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Comparative Analysis of Physicochemical and Pasting Properties between Traditional and High Yielding Rice Varieties of Bangladesh

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Abstract The physicochemical and pasting (rheological) properties between Bangladeshi traditional and high yielding varieties (HYV) of indica rice have been compared. Seven representatives of traditional indica parboiled rice namely Dudhkolom, Magursail, Ashiana, Kajalsail, Dadkhani, kataribhog, Jalidhan, and seven high yielding varieties namely BRRI 22, BRRI 23, BRRI 28, BRRI 29, BRRI 31, BRRI 40, and BRRI 41 have been chosen based on their popularity and availability. The flour particle size obtained after grinding ranged from 204.05 µm (Ashiana) to 311.85 µm (Magursail) for traditional variety and 224.87 µm (BRRI 31) to 281.70 µm (BRRI 28) for HYVs. Amylose content (AC) ranged from 21.18 % (Kajal sail) to 25.81 % (Dudhkolom) for traditional variety and 22.16 % (BRRI 31) to 30.37 % (BRRI 22) for HYVs. The protein contents of traditional varieties lie between 6.09 % (Dudhkolom) to 8.76% (Jolidhan) and that of HYV lie between 7.82 % (BRRI 41) to 9.09 % (BRRI 31). Gel consistency test reveals that all the varieties have a soft gel consistency. Rheological properties namely peak viscosity (PV), trough viscosity (TV), breakdown viscosity (BV), final viscosity (FV) and setback viscosity (SV) have been determined for all the fourteen samples. It has been found that all of these parameters were comparable between the analyzed traditional and HYVs.

Keywords: *physicochemical, pasting, traditional, high-yielding, rice varieties, amylose, viscosity*

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1. Introduction

Rice (Oryza sativa L.) is the staple food for more than half of the world’s population and is ranked as the world’s number one human food crop [1,2]. Rice is consumed mostly in the form of cooked whole (milled) grains. Among the various varieties of rice, Indica rice varieties are popular worldwide where cooked indica rice has been found hard but not sticky [3]. Rice is the main staple food of Bangladeshi people. In Bangladesh parboiled rice is eaten at least twice a day, which provides about 75% of the calories and 55% of the protein in the average daily diet [4-5]. Being the principal crop, rice covers about 75 % of the total cropped area and constitutes 92 percent of the total food grains produced annually in this country [6]. Traditional rice varieties are disappearing fast due to massive cultivation of high-yielding ones to meet the country’s growing food demand. Moreover, high yielding varieties are preferred because of their low price while the traditional varieties are preferred primarily because of better taste [4]. The HYVs were regarded as most suitable for poor people whereas the traditional rice varieties were regarded as best for special occasions, such as weddings and for certain population groups such as children, the sick and the rich [7]. However, there is a belief in the mind of the common people that the traditional cultivars are much more nutritious, storable and palatable compared to the high yielding varieties (HYVs). Although, rice can be used for various food processing applications such as breakfast cereals, snacks, and package mixes and as a thickener for baby food and sauces, it has been observed that neither HYV nor traditional rice variety have any other food processing applications rather than serving as the main food for the meal of Bangladeshi populations [8].

The physicochemical and textural properties of rice grains determine the basic food quality and palatability of the cooked product, including the overall quality, pasting properties and texture [9,10]. For example, the pasting properties of rice flour are key determinants of quality, which significantly impact the final product texture [11]. The texture is an important attribute of cooked rice and had been used as an indicator of consumer acceptance [12].

Factors that affect the textural quality of cooked rice include: rice variety, amylose content and pasting properties. Rice proteins consist mainly of glutelin and oryzenin, which form a complex with starch that decreases rice stickiness [13-15]. Moreover, a linear relationship between starch binding ratio and stickiness was also reported. As a consequence, amylose content alone may not be a good parameter to estimate cooked rice's sensory quality since protein also played a major role. Therefore, in this study, seven most popular representative parboiled rice samples within the traditional variety and seven within HYV were collected for measuring physicochemical and pasting properties to make a comparison and try to identify the best candidate variety for further food processing application.

2. Materials and Methods

2.1. Materials

Seven popular traditional Indica rice varieties namely Dudhkolom, Ashiana, Kajai sail, Dadkhani, kataribhog, Jolidhan, Magursail and seven popular high yielding variety (HYV) namely BR22, BR 23. BRRI Dhan 28, BRRI Dhan 29, BRRI Dhan 31, BRRI Dhan 40, BRRI Dhan 41 were collected in a total of three times from Bangladesh rice research institute (BRRI). The rice samples were ground using a turbo mill for further analysis.

2.2. Moisture Content

In this study, the Oven-Dry method was used to measure the moisture content of different samples [16]. In brief, in a pre-weighed aluminum container, 2-3 g of samples were taken. Containers were then dried in an oven at 135oC for one hour. After drying, samples were kept in an airtight desiccator containing silica gel as desiccant until it was cooled to ambient temperature.

2.3. Pasting Properties

A Rapid Visco Analyser was used to measure the pasting properties of the samples (RVA-4; Newport Scientific, Warriewood, NSW, Australia) [17]. Either 4.0 g of brown rice flour or 3.5 g of white rice flour (based on 14% moisture content) was transferred into a canister, and 25±0.1 mL of deionized water was added (corrected to compensate for the 14% moisture). The slurry was stirred at 960 rpm for 10 s for thorough dispersion. After that the slurry was held at 50 °C for 1 min, heated to 93°C over 4 min and held there for 7 min, and then cooled to 50°C over 4 min and held there for 3 min. The pasting temperature (at which viscosity first increases by at least 25 cP), peak viscosity (the maximum viscosity), peak time (when peak viscosity occurred), trough viscosity (the minimum viscosity), final viscosity (at the end of the test after cooling), breakdown viscosity (peak viscosity – trough viscosity), and setback viscosity (final viscosity – peak viscosity) were calculated from the pasting curve with Thermocline v. 2.2 software (Newport Scientific).

2.4. Solubility and Swelling Power

Water absorption index (WAI) and water solubility index (WSI) were determined using the method of Anderson et al. [18]. Each sample (2.5 g) was suspended with 30 mL of distilled water (30°C) in a 50 mL pre-weighed centrifuge tube by vortexing. The tubes were then placed in a 30°C water bath and intermittently stirred for 30 min. The suspension was centrifuged for 10 min at 3,000 × g and the supernatant was decanted into a preweighed 50 mL beaker. The weight of the precipitate was used to calculate the WAI, which was reported as a ratio (wt gain/wt of a sample, dwb). The supernatant from the WAI was dried at 95°C and the weight of dried solids were used to determine the solubility (%).

$$Solubility\% = \left(W_1 X\ 100\right) / W_{dm} \quad (1)$$

$$Swelling\ Power\ \left(SP\right) = \left(W2\ X\ 100\right) / W_{dm}\left(100 - Solubility\right) \quad (2)$$

$$W_{dm} = Ws\left(1 - MC/100\right) \quad (3)$$

Where:
W_1, W_2 -Weight of supernatant and centrifuged swollen granules
W_s = Weight of sample
MC = Moisture content of sample, dry basis
W_{dm}= Weight of dry matter.

2.5. Gel consistency (GC)

Gel consistency of differently sized rice flour was measured following the method of Cagampang et al. [19]. In brief, 100 mg rice powder (12 % moisture) was placed in 13x120 mm test tubes. The powder was made wet with 0.2 mL of 95% ethanol containing 0.025% thymol blue. The tube was then shaken and 2.0 ml of 0.2N KOH was added immediately and the mixture was dispersed. The test tubes were then covered with glass marbles and placed for 8 minutes in a boiling water bath. The sample was removed and kept at room temperature for 5 min, and then it was cooled in ice-cold water for 15 minutes. The tube was then kept horizontally over a ruled paper graduated in millimeters and the length of the gel from the bottom of the test tube was measured after 30-60 minutes.

2.6. Protein Content

The nitrogen content of the sample was measured using a LECO System (LECO FP-528, LECO Corporation, MI, USA). Supplied EDTA, from LECO Corporation, was used as the standard. The protein content of the sample was obtained from nitrogen by multiplying it by a nitrogen − protein conversion factor of 5.95.

2.7. Amylose Content (AC)

Amylose, Type III: from potato (Sigma-Aldrich) was used as standard amylose. Amylose contents were measured according to a previously described method [20]. 100 mg of dry rice powder was taken on a dry basis in a 100 mL volumetric flask. 1 ml 95% ethanol and 9 mL 1N

NaOH were added to the flask. It was then heated in a boiling water bath for 10 minutes. After cooling it was made up to the mark with distilled water. 5 mL from the 100 ml was transferred into another 100 ml volumetric flask. 1 mL 1N acetic acid and 2 mL iodine-potassium iodide solution were added into it. It was then made up to the mark using distilled water. The flask was shacked and stands for 20 minutes. The absorbance was measured at 620 nm against a reagent blank. A series of standard amylose solution was also prepared containing 0, 4, 8, 12, 16, 20 and 24% of amylose. After that, the amylose content of the samples was determined in reference to the standard curve and expressed on a percentage basis.

2.8. Statistical Analysis

Tukey-Kramer's test following one-way analysis of variance was used to compare mean values. Correlation analyses were done by Pearson's correlation method. Data analysis was performed with JMP 7.0.1. (SAS Institute inc., Cary, NC, USA). Means without a common letter differ, P values less than 0.05 were considered statistically significant.

3. Results and Discussion

3.1. Particle size, Moisture Content (MC), Water Absorption Index (WAI), Water Solubility Index (WSI) and Swelling Power (SP) of the Rice Varieties

Figure 1 shows the particle size (µm) of different rice varieties after grinding. It has been observed that in the traditional and HYV types the particle size ranged from 204.05 (Ashiana) to 311.85 (Magur sail) µm and 224.87 (BRRI 31) to 281.70 (BRRI 28) µm, respectively. Since particle size reportedly affected WAI, solubility, and swelling power [21], Table 1 shows the moisture content, WAI, solubility and swelling power of all the rice varieties. While particle size was compared with WAI and SP, a significant negative correlation was observed (Figure 2A & Figure 2B). Similarly, a negative correlation was observed between WSI and Particle size (r -0.36, P=0.21), which supports the observations of Jeong et al. [21].

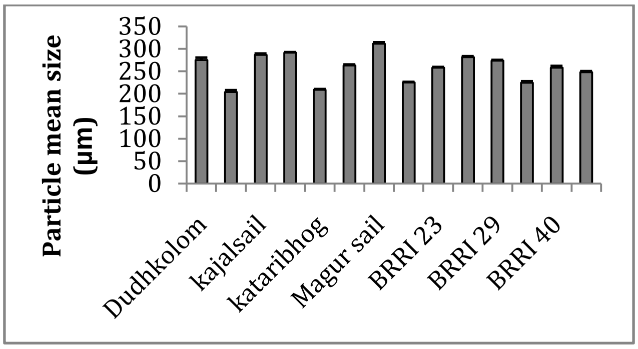

Figure 1. Particle size of different varieties of rice. The x-axis shows different rice varieties, where the traditional varieties are presented in first seven columns followed by the high-yielding varieties. Data is represented as mean of independent triplicate experiments ± SD (standard deviation). Tukey-Kramer's test following one-way analysis of variance was used to compare mean values

3.2. Amylose Content (AC), Gel Consistency (GC) Result and Protein Content (PC) of Different Rice Varieties

AC is considered as the single most important characteristic for predicting rice cooking and processing behaviors [22,23]. Singh et al. reported that the differences in the amylose content among various rice varieties are responsible for the differences in textural properties [24]. Moreover, AC is positively correlated with hardness and negatively correlated with stickiness [25,26]. Juliano et al. have suggested a classification of AC of rice as waxy (0-5%), very low (5-12%), low (12-20%), intermediate (20-25%) and high (25-33%) [27]. Based on this classification five variety, one from HYV group (BRRI 31) and four from the traditional group (Kajalsail, Kataribhog, Jolidhan, Magursail) have found to belong to the high amylose group and the rest of all belong to intermediate amylose group. Table 2 shows that BRRI 22 (HYV) contains the highest amount of amylose (30.37 %) and Kajalsail (traditional) contains the lowest (21.18%). In general, the trend of amylose content is much higher in HYV (22.16-30.37%) compared to that in traditional variety (21.18-25.81%). Similarly, Bhonsle et al. found AC ranged from 13.6-23.7% for traditional rice and 17.86-24.75% for high yielding varieties [28].

Table 1. Moisture content (MC), water absorption index (WAI), water solubility index (WSI) and swelling power (SP) of all the rice varieties

Sample	MC%	WAI	Solubility (%)	Swelling power
Dudhkolom	11.38±0.01	1.71±0.03	2.79±0.03	3.91±0.02
Ashiana	11.69±0.03	2.00±0.04	3.39±0.04	4.39±0.01
kajalsail	11.81±0.02	1.78±0.02	3.40±0.04	4.09±0.01
Dadkhani	11.36±0.01	1.79±0.03	3.90±0.09	4.06±0.04
kataribhog	12.02±0.45	1.96±0.04	4.00±0.06	4.41±0.05
Jalidhan	11.93±0.11	1.78±0.03	2.85±0.07	4.07±0.03
Magur sail	11.70±0.12	1.60±0.03	2.83±0.07	3.78±0.04
BRRI 22	11.89±0.20	1.75±0.02	3.42±0.05	4.05±0.04
BRRI 23	11.39±0.11	1.78±0.01	2.80±0.05	4.00±0.13
BRRI 28	11.00±0.30	1.63±0.03	3.31±0.06	3.75±0.12
BRRI 29	10.87±0.70	1.80±0.03	2.74±0.03	3.97±0.09
BRRI 31	11.30±0.02	1.93±0.04	3.34±0.03	4.22±0.11
BRRI 40	12.19±0.03	1.79±0.03	3.45±0.03	4.15±0.13
BRRI 41	11.89±0.04	1.95±0.04	2.84±0.04	4.33±0.03

Mean of independent triplicate experiments ± SD (standard deviation).

However, most consumers prefer rice with intermediate AC ranged between 20-25% [29]. This is maybe one of the reasons why the trend of acceptance of traditional rice varieties is relatively higher compared to HYVs among the consumers.

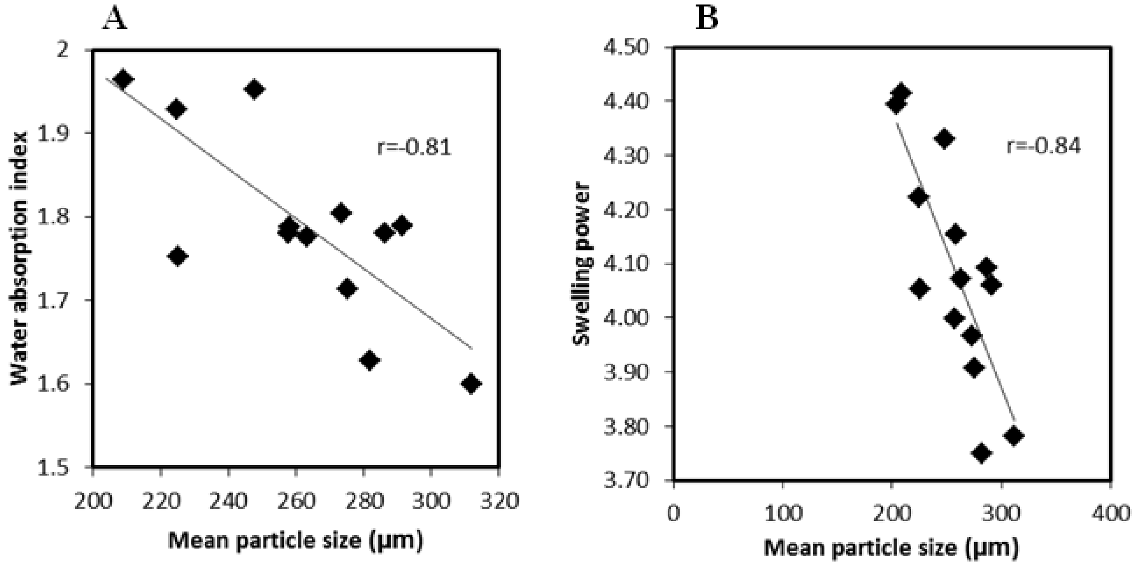

Figure 2. Correlation of mean particle size of all the rice varieties with WAI (A) and swelling power (B). Data is represented as mean of independent triplicate experiments. Correlation analyses were done by Pearson's correlation method.

Table 2. Amylose Content (AC), Gel consistency (GC) result and Protein content (PC) of different rice varieties

Name of Rice cultivars	Amylose Content (%)	GC Test	Protein content (%)
Dudhkolom	25.81±0.08[h]	Soft	6.09 ±0.01
Ashiana	25.67±0.15[h]	Soft	7.94±0.02
Kajal sail	21.18±0.19[i]	Soft	7.35±0.01
Dadkhani	25.59±0.19[h]	Soft	7.81±0.02
kataribhog	24.36±0.08[i]	Soft	8.69±0.01
Jolidhan	21.69±0.04[i]	Soft	8.76±0.03
Magursail	24.36±0.08[i]	Soft	7.10±0.05
BRRI 22	30.37±0.31[h]	Soft	8.70±0.05
BRRI 23	26.35±0.08[h]	Soft	8.28±0.04
BRRI 28	27.85±0.04[h]	Soft	6.63±0.05
BRRI 29	27.81±0.35[h]	Soft	6.48±0.01
BRRI 31	22.16±0.23[i]	Soft	9.09±0.04
BRRI 40	25.92±0.08[h]	Soft	8.79±0.04
BRRI 41	28.34±0.23[h]	Soft	7.82±0.02

(Mean of triplicate experiments ±SD)
[h]High, [I] Intermediate amylose content according to Juliano *et al*. [27].

GC measures the tendency of cooked rice to get harden when it cools down. Harder the gel means often the cooked rice is harder. Interestingly, consistent atypical gel consistency (>61mm for both traditional and HYVs) was observed in three independent experiments for all 14 samples (Table 2). GC experiments show that all the rice varieties (both high and intermediate AC types) belong to the soft gel consistency group. Interestingly, differences in the texture of cooked rice have been observed among rice of similar amylose content. High amylose rice differs widely in the rate of hardening of cooked rice and differences in the hardness of cooked rice correlate with differences in the gel consistency. Cooked rice with hard gel consistency (gel consistency value 27-40mm) hardens faster than that with a soft gel consistency (gel consistency value 61-100mm) and the later is tenderer than the former.

The protein content (PC) of the traditional varieties ranged from 6.09 % (Dudhkolom) to 8.69 % (Kataribhog) and that of the HYV from 6.48 % (BRRI29) to 9.09 % (BRRI 31). Interestingly, the trends of AC and PC of HYV varieties have been found higher compared to that in traditional variety (Table 2). However, Reddy and Sarala found that there was no significant correlation between AC and protein content [30]. In our study, we also don't find any significant correlation between AC and PC, while compared on the varietal basis as well as on amylose content (high and intermediate) basis. Suwannaporn et al. studied three varieties of intermediate and three varieties of high amylose contained rice and found the PC to be in the range of (9.0-9.1 %) and (6.7-8.7 %), respectively [31]. Singh et al. found high protein content in indica milled-rice (6.87%) compared to Japonica rice (5.2-6.1%) [32]. Lai measured the protein content of three Indica varieties of milled rice and found PC in the range (7.83-8.26%) [33]. In our experiments, we got the highest percentage of PC in HYV (among the HYVs, BRRI 31 had the highest PC).

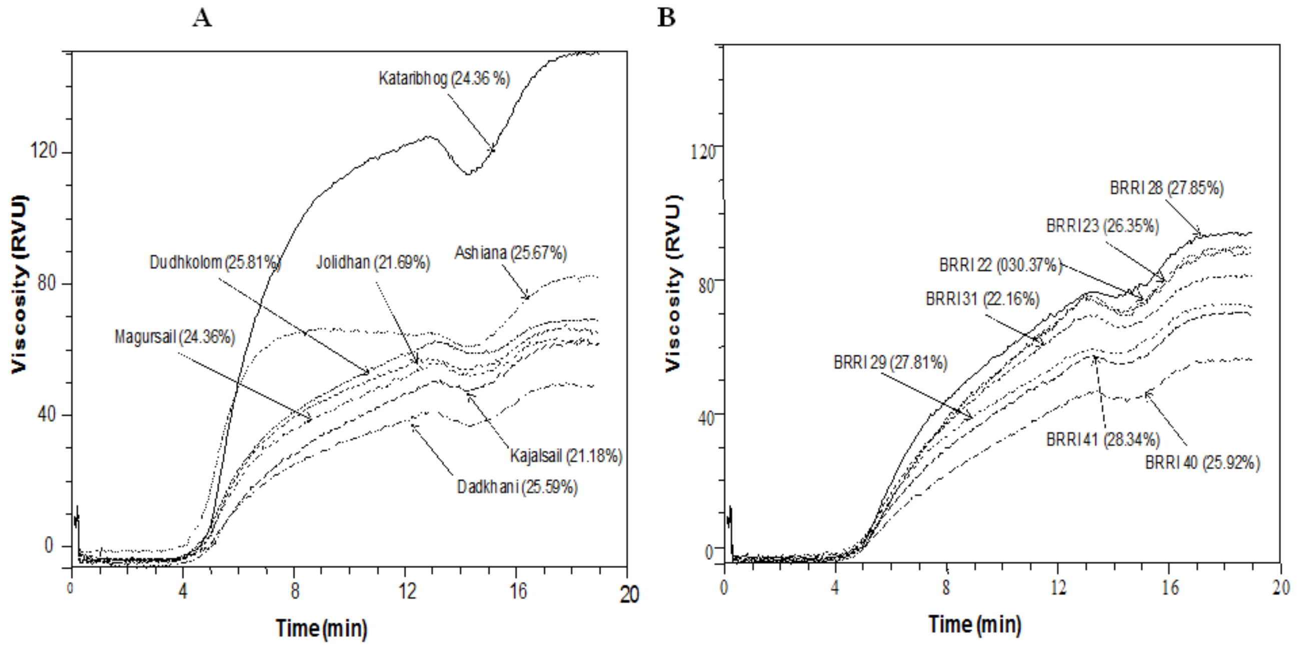

Figure 3. Viscosity profile of different traditional (A) and high-yielding rice varieties (B). Data is represented as mean of independent triplicate experiments. Correlation analyses were done by Pearson's correlation method

Table 3. Peak, trough, breakdown, final and setback viscosity of all the rice samples

Name of rice variety	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final (RVU)	Setback (RVU)
Dudhkolom	57.50±2.33^{d}	54.51±1.28^{fg}	2.99±1.36^{bc}	64.59±1.41^{fg}	7.09±1.26^{ef}
Ashiana	66.83±0.58^{c}	61.82±0.24^{e}	5.02±0.55^{bc}	83.39±0.40^{de}	16.56±0.18^{b}
Kajal sail	51.22±0.51^{e}	48.21±0.51^{h}	3.01±0.01^{bc}	57.4±0.61^{h}	6.18±1.11^{efg}
Dadkhani	41.37±0.51^{g}	37.29±0.63^{j}	4.07±0.32^{bc}	49.17±0.56^{i}	7.80±0.7^{def}
kataribhog	124.79±1.99^{a}	114.64±0.41^{a}	10.15±1.7^{9a}	151.12±1.08^{a}	26.33±0.91^{a}
Jolidhan	58.27±0.34^{d}	55.76±0.32^{f}	2.51±0.02^{c}	63.67±0.29^{g}	5.39±0.60^{fg}
Magursail	56.29±0.52^{d}	53.08±0.18^{g}	3.21±0.61^{bc}	58.9±0.85^{h}	2.61±0.74^{g}
BRRI 22	75.59±0.71^{b}	69.66±0.96^{c}	5.93±0.25^{b}	89.45±0.69^{c}	13.86±0.92^{bc}
BRRI 23	69.72±0.50^{c}	63.79±0.2d^{e}	5.93±0.30^{b}	85.55±2.13c^{d}	15.83±1.70^{b}
BRRI 28	77.69±1.19^{b}	75.37±0.59^{b}	2.32±1.52^{c}	94.94±0.99^{b}	17.25±1.0^{b}
BRRI 29	58.91±1.60^{d}	56.97±1.46^{f}	1.94±1.47^{c}	68.33±0.76^{f}	9.43±1.46^{def}
BRRI 31	68.38±1.53^{c}	64.98±0.23^{d}	3.40±1.36^{bc}	80.01±2.51^{e}	11.63±2.52^{cd}
BRRI 40	47.23±0.98^{f}	44.88±1.44^{i}	2.35±1.43^{c}	57.18±0.99^{h}	9.95±1.96^{cde}
BRRI 41	58.29±1.16^{d}	54.86±1.39^{fg}	3.43±1.08^{bc}	68.17±2.35^{f}	9.88±2.08^{cde}

Mean of independent triplicate experiments ± SD (standard deviation). Means without common letter differ, P values < 0.05 were considered statistically significant.

3.3. Pasting Properties of Different Rice Varieties

Pasting properties of the traditional and HYVs are shown in Table 3 and Figure 3A (traditional) and 3b (HYV). The peak viscosities of the rice flour samples range from 41.37 (Dadkhani) - 124.79 (Kataribhog) RVU (relative value units). Gang et al. studied 106 rice varieties and concluded that there is no significant correlation between RVA profile and the varieties with high or medium amylose content [34]. The amylose contents of the rice varieties also belong to medium to high (Table 2) and here we didn't find any appreciable correlation between amylose content and RVA profile.

Okadome et al. and other scientists reported that the FV had a strong correlation with the AC of rice. AC showed a negative correlation (-0.73) with SB in a study comprising 63 Chinese adapted non-waxy rice varieties [35,36]. Allahgholipour et al. found a highly significant (at p=0.01) positive correlation for SB with AC (%) for all AC group except for the high AC group (>24.1%), which showed a non-significant negative correlation [37]. In our study, we found 5 parboiled rice samples (with AC>24.1 %) namely Kataribhog, Magursail, BRRI22, BRRI 28 and BRRI40 have a significant negative correlation (r= -0.99, -0.90, -0.85, -0.96, -0.97 at P<0.05) between AC and SB. Ashiana, Dadkhani and BRRI 41 (AC>24.1 %) also showed negative correlations between AC and SB, which was not significant. Jolidhan and BRRI 31 (both have AC<24.1 %) showed a significant negative and positive correlation (-0.98 and 0.99) with SB, respectively. On the other hand, Kajalsail (AC<24.1 %) showed a negative correlation with no significance. The rest of the 3 varieties (Dudhkolom, BRRI 23 and BRRI 29) showed no significant positive correlation. We found significant positive correlation between AC and FV in 4 samples (Dudkolom r= 0.83; Ashiana 0.90; Kataribhog r= 0.99; BRRI 31= 0.80) and negative significant correlation in 4 samples (Jolidhan r= -0.89; BRRI 22, r= –0.94, BRRI 29, r= -0.81, BRRI 40, r= -0.96). No significant correlation between AC and FV were found for the rest of the samples. Figure 3A and Figure 3B clearly showing the differential RVA profile of traditional and HYV rice. It is apparent from the figures that the peak onset times for all the parboiled rice samples are relatively late and in most of the cases it starts at around 12 minutes.

4. Conclusion

It has been found in our study that the HYVs are comparable to the traditional varieties in terms of protein and amylose content. BRRI 31 has been found contained the highest amount of protein (9.09%) and BRRI 22 contained the highest amount of amylose (30.37 %). In the community, Kataribhog is the most popular and expensive variety, which showed the highest value for WAI, solubility, swelling power, and all RVA parameters.

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Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

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