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Variation in Physicochemical Properties and Proximate Composition of Improved and Traditional Varieties of Rice in Sri Lanka

R. F. Hafeel[1], V. P. Bulugahapitiya*[2], G. E. D de Zoysa[3] and A. P. Bentota[4]

ABSTRACT

Sri Lankan traditional rice varieties (SLTRV) have been known to be associated with higher nutritional and healthcare properties but along with the rice market, cultivation of improved rice varieties is highly dominated at present. Therefore, this comparative study was done to investigate physicochemical parameters and proximate composition of selected traditional and improved rice varieties grown in Sri Lanka. Thirty-nine rice varieties including traditional and improved were cultivated and harvested at Rice Research Station, Ambalantota, Sri lanka. The physicochemical parameters, Gelatinization Temperature (GT) and Amylose Content (AC) and the proximate composition (crude ash, crude fiber, crude protein, crude fat and carbohydrate) were analysed. GT of the samples varied between 66.14 – 71.74°C, where five improved rice varieties H4, At 405, At 362, Bw 272 6b and Ld 408 showed low GT of 66.14°C. AC varied between 17.0 - 31.3 % and only one improved variety (At 405) was found with low AC. The proximate compositions were also independent from each other within varieties. Higher protein contents (>9.0%) were found with the improved varieties of H4, H7 and Bw 272-6b whereas the lowest (5.2 %) was also recorded with the improved variety of At 362 which is a highly cultivated variety in Sri Lanka. Crude fat contents of ≥2.4 % were recorded with five rice varieties namely, Suduru samba, Rath suwandel, Suwandel, Bw 272-6b and Ld 368. The varieties of Beheth heenati, Suwndel, Bw 272-6b and Basmathi 442 showed crude ash content of ≥1.2 %. Carbohydrate content had significant negative correlations with other nutrients except for crude fibre. It can be concluded that there was no significant difference in physicochemical properties and proximate composition in the studied traditional varieties of rice over the improved varieties except for the protein content. Many of the improved varieties contained higher protein content compared to the SLTRV.

Keywords: Cooked rice, Physicochemical properties, Proximate composition, Sri Lankan improved rice, Sri Lankan traditional rice

[1]*Rice Research Station, Department of Agriculture, Ambalantota.*
[2]*Department of Chemistry, Faculty of Science, University of Ruhuna, Matara.*
[3]*Department of Bio Chemistry, Faculty of Medicine, University of Ruhuna, Galle.*
[4]*Ministry of Agriculture, Battaramulla.*

* *vajira@chem.ruh.ac.lk*
https://orcid.org/0000-0003-1178-1052

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food in Sri Lanka since ancient civilization and it is the main food in most of the other countries in Asia. It had been known that Sri Lanka was a producer for a large number of own rice varieties called Sri Lankan traditional rice varieties (SLTRV). This ancient rice cultivations had mainly been practiced on organic farming and also it had adaptability to the soil of the country, and harsh environmental conditions, etc. and hence, the quality, tasty, nutritional factors and aroma of SLTRV had been highlighted as the highest acceptance levels (Kariyawasam *et al.*, 2016; Rajkumar *et al.*, 2011). With the increase of population and with the technology developments, improved rice varieties were introduced in Sri Lanka which was bred adapting standard breeding techniques. As a result, production of SLTRV has been declined gradually, and this has resulted in high unaffordable costs for 1 kg of SLTRV in the market at present. The farmers in the country have been in the trend of cultivation of improved rice varieties due to economic benefits as it gives high grain yields.

The rice is usually consumed as a whole grain after cooking, and in a regular Asian diet, it can contribute to 40 to 80% of the total calorie intake (Bhattacharjee *et al.*, 2002). The latest scenario is that the rice consumers have a preference for SLTRV with the belief of reducing the risk of non-communicable diseases due to highlighted healthcare properties associated with them (Samaranayake *et al.*, 2017; Samaranayake *et al.*, 2018; Abeysekaera *et al.*, 2017; Rebeira *et al.*, 2014; Premakumara *et al.*, 2013; Abeysekaera *et al.*, 2008; Wickramasinghe, 2008). Despite the vast studies on SLTRV, very limited studies have been reported on improved varieties of rice in Sri Lanka on its grain quality characteristics particularly physicochemical properties such as gelatinization temperature, amylose content, and the proximate content that are the prime important factors on cooking and eating quality of the rice and for the nutritional properties (Cruz and Kush, 2000).

Therefore, the present study aimed at conducting detailed analysis on physicochemical properties such as gelatinization temperature and amylose content, and the proximate composition of different varieties of rice grown in Sri Lanka which include the categories of traditional and improved (new-improved, old-improved and exotic rice) varieties in order to make aware the scientific community, rice consumers as well as rice growers with the important scientific data for the correctly authenticated rice varieties.

MATERIALS AND METHODS

Rice Varieties

Thirty-nine (39) rice varieties (Table1) were selected for the study, based on their popularity in the country, level of variety improvement and for being the parents or off-springs of a selected variety. These varieties are comprised of red and white pericarp grains and different sizes and shapes of grain. Varieties were planted in separate plots with a plot spacing of 15 x 15 cm at the Rice Research Station, Ambalantota. The experimental design used was Randomized Complete Block Design with three replications and recommended practices were adopted throughout the cultivation. Rice varieties were harvested at the physiological maturity as advised by the Rice Research and Development Institute (RRDI).

Preparation of Rice for the Analysis

The harvested rough rice samples were sun-dried, without exposure to high temperature and the moisture content was brought down to 12±1% (wet basis). After leaving the rough rice for 3 months in ambient storage conditions for stabilization of grain quality attributes, each variety was de-hulled with a rubber roll de-husker (Model: Satake, THU-35 B, Japan) and brown rice (whole grain rice) was obtained. Abrasive milling for 30 seconds removed the rice bran partially (5±2% by weight) from brown rice (Model; TM 05, Satake, Japan).

Testing of Physicochemical Properties

Physicochemical properties such as gelatinization temperature (GT) and amylose content (AC) were determined for the polished rice of each variety following the procedures given below.

Table 1. Rice varieties used in the study and their parents/accession number, type of improvement and pericarp colour

	Rice variety	Parents/Accession number	Type of improvement	Pericarp colour
1	Murungakayan	PGRC Acc. No.06283	Traditional	Red
2	Pokkali	PGRC Acc. No.03251	Traditional	Red
3	Nonabokra	PGRC Acc. No.08269	Traditional	Red
4	Pachchaperumal	RRDI Acc. No. 798	Traditional	Red
5	Kalu heenati	RRDI Acc. No. 986	Traditional	Red
6	Beheth heenati	RRDI Acc. No. 1313	Traditional	Red
7	Herath banda	RRDI Acc. No. 689	Traditional	Red
8	Suwanda samba	RRDI Acc. No. 901	Traditional	White
9	Madathawalu	RRDI Acc. No. 1312	Traditional	Red
10	Suduru samba	RRDI Acc. No. 903	Traditional	White
11	Rath suwandel	RRDI Acc. No. 1321	Traditional	Red
12	Masuran	RRDI Acc. No. 86	Traditional	Red
13	Suwandel	RRDI Acc. No. 579	Traditional	White
14	H4	Murugakayan x Mas/ (PGRC Acc. No. 05212)	Old-improved	Red
15	H7	Pachchaperumal x H5 (PGRC Acc. No. 03298)	Old-improved	White
16	H5	Murugakayan x Mas (PGRC Acc. No. 03112)	Old-improved	White
17	At 405	At 402 x Basmathi 442	New-Improved	White
18	Bg 369	Bg 94-1 x Nonabokra	New-Improved	White
19	At 85-2	IR 36 x IR 2729-67-3	New-Improved	Red
20	Bw 367	Bw 361 x Bg 358	New-Improved	White
21	At 311	At 306 x At 3-105	New-Improved	Red
22	Bg 94-1	IR262 x Ld 66	New-Improved	White
23	At 362	At 85-2 x Bg 380	New-Improved	Red
24	At 402	IR44333-52-6-4 / Bg 90-2x763930/Ob 678	New-Improved	Red
25	At 306	IR 49517-41-1-6-2-3/At 405	New-Improved	White
26	Bw 361	IR 36 x Bw 267-3-11 M	New-Improved	Red
27	Bg 358	Bg 12- 1 x Bg 1492	New-Improved	White
28	Bg 380	Bg 90-2 x OB 677	New-Improved	White
29	At 354	Pokkali x Bg 94-1	New-Improved	White
30	Bg 352	Bg 380 x Bg 367-4	New-Improved	White
31	Bg 300	Bg 367-7 x IR 841 / Bg 267-5	New-Improved	White
32	Bg 360	3346/IR 36//Senerang	New-Improved	White
33	Bg 379-2	Bg 96-3 x Ptb 33	New-Improved	White
34	Bw 272-6B	Bw 242-5-5 x Bw 259-3	New-Improved	Red
35	Ld 408	At 01 x Ld 98-152	New-Improved	Red
36	Ld 368	Ld 356 x Ld 99-14-11	New-Improved	Red
37	Basmathi 370	AtRRS Acc. No. Ac/OV 05	Exotic-introduced	White
38	Mas	PGRC Acc. No.02349	Exotic-introduced	Red
39	Basmathi 442	Acc. No. IRGC 27790	Exotic-introduced	White

Testing of Gelatinization Temperature (GT)

In this study, GT was measured by its alkali spreading value (AACC 2000; Cruz and Kush, 2000) in which the starch gel area of the images of alkali-gelatinized grains was measured after a given gelatinization time. Duplicate sets of 6 milled kernels (from each replicate) without cracks were selected and placed in duplicate sets of Petri dishes.

Ten millilitres of 1.7% Potassium hydroxide (KOH) solution was added into the petri dish. Kernels were arranged to provide enough space between kernels allowing for spreading and the dish was covered to maintain the room temperature for 23 hours. GT was calculated according to the scoring values given in Table 2 and the equation below (Eq. 1),

$$Y=74.54-1.4X \quad \textbf{(Eq. 1)}$$

where; Y = GT and X = score in KOH solution, was used to calculate the approximate GT value of all 39 varieties (Bhattacharya, *et al.*, 1982).

Testing of Amylose Content (AC)

In the present study, AC was determined based on the Iodine binding procedure described by Juliano (1971), AACC (2000) and Cruz and Kush (2000), Chatterjee and Das (2018).

Table 2. Numerical scale for scoring gelatinization temperature (Cruz and Kush, 2000).

Score	Spreading	Alkali digestion	GT
1	Kernel not affected	Low	High
2	Kernel swollen	Low	High
3	Kernel swollen, collar complete or narrow	Low-Intermediate	High-Intermediate
4	Kernel swollen, collar complete and wide	Intermediate	Intermediate
5	Kernel split or segregated, collar complete and wide	Intermediate	Intermediate
6	Kernel dispersed, merging with collar	High	Low
7	Kernel completely dispersed and intermingled	High	Low

A sample of 100 mg of fine rice powder (sieve size 60 μm) was added into a 100 ml volumetric flask and mixed with 1 ml of 95% ethanol and 9 ml of 1.0 N sodium hydroxide. The sample was heated in a boiling water bath to gelatinize the starch for 15 min. After cooling (about 1 hr), the volume of the sample was made up to 100 ml using distilled water. Five millilitres of the above gelatinize starch solution was pipetted out into 100 ml volumetric flask and 1 ml of 1 N acetic acid and 2 ml of 0.2% iodine solution were added. Then the solution was volumerized up to 100 ml and mixed well before keeping it standing for colour development for about 20 min at room temperature of 30 ^{0}C. The absorbance of the solution was measured at 620 nm using a UV-visible spectrometer (Genesis-10S Vis). The amylose content of the samples was determined based on the standard curve prepared using a known amount of potato amylose (40 mg of purified potato amylose powder).

Testing of Proximate Composition

The rice was polished at a minimum level i.e., 5±2% and used in the analysis. The proximate composition was determined for cooked rice of 39 varieties as triplicate. The rice was cooked by following the procedure; first washing twice, and then adding a definite amount of water which was calculated based on the gelatinization temperature as measured by alkali spreading score of each rice variety and cooked in a mini rice cooker. The cooked rice was oven-dried at 65 ^{0}C for 3½ hrs. and then made into powder using a grinder, and subjected to proximate (crude protein, crude fat, crude fiber and crude ash) analysis following the AOAC (2000) approved method. Analysis of variance was performed using STAR for Windows version 2.0.1 (International Rice Research Institute, 2014).

RESULTS AND DISCUSSION

Physicochemical Properties

The gelatinization temperature of rice varieties which was measured using the alkali digestion method is shown in Table 3. Gelatinization temperature (GT) is an important property of the rice grain which affects cooking and eating qualities. The thermal transition of the starch is called gelatinization, in which starch transforms from its semi-crystalline phase to an amorphous phase, the peak temperature at which starch absorbs heat is the gelatinization temperature. In the presence of water, the hydrogen bridges are broken allowing water to be associated with the free hydroxyl groups of starch and this, in turn, facilitates the molecular mobility of starch in the amorphous regions and allowing the grains to swell. Therefore, the time required for cooking rice is depended on the GT of rice kernel starch (Bhattacharya, 1979; Cruz and Kush, 2000; Singh *et al.*, 2000).

Within new improved and old improved variety groups, gelatinization temperature ranged from low intermediate to low in contrast within traditional and exotic-introduced variety groups it ranged from high to intermediate. This indicates that a variety of improvements has led to make variability in alkali digestion among varieties. The alkali spreading score which was measured in this study showed that only 5 varieties viz. H4, At 405, At 362, Bw 272 6b and Ld 408 have alkali spreading score of 6 (Table 3) and high alkali digestion. Therefore, these 5 varieties could be gelatinized at lower temperatures compared to that of others. Contrastingly, parents of H4, At 405 and At 362 have low alkali spreading scores. All traditional varieties have comparably low alkali digestion except Suwanda samba and Suwandel. The cooking quality and cooking time of rice are associated GT, and it affects the texture of cooked rice.

Amylose Content (AC)

Amylose content is commonly used to predict the texture of cooked rice, and the eating quality of rice. Amylose contents of rice varieties varied significantly ($p \leq 0.05$) between 17.0 – 31.3 % (Table 3). Suwandel gives intermediate amylose content. These results are compatible with previously reported results by Rebeira *et al.* (2014). However, they reported different amylose contents for Pokkali, Pachchaperumal, Herath banda, Kalu heenati, Madathawalu, Masuran, and Suduru samba. Amylose contents of Kaluheenati, Herath banda and Suduru samba reported by Wickramasinghe and Noda (2008) are comparable with the values obtained in this study. They also reported amylose contents for new improved varieties of Bg 358, Bg 352, Bg 300, Bg 379-2 and At 405, which are similar to that of the present study. Only new improved varieties had entire range of amylose contents viz. low (At 405), intermediate (At 306) and high while traditional varieties had AC of

Table 3. Alkali spreading score, alkali digestion, gelatinization temperature and amylose content of 39 rice varieties.

Variety	Alkali spreading score	Alkali digestion	GT* (⁰C)	Amylose content (%)	Group
Traditional varieties					
Murungakayan	2	Low	71.74	24.2	Intermediate
Pokkali	2	Low	71.74	26.3	High
Nonabokra	2	Low	71.74	28.2	High
Puchchaperumal	2	Low	71.74	29.3	High
Kalu heenati	2	Low	71.74	27.9	High
Beheth heenati	2	Low	71.74	25.5	High
Herath banda	2	Low	71.74	28.6	High
Suwanda samba	3	Low-Intermediate	70.34	27.5	High
Madathawalu	2	Low	71.74	31.3	High
Suduru samba	2	Low	71.74	22.6	Intermediate
Rath suwandel	2	Low	71.74	27.5	High
Masuran	2	Low	71.74	25.5	High
Suwandel	3	Low-Intermediate	71.74	24.8	Intermediate
Improved varieties					
H4	6	High	66.14	29.1	High
H7	2	Low	71.74	27.9	High
H5	2	Low	71.74	26.1	High
At 405	6	High	66.14	17.0	Low
Bg 369	3	Low-Intermediate	70.34	28.9	High
At 85-2	2	Low	71.74	27.0	High
Bw 367	3	Low-Intermediate	70.34	26.9	High
At 311	2	Low	71.74	25.5	High
Bg 94-1	2	Low	71.74	31.1	High
At 362	6	High	66.14	27.1	High
At 402	2	Low	71.74	28.8	High
At 306	3	Low-Intermediate	70.34	24.8	Intermediate
Bw 361	2	Low	71.74	29.6	High
Bg 358	3	Low-Intermediate	70.34	25.5	High
Bg 380	2	Low	71.74	29.7	High
At 354	2	Low	71.74	29.7	High
Bg 352	5	Intermediate	67.54	28.6	High
Bg 300	5	Intermediate	67.54	29.9	High
Bg 360	2	Low	71.74	27.0	High
Bg 379-2	3	Low-Intermediate	70.34	29.1	High
Bw 272-6b	6	High	66.14	28.1	High
Ld 408	6	High	66.14	26.5	High
Ld 368	2	Low	71.74	25.7	High
Basmathi 370	4	Intermediate	68.94	24.8	Intermediate
Mas	2	Low	71.74	24.4	Intermediate
Basmathi 442	2	Low	71.74	21.2	Intermediate

* *GT-Gelatinization Temperature*

intermediate to high. As mentioned, before, the AC of endosperm starch is one of the important characteristics determining the eating and cooking qualities of rice. Rice with low amylose content is waxy, sticky and does not expand in volume when it is cooked, and rice with intermediate amylose content (30%) has high expansion volume and non-sticky but becomes hard on cooling (Kitara *et al*., 2018). However, three old improved varieties had high amylose contents while three exotic varieties had intermediate amylose contents.

Proximate Compositions

Proximate includes the nutrients of rice namely proteins, fats, carbohydrates, fibre etc. and the rice bran also contains such nutrients and vitamins but the polishing may remove nutrients to some extent depending on the polishing rate.

Table 4 shows the proximate composition of the individual rice variety obtained in this study. The highest to the lowest values of crude protein %, crude fat %, crude ash %, crude fiber % and carbohydrate % ranged from 8.4 to 5.19, 2.57 to 0.9, 1.32 to 0.57, 0.13 to 0.086 and 92.9 to 87.99, respectively among all the varieties. H4 (old - improved), Bw 272-6b (new - improved) and H7 (old - improved) recorded higher ($p \leq 0.05$) protein percentages of 9.53%, 9.07% and 9.06%, respectively compared to that of other rice varieties. The At 362 which is a very high yielding improved variety, recorded the lowest protein percentage (5.19%). The traditional varieties yielded comparatively low protein content which ranged from 5.32 to 8.88%. The protein contents of rice recorded in the present study is in agreement with the results reported by Kennedy *et al.* (2002), according to that protein content of Asian rice varieties can vary between 4 and 14%. A study done with local traditional rice varieties by Abeysekaera *et al.* (2017) has found protein contents varying from 10.6 to 13.3 % in milled rice. The range was comparatively higher than the protein content (5.2 – 9.5) of the present study where the samples were analyzed for protein content in cooked rice. However, Pachchaperumal has scored higher milled rice protein content compared to other tested traditional varieties in their study. Similarly, higher protein values were obtained by milled-cooked Pachchaperumal rice in the present study when compared to other traditional varieties tested. When

Table 4. Proximate compositions (dry weight basis) of 39 rice varieties used in the study

Variety	*Crude protein%	*Crude fat%	*Crude ash %	Crude fiber %	Carbohydrate %
Traditional varieties					
Murungakayan	6.89±0.709	1.55±0.147	0.915±0.020	0.112	90.54
Pokkali	5.57±1.013	0.96±0.262	0.637±0.016	0.101	92.72
Nonabokra	5.66±0.875	1.86±0.061	0.939±0.004	0.094	91.44
Puchchaperumal	7.46±0.003	1.50±0.195	0.938±0.006	0.089	90.02
Kalu heenati	6.90±0.112	1.58±0.085	0.809±0.026	0.110	90.60
Beheth heenati	5.32±0.193	1.92±0.079	1.322±0.040	0.129	91.31
Herath banda	8.33±0.463	1.49±0.145	0.904±0.064	0.096	89.19
Suwanda samba	7.27±0.888	2.14±0.077	1.027±0.059	0.099	89.47
Madathawalu	6.11±1.857	1.71±0.062	0.791±0.014	0.093	91.30
Suduru samba	5.73±0.156	2.47±0.077	1.091±0.010	0.089	90.61
Rath suwandel	6.68±0.402	2.57±0.051	1.073±0.093	0.086	89.59
Masuran	6.59±0.038	1.88±0.248	0.905±0.026	0.110	90.52
Suwandel	7.94±0.273	2.41±0.062	1.173±0.018	0.094	88.39
Improved rice varieties					
H4	9.53±0.347	1.35±0.030	1.033±0.035	0.090	87.99
H7	9.06±0.091	1.28±0.037	0.765±0.026	0.088	88.80
H5	6.66±0.417	1.13±0.045	1.008±0.013	0.111	91.09
At 405	6.69±0.205	1.74±0.096	0.874±0.023	0.098	90.60
Bg 369	7.58±0.320	1.60±0.135	0.810±0.041	0.970	89.04
At 85-2	7.55±1.409	1.38±0.097	0.938±0.011	0.112	90.01
Bw 367	5.23±1.793	1.80±0.031	0.821±0.023	0.107	92.03
At 311	6.07±0.655	1.24±0.011	0.803±0.029	0.089	91.80
Bg 94-1	5.98±1.387	1.27±0.050	0.826±0.018	0.101	91.82
At 362	5.19±0.701	1.39±0.036	0.566±0.026	0.112	92.74
At 402	5.88±0.387	1.53±0.009	0.666±0.009	0.112	91.81
At 306	6.02±0.504	1.23±0.074	0.999±0.015	0.113	91.64
Bw 361	7.83±1.003	2.01±0.093	0.853±0.017	0.098	89.22
Bg 358	7.56±2.105	0.90±0.044	0.779±0.007	0.113	90.65
Bg 380	5.38±1.375	1.06±0.016	0.595±0.005	0.097	92.87
At 354	8.47±0.348	1.33±0.059	0.779±0.034	0.096	89.32
Bg 352	8.00±0.408	1.53±0.334	0.923±0.054	0.091	89.46
Bg 300	8.77±0.034	1.70±0.056	0.889±0.023	0.089	88.55
Bg 360	7.52±0.167	1.09±0.009	0.965±0.020	0.090	90.34
Bg 379-2	7.10±0.099	1.26±0.040	0.811±0.052	0.086	90.74
Bw 272-6b	9.07±0.200	2.36±0.001	1.148±0.086	0.091	87.33
Ld 408	7.50±0.487	1.90±0.018	0.921±0.153	0.087	89.59
Ld 368	6.96±0.603	2.41±0.150	1.011±0.006	0.840	88.78
Basmathi 370	8.64±2.090	1.03±0.009	0.847±0.010	0.089	89.40
Mas	7.70±0.763	1.86±0.127	1.126±0.058	0.087	89.23
Basmathi 442	8.12±0.252	1.30±0.011	1.147±0.045	0.096	89.34

* *Mean ± SD of samples*

considering the fat content, traditional varieties viz. Rath suwandel, Suduru samba, Suwandel, Suwanda samba and improved varieties viz. Ld 368 and Bw 272-6b recorded fat contents more than 2% compared to that of other rice varieties. Abeysekaera *et al.* (2017) also reported similar values for crude fat content in Suduru samba and high ash content in Beheth heenati. The present study also recorded the highest ash content of 1.13% for Beheth heenati, Suwandel, Bw 272-6b, Basmathi 442 and Mas varieties. Out of all the varieties studied, 272-6b is the most attractive variety as it has given good proximate composition in all aspects.

Correlation between Amylose Content and Components of Proximate

Amylose content had a significant negative correlation ($p \leq 0.05$) only with ash content (Table 5). Thus, varieties with lower amylose contents are higher in ash content. Carbohydrate content always had significant negative correlations with other nutrients except with crude fibre content. Interestingly, crude ash content showed a significant positive correlation with crude fat content indicating that varieties with higher fat content are generally associated with higher ash content.

CONCLUSION

Physicochemical properties and proximate composition of polished cooked rice varied within rice varieties. There was no significant difference in physicochemical properties and proximate composition in traditional varieties over improved varieties except protein content. The parameters studied have no influence by the pericarp colour of the rice grain. Improved varieties of H4, H7 and Bw 272-6b contain more than 9% of protein content which is higher when

Table 5. Correlation between amylose content and components of proximate analysis of rice.

Components of proximate composition	Crude fat%	Crude ash%	Crude fiber%	Carbohydrate %	Amylose content%
Crude protein%	-0.0108^{ns}	0.2576^{ns}	0.0140^{ns}	-0.8972^{*}	0.1025^{ns}
Crude Fat%		0.5533^{*}	0.1828^{ns}	-0.4061^{*}	0.4781^{ns}
Crude Ash%			-0.0118^{ns}	-0.5213^{*}	-0.3457^{*}
Crude fiber%				-0.2031^{ns}	0.0364^{ns}
Carbohydrate%					0.0145^{ns}

**Significant at 5% probability level, ^{ns} Not significant at 5% probability level* compared to the protein content of other varieties. The improved variety Bw 272-6b illustrated promising proximate values compared to all the other tested rice varieties. Most of the components of the proximate composition are independent from each other except for a few associations. Rice varieties with lower amylose contents were higher in ash contents as shown in the correlation analysis. Except for crude fibre levels, carbohydrate content continuously showed significant negative correlations with other nutrients such as crude protein, crude fat and crude ash. Interestingly, varieties with higher fat content are generally associated with higher ash contents. Both traditional or improved groups had verities with high or low nutrient contents in relation to proximate composition. At the initial stages of development of new rice varieties, grain yield was the main concern rather than improving the nutritional qualities. However, the findings of this study showed that the nutritional status of the improved varieties remains at acceptable levels, and importantly most of the improved varieties contain higher protein content. Therefore, the cultivation of high-yielding-improved rice varieties could be considered to fulfill the demand of rice consumers at an affordable price.

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