consumer preferences for rice grain qualities might be exist. The goal of the current study was to assess the cooking and eating qualities of a few major different rice cultivars in order to learn more about Bangladeshi consumers' preferences for rice and the potential for future breeding programs to boost rice production.

MATERIALS AND METHODS

Plant materials and experimentation

The experiment was conducted at the Plant Stress Breeding Laboratory, Dept. of Genetics and Plant Breeding and Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University (BAU), Mymensingh. A total of 21 rice cultivars were studied for physical and cooking quality traits (Table 1). Seed of the selected rice cultivars were collected from Bangladesh Rice Research Institute (BRRI), Gazipur. The investigation was carried out during the period of May to November 2015 following a complete randomized design with 5 replications. Seeds were subjected to record several physical and cooking quality traits following standard formulae and procedure. The physical and cooking quality features *viz.* length before cooking (L1), length after cooking (L2), width before cooking (W1), width after cooking (W2), length elongation ratio (L2/L1), length width ratio after cooking (L2/W2), length width ratio before cooking (L1/W1), water uptake (WU), solid in cooking water (SCW) and cooking time (CT) were determined following procedures described by Oko et al. (2012); amylose content (AC) with procedure by Juliano (1971); gelatinization temperature (GT) with procedure by Little et al. (1958) and 7-point numerical scale by Jennings et al. (1979) and Khush et al. (1979).

Table 1. List of rice Genotypes used in this study

Sl. No.	Genotypes	Source / Courtesy
1	BR 3	
2	BR 14	
3	BR 16	
4	BRRI dhan28	
5	BRRI dhan29	
6	BRRI dhan36	
7	BRRI dhan45	Bangladesh Rice Research Institute (BRRI)
8	BRRI dhan47	
9	BRRI dhan55	
10	BRRI dhan57	
11	BRRI dhan58	
12	BRRI dhan59	
13	BRRI hybrid dhan1	
14	BRRI hybrid dhan3	
15	Iratom-24	
16	BINA dhan-5	
17	BINA dhan-6	Bangladesh Institute of Nuclear Agriculture (BINA)
18	BINA dhan-8	
19	BINA dhan-10	
20	BINA dhan-14	
21	Yukihikari (*Japonica* cultivar)	Professor Dr. G. H. M. Sagor, Bangladesh Agricultural University (BAU)

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 studied genotypes (Table 2).

Physical properties of rice grain of 21 cultivars: before and after cooking

The physical and cooking properties of the rice samples were shown in Table 2. The length of the rough rice before cooking ranged between 7.716 mm to 5.146 mm with BRRI Dhan55 having the highest value and Yukihikari having the lowest value. Customers prefer longer grain; therefore, BRRI Dhan55 can be popular compared to other cultivars in terms of grain length. After cooking the grain length ranged between 9.914 mm to 7.604 mm with BRRI Dhan36 having the highest value and Binadahn-8 having the lowest value. Rice grains retain water upon boiling and grow longer and wider in order to expand in volume (Hogan et al., 1958). As grain length is a desirable character so BRRI Dhan36 is good performer. This finding was supported by Khush et al. (1979).

Table 2. Mean performance of 21 rice genotypes based on 11 quality characters

Genotypes	L_1	L_2	W_1	W_2	L_2/L_1	L_2/W_2	L_1/W_1	WU	SCW	CT
BR 3	6.4e	8.6eg	2.6bc	3.2de	1.33f-i	2.64fg	2.5h-j	304.1b	1.52 g	22.8h
BR 14	6.8de	8.5g	2.7b	3.1e	1.29jk	2.71fg	2.4ij	249.3e	1.56e	19.12l
BR 16	7.0b	9.6c	2.3f-g	2.9f	1.36d-f	3.3bc	3.04de	238.0h	1.26j	25.0k
BRRIdhan28	6.8c	8.6eg	2.1ij	2.9fg	1.27kl	2.99e	3.3cd	180.1t	0.96m	20.0k
BRRIdhan29	6.7cd	8.6fg	2.1h-j	2.6i	1.28j-l	3.31bc	3.2de	204.0q	1.05l	22.0i
BRRIdhan36	6.7c	9.9a	2.2gh	2.6i	1.47b	3.79a	3.1de	209.1n	0.90n	24.0c-f
BRRIdhan45	6.7cd	8.7df	2.4de	2.8gh	1.30i-k	3.17d	2.8f-h	212.5l	1.16k	24.0c-f
BRRIdhan47	5.8g	7.7i	2.9a	3.6a	1.34e-g	2.18h	2.02k	196.1r	1.5g	24.5a-d
BRRIdhan55	7.7a	9.6bc	2.2gh	2.9f	1.2l	3.26bc	3.5bc	211.3m	1.07l	23.4f-h
BRRIdhan57	7.0b	9.9ab	1.7l	2.6i	1.4c	3.88a	4.3a	340.3a	1.55ef	19.8k
BRRIdhan58	6.5e	8.8de	2.2hi	2.9f	1.4c-f	3.01de	2.97ef	232.2i	1.82b	18.4m
BRRIdhan59	6.2f	8.1h	2.5de	3.1e	1.3h-k	2.59g	2.5ij	287.2c	1.34i	24.3b-e
BRRI hybrid dhan1	6.8cd	9.0d	1.9k	2.7hi	1.3e-h	3.38b	3.6b	244.1g	1.4h	23.0gh
BRRI hybrid dhan3	5.6gh	8.5g	2.5c-e	3.2de	1.5ab	2.68fg	2.3jk	250.1d	1.61d	24.6a-c
Iratom-24	6.7cd	8.8df	2.5cd	3.2de	1.3g-j	2.68f	2.7g-i	216.1k	1.61d	21.1j
BINAdhan-5	6.7c	8.6eg	2.3fg	3.4bc	1.3jkl	2.55g	2.9e-g	238.1h	1.6e	24.8ab
BINAdhan-6	7.1b	9.8ac	2.4ef	3.3cd	1.4c-e	2.98e	2.96ef	208.1o	1.8b	23.0gh
BINAdhan-8	5.5h	7.6i	2.7b	3.5ab	1.4c-e	2.2h	2.1k	223.1j	1.9a	23.7f
BINAdhan-10	6.4e	8.9d	2.5cd	3.5ab	1.4cd	2.6g	2.6hi	248.1f	1.8b	23.9d-f
BINAdhan-14	7.1b	9.5c	2.0j	2.9fg	1.3e-i	3.35b	3.53bc	187.3s	1.71c	23.4fg
Yukihikari	5.1i	7.8i	2.9a	3.4b	1.5a	2.28h	1.73	204.9p	1.04l	23.7ef
CV(%)	1.9	2.4	4.0	3.0	2.8	4.46	8.18	0.10	0.25	2.2
Max.	7.7	9.9	2.9	3.6	1.5	3.88	4.26	340.3	1.88	25.0
Min.	5.1	7.6	1.70	2.6	1.3	2.18	1.73	180.1	0.90	18.4
Mean	6.5	8.8	2.36	3.06	1.4	2.93	2.85	232.58	1.43	22.8
Lsd(.05)	0.15	0.261	0.119	0.113	0.0398	0.164	0.292	0.2923	0.040	0.63

Legend: L1=Length before cooking; L2=Length after cooking; W1=Width before cooking; W2=Width after cooking; L_2/L_1=Length elongation ratio; L_2/W_2=Length width ratio after cooking; L_1/W_1=Length width ratio before cooking; WU=Water uptake; SCW=Solid in cooking water; CT=Cooking time; AC=Amylose content.
Note: The mean values having common letters are statistically identical.

The width of the rough rice ranges between 2.972 mm to 1.700 mm with BRRI Dhan57 has the lowest grain breadth before cooking; therefore, this cultivar has more potential to become popular. Similarly, the width of cooked rice grain were ranged between 2.550 mm to 3.572 mm. BRRI dhan57 demonstrated lowest width of the cooked grain.As grain width is not desirable character so BRRI dhan57 was good performer. This finding was also supported by Kush et al. (1979).The grain elongation ratio was ranged between 1.247 to 1.526, where Yukihikari was the best performer in case of grain elongation ratio. This finding was supported by Hossain et al. (2009).The grain length and width ratio before and after cooking was ranged between 1.732 to 4.262 and 2.179 to 3.877, respectively. The genotypes with highest grain length and width ratio before and after cooking were BRRI dhan57 (4.262) and BRRI dhan57 (3.877) trailed by BRRI dhan36 (3.793). BRRI dhan57 showed the highest grain length and width ratio both before and after cooking.

The cultivar with higher grain length and width ratio is always preferred by consumers (Khush et al., 1979).The rice genotypes were further evaluated for length/breadth ratio according to ISO classified scale (IRRI, 2013 and Hogan et al., 1958). The rice genotypes, in the present study, were classified as slender (>3.00), medium (2.10- 3.00) and bold (1.01-2.00) (Hogan et al., 1958). The shapes determined were slender for the long genotypes, medium for the medium genotypes and bold for the small genotypes sample (Table 3). The shape of the rice grain influences its volume and weight. In slender genotypes of rice occupy more volume than round genotypes (Kush et al., 1979). Most of the genotypes were in medium and slender but interestingly BRRI dhan47, BINA dhan-8 found in the same category with Yukihikari and the category was bold class. No round grain was found among the genotypes.

Table 3. Classification of rice grain according to ISO classified scale

Scale	Shape	L/W ratio	Genotypes
1	Slender	Over 3.00	BR 16, BRRI dhan28, BRRI dhan29, BRRI dhan36, BRRI dhan55, BRRI dhan57, BRRI hybrid dhan1, BINA dhan-14
3	Medium	2.10 – 3.00	BR 3, BR 14, BRRI dhan45, BRRI dhan58, BRRI dhan59, BRRI hybrid dhan3, Iratom-24, BINA dhan-5, BINA dhan-6, BINA dhan-10
5	Bold	1.1 – 2.00	BRRI dhan47, BINA dhan-8, Yukihikari
9	Round	1.00 or less	-

Performances of 21 rice cultivars for water uptake ratio, solid in cooking water, and cooking time

According to Hogan and Plank (1958), the hydration characteristics of rice is influenced by variety and drying method, where, short and medium grain varieties have higher water absorption than long grain types. In the present study, water uptake ratio ranged from 180% to 340.30% (Table 2). The highest water uptake capacity was found in BRRI dhan28, BINA dhan-14 and BRRI dhan47, which are graded as short to medium grain size category. Similar to the observation of Metcalf & Lund (1985) for other cultivars, demonstrated lower water uptake ratio. Solid in cooking water indicated loss of solids from grain, which is not desirable because in South Asia, rice is cooked in excess water and water is poured off after cooking (Choudhury, 1979), which eventually caused nutrient loss. Saleh & Meullenet (2013) have found that continuous heating increases the solubilization of more starch molecules which eventually leached out in to water. In the present study, positive correlation was found between solid in cooking water and cooking time as suggested. During cooking, the starch of the cooking rice grain usually absorbs water and swells due to its gelatinization. In the present study, solid in the cooking water of the rice samples ranged between 0.897 to 1.883 gm with BINA dhan8 having the highest values and BRRI dhan36having the lowest (Table 2). The mean value of all genotypes of cooking time was 22.797 minutes and ranged between 18.38 minutes to 25.00 minutes. The genotype with lowest cooking time was BRRI dhan58 (18.38 minutes). So BRRI dhan58 was good performer for lowest cooking time.

Changes of grain dimension after cooking in 21 rice cultivars

Increase in grain dimension of rice after cooking is a positive quality factor for low- income group of people (Choudhury, 1979) which indicates higher volume of the rice after cooking either lengthwise or crosswise (Chukwuemeka et al., 2015). Furthermore, length-wise expansion without a corresponding increase in girth is considered highly desirable for fine rice quality (Sood and Sadiq, 1979; Choudhury, 1979). In this study, the highest length after cooking occurs in genotype BRRI dhan58 (3.424 mm) and the lowest length after cooking was BR 14 (1.72 mm).On the other hand, highest width after cooking was BINA dhan-5 (1.09 mm) and lowest width after cooking was BRRI dhan36 (0.436 mm). Significant variation was found in changes of length and width after cooking.

Amylose content of the rice grain of 21 rice cultivars

Amylose content is considered as the most important factors to determine the cooking quality of rice (Balindong et al., 2018) along with gelatinization temperature (Hettiarachchy et al., 1997). Cooked rice become harder with increasing amylose contents, whereas, low amylose content makes rice sticky, and intermediate amylose makes rice firm and fluffy (Bao et al., 2006; Pandarinathan, 2015). Therefore, intermediate level of amylose rice are the preferred types in most of the rice growing areas of the world, except where low amylose *japonica* is cultivated. Hence, development of improved cultivar with intermediate amylose content should be always in the consideration in the grain quality improvement program. Rice with high amylose content show high volume expansion during cooking and cook dry, less tender and become harder upon cooling (Juliano, 1985). Amylose content of the used genotypes was presented in Table 4. Most of the genotypes showed intermediate AC except BRRI dhan47 (25.40%) BRRI hybrid dhan1 (25.40%) and BINA dhan-5 (25.40%). The genotypes showed lowest AC were Yukihikari (19.42%) and BINA dhan-14 (18.22%).

Table 4. Amylose content of 21 rice genotypes used in the study

Sl No.	Genotypes	Amylose content (%)	Class
1	BR 3	20.42	Intermediate
2	BR 14	23.42	Intermediate
3	BR 16	24.41	Intermediate
4	BRRI dhan 28	24.90	Intermediate
5	BRRI dhan 29	23.90	Intermediate
6	BRRI dhan 36	22.91	Intermediate
7	BRRI dhan 45	24.41	Intermediate
8	BRRI dhan 47	25.40	High
9	BRRI dhan 55	24.90	Intermediate
10	BRRI dhan 57	22.41	Intermediate
11	BRRI dhan 58	21.91	Intermediate
12	BRRI dhan 59	24.90	Intermediate
13	BRRI hybrid dhan1	25.40	High
14	BRRI hybrid dhan3	24.41	Intermediate
15	Iratom-24	22.41	Intermediate
16	BINA dhan-5	25.40	High
17	BINA dhan-6	23.42	Intermediate
18	BINA dhan-8	20.92	Intermediate
19	BINA dhan-10	22.91	Intermediate
20	BINA dhan-14	18.92	Low
21	Yukihikari	19.42	Low

Gelatinization temperature of the rice grain of 21 rice cultivars

Gelatinization temperature (GT) is also closely related to the eating and cooking quality of rice (Juliano, 1972) through association with cooking time, texture of cooked rice and cool cooked rice (Maniñgat and Juliano, 1979) and molecular size of starch function (Li et al., 2008). It is the temperature at which 90% of rice starch granules swell irreversibly in hot water with loss of crystalline structure and birefringence (Little, et al., 1958). Rice varieties with high GT require more water and cooking time than those possessing low or intermediate GT, therefore, intermediate GT is preferred in most rice-producing country as high-quality cultivars (Pang et al., 2016). In the present study, most of the genotypes (16 cultivars) exhibited intermediate gelatinization temperature, and rest of the cultivars exhibited high (3 cultivars) and low (2 cultivars) GT (Table 5). Based on the mean performance of the genotypes, a ranking table is presented in table 6. From the table it is clear that BINA dhan-10 was ranked first and BRRI dhan47 was the lowest performer.

Table 5. Gelatinization temperature of rice genotypes

Sl No.	Genotypes	Temperature
1	BR 3	Low
2	BR 14	Low
3	BR 16	Low
4	BRRI dhan 28	Low
5	BRRI dhan 29	Low
6	BRRI dhan 36	Low
7	BRRI dhan 45	Low
8	BRRI dhan 47	Low
9	BRRI dhan 55	Low
10	BRRI dhan 57	Intermediate
11	BRRI dhan 58	Low
12	BRRI dhan 59	Intermediate
13	BRRI hybrid dhan1	Low
14	BRRI hybrid dhan3	Low
15	Iratom-24	Low
16	BINA dhan-5	Low
17	BINA dhan-6	Low
18	BINA dhan-8	Low
19	BINA dhan-10	Low
20	BINA dhan-14	Low
21	Yukihikari	Intermediate

Table 6. Ranking of the genotypes based on mean performance

SL No.	Genotypes	L_1	L_2	W_1	W_2	L_2/L_1	L_2/W_2	L_1/W_1	WU	SCW	CT	Total	Rank
1	BR 3	5.0	6.0	10.5	5.5	5.5	2.5	6	1.0	8.0	8.0	58.0	15
2	BR 14	10.5	3.0	11.0	5.0	2.5	2.5	3.5	16.0	10.0	12.0	76.0	4
3	BR 16	8.0	7.0	6.5	4.0	8.0	6.5	8.5	13.0	5.0	11.0	77.5	2
4	BRRI dhan28	7.0	6.0	3.5	3.5	1.5	4.0	9.5	1.0	2.0	11.0	49.0	19
5	BRRI dhan29	6.5	6.5	6.0	1.0	3.	6.5	8.5	4.0	3.0	9.0	54.0	17
6	BRRI dhan36	7.0	9.0	10.5	1.	11.0	8.0	8.5	7.0	1.0	4.5	67.5	9
7	BRRI dhan45	6.5	7.5	8.5	2.5	4.5	5.5	6.0	9.0	4.0	4.5	58.5	14
8	BRRI dhan47	3.0	1.0	12.0	9.0	7.0	1.0	2.0	3.0	8.0	2.5	48.5	20
9	BRRI dhan55	9.0	7.5	10.5	4.0	1.0	6.5	10.5	8.0	3.0	7.0	67.0	10
10	BRRI dhan57	8.0	8.5	1.0	1.0	10.0	8.0	12.0	1.0	9.5	11.0	70.0	7
11	BRRI dhan58	5.0	5.5	4.5	4.0	8.5	4.5	7.5	12.0	13.0	13.0	77.5	2
12	BRRI dhan59	4.0	2.0	8.5	5.0	3.5	2.0	3.5	18.0	6.0	3.5	56.0	16
13	BRRI hybrid dhan1	6.5	6.0	2.0	1.5	6.5	7.0	11.0	14.0	7.0	7.5	69.0	8
14	BRRI hybrid dhan3	2.5	3.0	8.6	5.5	11.5	2.5	2.5	17.0	11.0	2.0	66.1	11
15	Iratom-24	6.5	7.5	9.5	5.5	4.5	3.0	7.5	10.0	11.0	10	75.0	5
16	BINA dhan-5	7.0	6.0	6.5	7.5	3.0	2.0	7.0	13.0	10.0	1.5	63.5	13
17	BINA dhan-6	8.0	8.0	7.5	6.5	9.0	4.0	7.5	6.0	13.0	7.5	77.0	3
18	BINA dhan-8	2.0	9.0	11.0	8.5	9.0	1.0	2.0	11.0	14.0	6.0	73.5	6
19	BINA dhan-10	5.0	6.0	9.5	8.5	9.5	2.0	4.5	15.0	13.0	7.5	80.5	1
20	BINA dhan-14	8.0	7.0	3.0	3.5	6.5	7.0	10.5	2.0	12.0	6.5	66.0	12
21	Yukihikari	1.0	1.0	12.0	8.0	12.0	1.0	1.0	5.0	3.0	5.5	49.5	18

Legend: L1=Length before cooking; L2=Length after cooking; W1=Width before cooking; W2=Width after cooking; L_2/L_1=Length elongation ratio; L_2/W_2=Length width ratio after cooking; L_1/W_1=Length width ratio before cooking; WU=Water uptake; SCW=Solid in cooking water; CT=Cooking time; AC=Amylose content

Note: Letter A represents highest number for all the genotypes except CT. In case of CT, A represent lowest number.

Association of characters related to quality in 21 rice cultivars

The correlation coefficient among the characters related to seed quality of rice is presented in the Table 7. Negative correlation of grain length before cooking has been found with grain width before and after cooking. On the other hand, Positive correlation has been found between grain length before cooking and grain length and width ratio after cooking. Grain width before and after cooking was positively correlated with grain elongation ratio and negatively correlated with grain length and width ratio at both before and after cooking.

A positive correlation was observed between grain elongation ratio and grain length and width ratio after cooking and solid in cooking water. Its means if grain elongation ratio has increased then grain length and width ratio after cooking and solid in cooking water will also be increased. On the contrary, grain elongation ratio was negatively correlated with amylose content. Thus, higher amylose content in rice grain is undesirable for cooking and eating purposes. Grain length and width ratio before and after cooking was positively correlated with each other but grain length and width ratio after cooking was negatively associated with solid in cooking water. These findings were supported by Odenigbo et al. (2014), Rasool et al. (2015) and Kumar et al. (2010).

Table 7. Correlation coefficients of eleven (11) characters associated with rice grain quality in 21 rice cultivars

Character	L_2	W_1	W_2	L_2/L_1	L_2/W_2	L_1/W_1	WU	SCW	CT	AC
L1	0.376	-0.64**	-0.54*	-0.029	0.467*	0.424	0.001	-0.162	-0.031	0.037
L_2		-0.55**	-0.50*	0.275	0.545*	0.329	0.001	-0.089	-0.019	0.005
W_1			0.434*	0.599**	-0.991**	-0.114	-0.003	0.223	0.074	-0.051
W_2				0.750**	-0.304	-0.704**	-0.001	0.888**	0.104	-0.041
L_2/L_1					0.777**	-0.427	0.007	0.652**	0.190	-0.44**
L_2/W_2						0.527**	0.001	-0.449*	-0.054	0.020
L_1/W_1							0.001	-0.136	-0.042	0.024
WU								0.005	0.001	0.001
SCW									-0.035	-0.093
CT										0.009

Note: * and ** indicate significant at 5% and 1% levels of probability, respectively
Legend: L1=Length before cooking; L2=Length after cooking; W1=Width before cooking; W2=Width after cooking; L_2/L_1=Length elongation ratio; L_2/W_2=Length width ratio after cooking; L_1/W_1=Length width ratio before cooking; WU=Water uptake; SCW=Solid in cooking water; CT=Cooking time; AC=Amylose content.

CONCLUSION

Twenty-one popular rice cultivars were evaluated for different physical, cooking and eating quality of grains for the consideration of consumers and to develop quality rice cultivar. All the genotypes displayed significant differences based on their mean performances. Based on the mean performance of all the quality character BINA dhan-10 was found best as consumer of Bangladesh prefers. Considering analysis of all the quality characters *viz*. grain length before cooking, grain length after cooking, grain width before cooking, grain width after cooking, grain elongation ratio, grain length and width ratio before cooking, grain length and width ratio after cooking, water uptake per cent, cooking time, amylose content suggesting that the selection based on these quality characters could effectively be practiced for developing rice varieties.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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