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Research Article

Physico-chemical Properties and Cooking Quality of Rice Somaclone (RSC2018-1) Developed from an Aromatic Local Landrace

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ABSTRACT

Local rice cultivars are an important source of biotic and abiotic stress-resistant genes and require special assistance to improve their qualitative and quantitative traits. A rice somaclone RSC2018-1 was isolated from a vulnerable aromatic rice cultivar *Benapole*. We investigated nutritional, physical, and cooking qualities of this line and compared with its mother genotype. The experiment was laid out in Completely Randomized Design with four replications. Nutritional analysis revealed that somaclone RSC2018-1 had more protein (16.14%), less fat (0.70%) and carbohydrate (75.19%) than those of mother *Benapole.* Mineral components e.g. Na and Fe were higher (91.23 ppm and 20.02 ppm, respectively) in the RSC2018-1, while K and Zn contents were higher (196.67 ppm and 31.70 ppm, respectively) in mother *Benapole*. The size of the grain was much shorter in RSC2018-1 than in *Benapole*. Shape of the grain is round in RSC2018-1 while *Benapole* has a bold shape grain. Thousand-grain weight, geometric mean dimension, and surface area were comparatively much lesser in the somaclone line. Sphericity, aspect ratio, bulk density and porosity were higher in somaclone than in *Benapole*. RSC2018-1 showed a shorter cooking time (21.78 minutes), intermediate alkali digestion, intermediate gelatinization temperature, and soft gel consistency (60.78 mm) through cooking qualities analysis. Considering all physicochemical and cooking properties, the somaclone (RSC2018-1) has been found more superior in comparison with mother cultivar *Ranisalute*.

Introduction

Rice (*Oryza sativa* L.) is one of the world's most important sources of carbohydrates and energy, feeding an estimated 3.5 billion people (Muthayya et al., 2014). Bangladesh occupies the 3rd position in the cultivation area and 4th position in rice production (Food Outlook, 2022). Bangladesh produced 37.84 million metric tons of rice overall in 2021–2022 (BBS, 2022). HYV rice is predominant in the existing cropping system, but still, local rice cultivars occupy about 12.16% of the rice-growing areas. These local varieties have unique characteristics such as special taste, aroma, cooking quality, etc. Their cultivation is less costly and eco-friendly (Islam et al., 2016).

Local rice cultivars are a repository of biotic and abiotic stress-resistant genes that have been replaced by HYVs (Mondal et al., 2021). Many local rice landraces have been permanently lost. A famous coarse-grained aromatic rice cultivar native to Bangladesh, "*Benapole*" (also known as *Benapole Rani*) is grown in some parts of the Jashore district and the southern region of Khulna (Batiaghata and Dumuria Upazilas) (Remme et al., 2023). Due to its special aroma, lower production costs, and little input requirements for intercultural operations, the '*Benapole*' cultivar has gained popularity. There has been virtually little research on these cultivars. To improve indigenous landraces, an endeavor was carried out using an *in vitro* somaclonal variation technique and a new variant RSC2018-1 was

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developed from the cultivar *Benapole*. Compared to the mother cultivar, the somaclone RSC2018-1 shows significant characteristic changes in connection with nutritional value, physicochemical properties, and cooking quality.

The nutritional and mineral quality of rice is greatly affected by milling processes and parboiling. Parboiling rice improves its texture, increases its shelf life, and provides health benefits by migrating some water-soluble nutrients from the bran of the rice kernel into the starchy endosperm resulting in the reduction of nutritional loss during refining for producing white rice. Parboiled rice has more fiber and protein than white rice but less nutritional value than brown rice (McCulloch, 2019). To date, the physical properties of the newly invented RSC2018-1 rice including grain dimensions, hardness, grain friction, bulk density, sphericity, porosity, etc., has not been investigated along with the handling, storing, and processing.

Now we investigated the nutritional and physicochemical properties of somaclone RSC2018-1 and mother cultivar '*Benapole'* and analyzed the cooking properties under three post-harvest milling methods.

Materials and Methods

Rice seed samples of two rice genotypes e.g., *Benapole* and somaclone of *Benapole*, RSC2018-1 obtained from Plant Breeding and Biotechnology Laboratory of Agrotechnology Discipline, Khulna University. A 2-factorial experiment was laid out using A Completely Randomized Design (CRD) having four replications. Two rice genotypes e.g., *Benapole* and its somaclone (RSC2018-1) were denoted as factor A and three milling procedures used as factor B such as brown rice (processed with husking pedal or dheki), parboiled brown rice (parboiled and processed with husking pedal) and white rice (processed and polished with machine).

Nutritional and mineral component analysis

The proximate composition of *Benapole* and somaclone (RSC2018-1) was determined using a standard protocol AOAC (2005). Mineral composition like Sodium (Na) and Potassium (K) were determined with a PFP7 flame photometer (model no- 8515) (AOAC, 2000). Calcium (Ca), Magnesium (Mg), Zinc (Zn), and Iron (Fe) were determined with an atomic absorption spectrophotometer (SHIMADZUAA-7000) (AOAC, 2000) in the laboratory of Soil Resource Development Institute (SRDI), Dhaka.

Physical properties

Length, width, and thickness of manually dehusked seeds were measured with Vernier calipers. Grain shape index was determined based on length to width ratio L/W = Average length / Average width

1000-grain weight: Mass of 1000 seeds was determined using an electronic Digital Balance. To determine the average weight of 1000 seeds, a sample size of 100 seeds was randomly selected and weighed. This result was then multiplied by 10 to get a mass of 1000 seeds (Varnamkhasti et al., 2008).

Geometric Mean Dimension: Calculation of the diameter was done based on three diameters of rice grain, length, width, and thickness by $De = (LWT)(\frac{1}{3})$ (Mohsenin, 1980). Where, De = Geometric Mean Dimension (mm), L = Length (mm), W = Width (mm), and T = thickness (mm).

Sphericity: Sphericity was calculated using the following equation (Mohsenin, 1980)

$$Sp(\%) = \left[\left\{(LWT)^{\frac{1}{3}}\right\}\backslash L\right] \times 100$$

Where, Sp = Sphericity (%), L = Length (mm), W = Width (mm) and T = Thickness (mm).

Aspect ratio: Aspect ratio was determined by the ratio of length and width of the grain: Ra (%) = (W\L) × 100. Where, Ra = Aspect ratio (%), W = Width (mm), L = Length (mm).

Surface area: The surface area was found by the following equation (McCabe et al., 1993)

$$Sa = \pi De2$$

Where, Sa = Surface area (mm^2), De = Geometric mean dimension (mm).

Bulk density: A 200 ml beaker was filled with rice grain up to 100ml and then the mass of rice grain was weighed. The weight of the rice was divided by the volume of the beaker (100 ml).

$$Pb = \frac{m}{v}$$

Where, Pb = Bulk density (g/ml), m = mass of grain, v = Volume of the beaker.

Solid density: A 100 ml measuring cylinder was filled with 50 ml distilled water, and then 3g grain was placed into the cylinder. The displaced water is the volume and the mass is 3g.

$$Pt = mass\ of\ grain/volume$$

Porosity: This was calculated from the measured values of densities (bulk and true) using the relationship given in the equation (Mohsenin, 1980; Mustafa, 2007).

$$€ = 100 \times (1 - \frac{pb}{pt})$$

Where ρb is the bulk density and ρt is the solid density.

Cooking qualities

Cooking Time: The minimum cooking time was evaluated according to Singh et al. (2005).

Gelatinization Temperature

Alkali Digestion Test: Duplicate sets of 6 whole milled kernels from each genotype were placed in a plastic box. 10 ml 1.7% KOH was added and samples were incubated for 23 hours at 30^{o}C in an oven. The starchy endosperms were rated according to the scale (IRRI, 1996).

Gel Consistency: 0.1g finely grounded rice sample was weighed and was taken in the test tube. 95% 0.2 ml ethyl alcohol with 0.025% thymol blue was also added. To make the solution for six samples, 20 ml distilled water was taken and 0.005g thymol blue was dissolved in it. 0.2mL ethyl alcohol was taken and then 0.2 N KOH was added. Test tubes were placed into the water bath having 100°C water and gel began to rise. After 8 minutes' tubes were removed and kept in a beaker filled with ice for 20 minutes to cool. Tubes were placed on the graph paper horizontally and gel was determined (Juliano, et al., 1990).

Statistical Analysis: The collected data were analyzed using statistical package MSTAT-C software. Data were analyzed using the Analysis of variance (ANOVA) and Student t-test was done to compare the rice genotypes. Means for significant treatment effects were compared by Duncan's New Multiple Range test (DMRT) at $p < 0.05$.

Results and discussion

Nutritional analysis

The interaction effect of the genotype × milling procedure was significant ($p<0.05$) for all measured traits (Table 1), whereas variation attributable to the genotypes was significant only for crude protein, fat and carbohydrates (Table 2). Significant variation was observed for moisture content among different genotypes × milling procedures, ranging from 6.25% (*Benapole* parboiled brown rice) to 2.00% (*Benapole* white rice) (Table 1). The tested genotypes × milling procedures significantly ($p<0.01$) varied in crude protein, where RSC2018-1 brown rice produced the highest crude protein (16.59%), which was statistically similar to RSC2018-1 parboiled brown rice (Table 1). Similarly, the highest crude fiber 3.34% was found in RSC2018-1 brown rice and RSC2018-1 white (milled) (Table 1). The lower amount of fat (0.36%) and carbohydrate (74.34%) was noticed in RSC2018-1 white (milled) rice and RSC2018-1 parboiled brown rice (Table 1). However, the *Benapole* brown rice had the highest ash percentage (0.38%) followed by RSC2018-1 Brown rice (0.33%).

Table 1. Nutritional composition of *Benapole* and RSC2018-1 under various milling procedures

Genotype × milling procedure	Moisture content (%)	Crude protein (%)	Crude fiber (%)	Ash (%)	Fat (%)	Carbohydrate (%)
V_1P_1	5.90 b	15.65 c	3.19 b	0.38 a	1.33 a	73.58 d
V_1P_2	6.25 a	10.80 d	3.16 bc	0.20 e	0.66 c	78.93 b
V_1P_3	2.00 f	10.02 e	3.18 b	0.20 e	0.63 c	83.97 a
V_2P_1	4.00 d	16.59 a	3.34 a	0.33 b	1.06 b	74.66 d
V_2P_2	4.97 c	16.59 a	3.10 c	0.30 c	0.70 c	74.34 d
V_2P_3	3.48 e	16.06 b	3.30 a	0.22 d	0.36 d	76.58 c
CV (%)	3.85	0.20	1.28	5.11	9.73	0.22
Level of significance	**	**	**	**	**	**

CV=Coefficient of variation; *=p <0.05; **=p<0.01, V_1P_1= *Benapole* Brown rice, V_1P_2= *Benapole* Parboiled brown rice, V_1P_3= *Benapole* White (milled) rice, V_2P_1= RSC2018-1 Brown rice, V_2P_2= RSC2018-1 Parboiled brown rice, V_2P_3= RSC2018-1 White (milled) rice

The mineral elements of a food sample are reflected by the ash content. It provides an idea of the levels of essential minerals present in the food (Verma and Srivastav, 2017). The ash of two rice genotypes processed with different milling procedures is shown in Table 1. Statistical analysis revealed a significant difference ($P<0.01$) in ash content for the interaction effect of rice genotype and different milling procedures. The interaction effect of V_1P_1 had the highest ash (0.38%) while both V_1P_2 and V_1P_3 had the lowest ash (0.2%). The other ash percentages were 0.33, 0.30 and 0.22, respectively in the interaction effect of V_2P_1, V_2P_2 and V_2P_3. From the study, we can explore that ash content is high in brown rice and generally decreases in white rice. Similar results were found in the literature, as reported by Doesthale et al. (1979) who discovered a 19.2% increase in ash content by the parboiling process, while data calculated from the USDA Nutrient Database

(USDA, 2004) revealed a 20% increase in ash content of parboiled rice in comparison to milled rice.

Rice fat is high in linoleic and other essential fatty acids, but it does not contain cholesterol. The fat content of cooked rice influences its flavor because rice with a high fat content is tastier and contains less starch (Verma and Srivastav, 2017). The fat of two rice genotypes processed with different milling procedures is shown in Table 1. Statistical analysis revealed a significant difference (P<0.01) on fat values for the interaction effect of rice genotype and different milling procedures. Lowest fat was found in V_2P_3 (somaclone white rice) (0.36%) while highest in V_1P_1 (*Benapole* brown rice) (1.33%). Fat was higher in *Benapole* variety and among the 3 post-harvest processing methods brown rice had greater fat which was decreased in white rice because maximum fat remained in aleurone layer of the rice. Due to milling process it is removed that's why, white rice contains less fat than brown rice and parboiled brown rice. It was reported that up to 79% fat can be lost during milling process (polished rice) (Abbas et al., 2011). These results were consistent with those reported in some food composition tables (USDA, 2004 and Juliano, 1985).

Carbohydrate is the most prominent compound in rice. Rice carbohydrates are mostly made up of starch, which is made up of amylose and amylopectin (Verma and Srivastav, 2017). Statistical analysis revealed a significant difference (P<0.01) in carbohydrate values for the interaction effect of rice genotype and different milling procedures. The higher amount of carbohydrate was found in V_1P_3 (83.97%) (*Benapole* white rice) followed by V_1P_2 (*Benapole* parboiled brown rice) (78.93%). The lowest carbohydrate was found in V_1P_1 (*Benapole* brown rice) (73.58%). Manu and Amamoo (2017) reported that carbohydrate content in the varieties ranged from 74.20% to 79.41%. Low carbohydrate was found in *Maawuwoe coop* white rice (MCWR) and high carbohydrate was found in *Shigafa* white rice (SWR). Other carbohydrate percentages were 75.74%, 78.30%, 75.92%, 76.94%, and 78.21% respectively in MCBR, LGPR, SBR, IB 1 and IB 2. The analysis revealed that different rice varieties contained different carbohydrate percentages which is quite similar to the present study.

Table 2. Comparison of nutritional composition of *Benapole* and RSC2018-1

Rice genotype	Moisture content (%)	Crude protein (%)	Crude fiber (%)	Ash (%)	Fat (%)	Carbohydrate (%)
Benapole	4.72	12.15	3.22	0.26	0.87	78.83
RSC2018-1	4.15	16.14	3.25	0.28	0.70	75.19
t-value	1.26	6.06	1.06	0.68	3.19	3.42
p-value	0.23	0.001	0.31	0.5	0.008	0.005
Significance level	NS	**	NS	NS	**	**

NS= non-significant, *=p <0.05; **=p<0.01

Proximate compositions of *Benapole* and RSC2018-1 are shown in table 2. The Table indicates that the rice genotypes (*Benapole* and RSC2018-1) had no significant effect (P>0.05) on moisture content, crude fiber and ash. On the other hand, the rice genotypes had a significant effect (P<0.05) on crude protein, fat and carbohydrate. The higher t value indicates a larger difference between the two rice samples and the lower t value indicates less difference between two rice samples. The high value of crude protein (16.14%) was found in RSC2018-1 rice while *Benapole* contained high value of the carbohydrate (78.83%) and fat (0.87%). Oko and Ugwu (2011) reported that there is a significant effect (p<0.05) of the rice varieties on the proximate compositions. Five major rice varieties (*Sipi, Faro14, Awilo, Faro15 and Canada*) in Abakaliki, South-Eastern Nigeria, were analyzed to determine the proximate composition. The rice samples from the study contained high quantities of carbohydrates ranging from 76.92 to 86.03%, moisture content ranging from 3.67 to 18.00%, fiber content ranging from 1.5 to 2.0%, crude protein contents ranging from 1.58 to 6.22%, fat content ranging from 0.5 to 3.5%. The range is quite similar to the present findings except for moisture content and protein. The range of moisture content was lower and protein was higher in the present study.

Mineral content analysis

The Na content of two rice genotypes processed with different milling procedures is shown in Table 3. Statistical analysis revealed a significant difference (P<0.01) in Na values for the interaction effect of rice genotype and different milling procedures. The interaction effect of V_2P_2 (somaclone parboiled brown rice) had the highest Na (131.10 ppm) followed by V_1P_2 (*Benapole* parboiled brown rice) (103.50 ppm) while the interaction effect of both V_1P_3 (*Benapole* white rice) and V_2P_3 (somaclone white rice) had lowest Na (69.00 ppm). From the findings, it is observed that Na content is higher in brown rice than white rice. Dikeman et al. (1981) also reported that the Na content present in brown and white (polished) rice ranged from 17 to 340 µg/g and 5 to 86 µg/g, respectively.

Table 3. Mineral contents of *Benapole* and RSC2018-1 under various milling procedures

Genotype × milling procedure	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Zn (ppm)
V_1P_1	73.60 c	210.00 a	48.66 a	9.04 d	14.76 d	36.40 a
V_1P_2	103.50 b	210.00 a	39.36 e	17.27 a	11.54 e	32.50 b
V_1P_3	69.00 d	170.00 b	38.06 f	8.54 e	10.72 f	26.21 f
V_2P_1	73.60 c	170.00 b	43.57 c	11.37 c	19.47 b	30.76 c
V_2P_2	131.10 a	210.00 a	43.92 b	15.28 b	21.22 a	29.79 d
V_2P_3	69.00 d	110.00 c	42.15 d	5.40 f	19.36 c	27.93 e
CV (%)	0.04	0.02	0.06	0.14	0.10	0.04
Level of significance	**	**	**	**	**	**

V_1= Benapole rice, V_2= somaclone (RSC2018-1), P_1=Brown rice, P_2=Parboiled brown rice, P_3= White (milled) rice, CV=Coefficient of variation; *=p <0.05; **=p<0.01

The K content of two rice genotypes processed with different milling procedures is shown in Table 3. The interaction effect of genotype and different milling procedures had high significant effect (P<0.01) on K content. The interaction effect of V_1P_1 (*Benapole* brown rice), V_1P_2 (*Benapole* parboiled brown rice) and V_2P_2 (somaclone parboiled brown rice) had the highest K content which was 210.00 ppm and the interaction effect of V_2P_3 (somaclone white rice) had the lowest K (110.00 ppm). Heinemann et al. (2005) reported that white rice contained the lower content of K (65.46 mg/100g) than brown rice (181 mg/100g) and parboiled brown (152 mg/100g) rice which is similar to the present findings.

Ca is also an essential element for the human body. Ca is mainly stored in human bones and teeth. Muscle contraction, nervous system function, blood vessel expansion and contraction, and hormone and enzyme release are all dependent on it (Govarethinam, 2014).

The Ca content of two rice genotypes processed with different milling procedures is shown in Table 3. Statistical analysis revealed a significant difference (P<0.01) on Ca values for the interaction effect of rice genotype and different milling procedures. The interaction effect of V_1P_1 (*Benapole* brown rice) had the highest Ca content (48.66 ppm) followed by V_2P_2 (somaclone parboiled brown rice) (43.92 ppm) and the interaction effect of V_1P_3 (*Benapole* white rice) had the lowest Ca (38.06 ppm). From the analysis, we can be observed that Ca content is low in white rice and high in brown rice and low in white rice. Heinemann et al. (2005) reported that Ca content was lower in white rice due to the removal of the external layer while brown rice had higher Ca content which is partially similar with the present findings.

The Mg content of two rice genotypes processed with different milling procedures is shown in Table 3. Statistical analysis revealed a significant difference (p<0.01) in Mg values for the interaction effect of rice genotype and different milling procedures. The interaction effect of V_1P_2 (*Benapole* parboiled brown rice) had the highest Mg content (17.27 ppm) followed by V_2P_2 (somaclone parboiled brown rice) (15.28 ppm) while the interaction effect of V_2P_3 (somaclone white rice) had the lowest Mg (5.40 ppm). These findings are consistent with findings of Heinemann et al. (2005) who discovered that the Mg content of brown and parboiled rice was higher than that of white rice.

Fe is an essential component for improving grain nutritional quality for human consumption (White and Broadley, 2005; Cakmak, 2008; McDonald et al., 2008; Wissuwa et al., 2008). The Fe content of two rice genotypes processed with different milling procedures is shown in Table 3. The interaction effect of genotype and different milling procedures had high significant effect (p<0.01) on Fe content. The interaction effect of V_2P_2 (somaclone parboiled brown rice) had the highest Fe content which was 21.22 ppm followed by V_2P_1 (somaclone brown rice) (19.47 ppm) and the interaction effect of V_1P_3 (*Benapole* white rice) had the lowest Fe (10.72 ppm). From the analysis, we can explore that Fe content is low in white rice and high in parboiled brown rice and brown rice. These results of Fe are consistent with previous findings by Eppendorfer et al. (1983); Sotelo et al. (1990) who found that bran was particularly high in Fe while white rice had a lower Fe concentration.

The Zn content of two rice genotypes processed with different milling procedures is shown in Table 3. Statistical analysis revealed a significant difference (p<0.01) on Zn values for the interaction effect of rice genotype and different milling procedures. The interaction effect of V_1P_1 (*Benapole* brown rice) had the highest Zn content (36.40 ppm) followed by V_1P_2 (*Benapole* parboiled brown rice) (32.50 ppm) while the interaction effect of V_1P_3 (*Benapole* white rice) had the lowest Zn (26.21 ppm). Zn content is high in brown rice and low in white rice among different milling procedures. The Zn content results are consistent with previous findings reported by Eppendorfer et al. (1983), and Sotelo et al. (1990) who found higher Zn contents in bran and lower Zn contents in white rice.

Table 4. Comparison of different minerals of *Benapole* and RSC2018-1

Rice genotype	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Zn (ppm)
Benapole	82.03	196.67	42.03	11.62	12.34	31.70
RSC2018-1	91.23	163.34	43.21	10.68	20.02	29.49
p-value	0.03	0.001	0.3	0.2	0.00	0.03
t-value	2.35	4.43	0.89	1.31	11.53	2.42
Level of significance level	*	**	NS	NS	**	*

NS= non-significant, *=p <0.05; **=p<0.01

Minerals Contents of *Benapole* and RSC2018-1 are shown in Table 4. The rice genotypes (*Benapole* and RSC2018-1) had no significant effect (P>0.05) on Ca and Mg content. On the other hand, the rice genotypes had a significant effect (P<0.05) on Na, k, Fe and Zn. RSC2018-1 had the greater Na concentration (91.23 ppm) while *Benapole* had the lower Na (82.03 ppm). The higher amount Fe (20.02 ppm) was observed in RSC2018-1 than in *Benapole*. The amount of Fe in *Benapole* was 12.34 ppm. *Benapole* had greater levels of K (196.67 ppm) and Zn (31.7 ppm) and RSC2018-1 had lower levels of K (163.34 ppm) and Zn (29.49 ppm). Zubair et al. (2012) reported that different rice varieties had significant effect (p<.05) on Na, K, Mg, Ca, Zn and Fe. The results are consistent with the present study.

Physical parameters of rice grains

The physical parameters of rice (length, width, thickness, 1000-grain weight, geometric mean dimension, surface area, sphericity, aspect ratio, solid density, bulk density and porosity) were measured and the results are shown in Table 5.

Table 5. Comparison of different physical properties between *Benapole* and somaclone line (RSC2018-1)

Genotypes	Length (mm)	Width (mm)	Length/ width	Thickness (mm)	1000-grain weight (g)	Geometric mean dimension (mm)	Surface area (m^2)	Sphericity (%)	Aspect ratio (%)	Solid density (g/ml)	Bulk density (g/ml)	Porosity (g/ml)
Benapole	6.17	2.86	2.16	2.07	27.01	3.31	34.44	53.66	48.37	1.6	0.77	46.98
RSC2018-1	4.75	2.58	1.84	1.81	17.30	2.81	24.81	58.90	53.46	1.58	0.82	58.50
t-value	27.45	4.92	38.77	7.25	65.81	118.00	993.65	126.53	3.88	0.08	10.13	139.75
Significance level	**	**	**	**	**	**	**	**	**	NS	**	**

NS = non-significant (p≥0.05), ** = highly significant (p< 0.01)

Length of rice grains

Grain size and shape are the crucial criteria to be considered for commercial production as well as developing new varieties (Rani et al., 2006). The length of *Benapole* and somaclone was found to be 6.17 mm and 4.75 mm, respectively which can be categorized as long and short according to the findings of Khush et al. (1978) as he classified grain length as extra-long (>7.50 mm), long (6-7.50 mm) and short (<5.50 mm). The rice genotypes had highly significant effect (p<0.01) on grain length. The value of length between two genotypes differs highly as t value is high. The study of Biswas & Juliano (1988) narrated that most modern rice varieties have short to medium grain size.

Width of rice grains

Grain width is very important to be determined as it influences eating quality (McKenzie et al., 1993). The width of *Benapole* and RSC2018-1 was found 2.86 mm and 2.58 mm, respectively. The genotypes had high significant effect (p<0.01) on width. Dipti et al. (2003) found the mean width of 11 Beruin rice to be 2.08 mm. The t value shows little difference between the varieties on width. The present finding is partially consistent with that findings of (Dipti et al., 2003).

Thickness of rice grains

Thickness is an important factor for diffusion water during cooking (Mohapatra and Bal, 2006). The thickness of *Benapole* was found 2.07 mm and 1.81 mm for that of somaclone. High significant effect (p<0.01) was found on grain thickness. The t value is showing there is minimum difference between the varieties on thickness. The result for *Benapole* complements the finding of Chemutai et al. (2016) as they found the thickness of long grain to be in the range of 2-2.6 mm. The result of somaclone line complements with the finding of Jahan et al. (2021) as the shortest variety found to have the lowest thickness.

Shape (length/width ratio)

Grain shape influences the volume, weight, dehusking, polishing, storage, and cooking properties. The length/ width ratio was found to be higher (2.16 mm) in *Benapole* and lower (1.84 mm) in that of the somaclone line. The two rice genotypes had high significance effect (p<0.01) on length/width ratio. A high T value found in the result means the difference of the ratio between the genotypes is high. According to the standard maintained by IRRI, ratio more than 3 is classified as 'slender' type, ratio between 2-3 is 'bold' type and ratio below 2 is categorized as 'round'. So, *Benapole* was found to be bold type and somaclone was found to be round. Grain with round shape occupy less volume, therefore, it is more preferable in Bangladesh.

Thousand grain weight and geometric mean dimension

Thousand grain weight is an important parameter in measuring relative amount of foreign substance, shriveled grains in a given lot (Reddy and Chakraverty, 2004). The thousand-grain weight was found higher in Benapole (27.01 g) than that of somaclone (17.30 g) and highly significant effect ($p<0.01$) observed on thousand grain weight among the genotypes. T value was found to be high so there is high difference between the varieties on thousand grain weight. The geometric mean dimension was found 3.31 mm in *Benapole* and 2.81 mm in somaclone. The two genotypes had highly significant effect ($p<0.01$) on the geometric mean dimension of the two rice genotypes. The genotypes have huge difference on geometric mean dimension as t value is showing.

Surface area of rice grains

The surface area of grain is a very important property as it influences the cooking process (Juliano et al., 1993). The surface area was higher in Benapole (34.44 m^2) than that of somaclone (24.81 m^2). The genotypes had a highly significant effect ($p<0.01$) on surface area. There is a high difference in the surface area among the genotypes as the t value is showing. Surface area determines how the grain will behave during processing according to the study of (Alonge and Adigun, 1999).

Sphericity and aspect ratio of rice grains

The sphericity and aspect ratio are very important parameters to determine whether the grains will slip or roll on their flat surface (Delshadian et al., 2015). The sphericity of Benapole was lower (53.66%) than that of somaclone (58.90%) and the genotypes had highly significant effect ($p<0.01$) on sphericity of rice genotypes. The t value shows high difference on sphericity between the genotypes. The aspect ratio was found to be higher in somaclone (53.46%) than that of Benapole (48.37%) and the genotypes had highly significant effect ($p<0.01$) on aspect ratio. t value showing less difference among the genotypes on aspect ratio. According to Alonge and Adigun, (1999) lower sphericity and aspect ratio is not preferred as it is difficult to get the grains roll.

Solid density, bulk density and porosity of rice grains

Soild density was found to be 1.6 g/ml in *Benapole* and 1.58 g/ml in that of somaclone. The result indicates that the grain density is higher than water which is an important aspect during wet cleaning as grains do not float on water. The result is in agreement with the findings of Ghadge and Prasad (2012) and also with Tiwari et al. (2017). The genotypes had no significant effect ($p>0.01$) on solid density. Bulk density is important to measure required capacity of storage chambers and transportation equipment (Adebowale et al., 2011). Bulk density is crucial for storage space for grain and has an influence on transport properties. The bulk density in Benapole was found 0.77 g/ml and 0.82 g/ml in somaclone. The t value showing no such difference between the genotypes on solid density. The genotypes had high significant effect ($p<0.01$) on bulk density. The difference between the genotypes bulk density is not high as t value was found to be 10.13.

Porosity is an important factor in drying process. The porosity found higher in somaclone (58.50%) than Benapole (46.98%). High porosity is preferable as it improves aeration quality in drying process (Adebowale et al., 2011). High significant effect ($p<0.01$) was observed among genotypes on porosity. The higher t value means there is huge difference in porosity between the genotypes. These observations are complementing the finding of Tiwariet al. (2017) where solid density, bulk density and porosity was found in the range of (1.19-1.5) g/ml, (0.54-0.56) g/ml and (53.31%-58.69%), respectively.

Table 6. Cooking quality of grains of two rice genotypes under various post-harvest milling

Variety/milling procedures interaction	Gelatinization temperature	Alkali digestion	Alkali spreading score (1-7 scale)	Cooking time (mins)	Gel length (mm)	Gel consistency
$V_1 P_1$	High	Low	1	18.67 d	47.67 b	Medium
$V_1 P_2$	High	Low	1	24.67 b	95.67 a	Soft
$V_1 P_3$	High	Low	1	28.00 a	95.33 a	Soft
$V_2 P_1$	Low	High	6	15.67 e	42.33 d	Medium
V_2P_2	Intermediate	Intermediate	4	22.33 c	44.33 c	Medium
$V_2 P_3$	Intermediate	Intermediate	5	27.33 a	95.67 a	Soft
CV (%)				2.31%	1.01 %	
Significance level				**	**	

Data followed by same alphabet are not different significantly, V_1 = Benapole, V_2 = Somaclone, P_1 = Brown rice, P_2 = Parboiled brown rice, P_3 = White rice;
** =p<0.01; * = p<0.05; = p>0.05

Cooking quality of two rice genotypes

Gelatinization temperature is very important cooking trait as it determines the time for cooking of rice (Heda and Reddy, 1986). The interaction effect of varieties and milling procedures on gelatinization is shown in Table 6. The interaction effect of V_1P_1, V_1P_2, and V_1P_3 had the same high gelatinization temperature. In case of V_2P_1 interaction, low gelatinization temperature was found which differs from other two interaction effect (V_2P_2 and V_2P_3) that was found to be intermediate. Varieties having long grain have high gelatinization temperature because unlike short grain the granules in long grain tend to remain intact after cooking. Consumers prefer low gelatinization temperature as it is linked to shorter cooking time (Frei and Becker, 2003).

Alkali digestion is very crucial determinant of eating, cooking and processing quality of rice (Nishi et al., 2001). The interaction effect of varieties and milling procedures on alkali digestion is shown in Table 6. The interaction effect of V_1P_1, V_1P_2 and V_1P_3 had similar alkali digestion (low). Intermediate alkali digestion was found in both V_2P_2 and V_2P_3. The interaction effect of V_2P_1 had high alkali digestion. The interaction effect of post harvesting processing and rice genotypes had high significant effect ($p< 0.01$) on alkali digestion. As the study of Sthapit et al. (2004) showed the intermediate alkali digestion in rice genotypes is the most accepted worldwide for having good qualities like softness, moistness, volume expansion, water absorption upon cooling. In the present study, two interaction effect had intermediate alkali digestion.

Determination of cooking time is very crucial as it is linked to fuel savings, digestibility of cooked rice etc. The interaction effect of varieties and milling procedures on cooking time is shown in Table 6. The interaction effect of V_1P_3 had the highest cooking time which is 28.00 mins and the lowest cooking time observed in the interaction of V_2P_1. The interaction effect of milling procedures and rice genotypes had highly significant effect ($p<0.01$) on cooking time. The results obtained are similar with that of Saeed et al. (2011) where the cooking time for non-parboiled rice was found to be lesser (20.67 mins) than that of parboiled rice (25 mins). Shorter cooking duration allows consumers to save fuel cost. In present finding, three interaction effect showed shorter cooking duration.

Gel consistency is an important cooking quality trait to evaluate the texture of cooked rice. The interaction effect of varieties and milling procedures on gel consistency is shown in Table 6. The interaction effect of V_1P_2, V_1P_3 and V_2P_3 had the highest gel length which are 95.67 mm, 95.33 mm and 95.67 mm respectively which means they have soft gel consistency. The lowest gel length (42.33 mm) was observed in the interaction of V_2P_1. The interaction effect of milling procedures and rice genotypes had high significant effect ($p<0.01$) on gel consistency. Among all the interactions the highest gel length was found in V_1T_2 and V_2T_3. Singh et al. (2005) found that the gel consistency of Kenyan BS 370 had soft gel consistency whereas Chemutai et al. (2016) found that traditional aromatic Indian BS 370 genotype had medium gel consistency. The present study shows gel consistency of rice genotypes varied from medium to soft.

Table 7. Comparison on different cooking qualities of *Benapole* and somaclone line (RSC2018-1)

Genotype	Gelatinization temperature	Alkali digestion	Alkali spreading score (1-7 scale)	Cooking time (mins)	Gel length (mm)	Gel consistency
Benapole	High	Low	1	23.78	79.56	Soft
RSC2018-1	Intermediate	Intermediate	4	21.78	60.78	Soft
t-value				4.9	2.29	
Significance level				**	NS	

NS = non-significant ($p\geq0.05$), ** = highly significant ($p< 0.01$)

The cooking parameters of rice genotypes *Benapole* and RSC2018-1 were determined and the result is shown in Table 7. The gelatinization temperature is high in *Benapole* and intermediate in somaclone. The result is in agreement with the finding of Juliano et al. (1990) as he described the gelatinization temperature as high (75-79) ^{o}C, high intermediate (71-74) ^{o}C, medium (70-74) ^{o}C and low (55-69) ^{o}C.

The alkali digestion for *Benapole* is low and for somaclone it is intermediate. Alkali digestion is measured by standard evaluation system for rice by IRRI determining alkali spreading value using 1-7 scale where 1-3 scale means low, 4-5 means intermediate and 6-7 means low. So, the present study complements the standard evaluation system. The varieties had high significant effect ($p <0.01$) on alkali digestion.

The cooking time is higher (23.78 mins) in *Benapole* than that of somaclone (21.78 mins) as shown in Table 7. The variation in cooking time can be relate to gelatinization temperature as the findings of Frei and Becker, (2003) shows higher gelatinization temperature leads to more time in cooking. According to

Bhatlacharga and Snowbhagya (1971), cooking time differs significantly among milling procedures. The rice genotypes had high significant effect (p<0.01) on cooking time. The t value was found to be 4.9 which means there is no huge difference between the cooking time of these two rice genotypes.

Gel consistency can be grouped into hard (25-40 mm), medium (41-60 mm) and soft (100 mm) according to Juliano (1990). As we can see in Table 7, the gel length for *Benapole* is 79.56 mm and for somaclone line it was 60.68 mm. According to the findings of Juliano (1990), gel consistency was found the soft in case of both *Benapole* and somaclone. Rice with soft gel consistency tends to cook slowly and remains soft after cooling. The statement complements the present study as higher cooking time in *Benapole* was found. The varieties had no significant effect (P≥0.05) on gel consistency. The t value was found to be 2.29 which means there is very minute difference in the gel consistency between the rice genotypes.

Conclusion

The present investigation revealed that the studied rice somaclone RSC2018-1 contained more crude protein, less fat, and carbohydrate than the mother *Benapole.* Among the minerals, Na and Fe were found in greater quantities in RSC2018-1, while K and Zn were higher in *Benapole. RSC2018-1* showed better physical properties except for solid density and better cooking qualities.

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