Physicochemical Characteristics of Different Rice Varieties Found in Sabah, Malaysia

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ABSTRACT: Five rice varieties found in Sabah (white, red, black, brown and aroma rice) were evaluated for physicochemical characteristics. The relationship between different properties was determined using Pearson correlation. The varieties showed significant variations in their physicochemical characteristics. Thousand grains weight, length–breadth ratio, and moisture content ranged between 15.30-20.90 g, 2.18-3.33, and 12.30-16.40%, respectively among the varieties. Minimum cooking time, water uptake ratio, gruel solid loss, and elongation ratio varied between 21.97-47.20 min, 2.30-3.51 g/g, 6.02-13.62% and 1.25-1.65 respectively. Brown rice showed a lower elongation ratio and water uptake ratio, and a higher cooking time than the other rice varieties. The water uptake and elongation ratio of rice kernels showed a negative correlation with cooking time, with a correlation coefficient of -0.960 and -0.900 respectively ($p \leq 0.05$). Starch content, starch swelling power, and amylose content of the rice varieties ranged between 33.73-64.98%, 9.31-13.01 g/g and 10.83-14.93% respectively. The results suggest the rice varieties in Sabah can serve as gene sources in rice breeding programme for grain quality.

KEYWORDS: Physicochemical, Rice, Traditional rice, Grain quality, Rice breeding

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INTRODUCTION

Rice (*Oryza sativa* L.) is an important staple food in many parts of the world and including Malaysia. Rice is unique as it consumed mainly in form of whole grains. It feeds more than two-thirds of the world's population by supplying high-value carbohydrate and consisting of more than 50% of the human's daily caloric intake (Anjum *et al.*, 2007; Oko and Onyekwere, 2010; Fedoroff, 2015). Rice is very rich in carbohydrate and protein content. Minerals present in rice like potassium, manganese, iron and zinc play an important role in body regulatory functions (FAO, 2004). Although rice has a relatively low mineral content, it is still sufficient to sustain the daily needs of an adult. In Malaysia, rice plays a crucial cultural role in beyond providing nourishment. For thousands of years, it has shaped the cultures, economies, and diets of many regions in Malaysia. With the rapid economic growth in Malaysia, consumers are becoming smarter in their choice of quality of rice. The quality of rice becomes the choice determinant factor. Therefore, the aspect of commercial rice grading based on grain quality has gained more attention in recent years.

Among the cereals, rice has a great diversity consisting more than 120,000 different varieties (IRRI, 2008). There are many varieties of rice and each type has its own characteristics. Unlike other cereals, rice is consumed as a whole grain. Therefore, the physical appearance of rice such as size, shape, and colour are of utmost importance. However, quality of rice does not only include the physical appearance, rather it encompasses both the chemical and cooking properties. This implies that physicochemical characteristics of rice are the determining factors of quality. This study aimed to compare the physicochemical characteristics of five rice varieties found in Sabah, Malaysia.

MATERIALS AND METHODS

Materials

The five rice grains (white, red, black, brown and aroma rice) found in Sabah were selected for this study. Rice grains were collected from the local market and kept in glass containers and stored at the cool room prior to the study.

Methods

(A) Physicochemical Measurements

Grain size and shape

The length and width of ten whole grains were measured (in mm) using a vernier micrometer. The length-breadth ratio (L/B) was determined by dividing the length by the breadth of rice grains. The size and shape classification were determined based on the criteria as described by Graham (2002).

1000-Grains Weight

One thousand rice grains were selected using a seed counter. The 1000-grains weight (TGW) was weighed using an electronic balance.

Grain Colour

The colour of bulked grains for each sample was determined visually using a colour chart provided by Royal Horticultural Society.

Moisture Content

The moisture content of rice was determined using the standard AOAC (1984) official methods of analysis and the method was detailed by Oko and Ugwu (2011). The moisture content of rice was calculated after oven drying at 85 °C for three days. The moisture content of rice was calculated using equation (1).

$$\text{Moisture content (\%)} = (\text{Fresh weight} - \text{Dry weight}) / \text{Fresh weight} \times 100\% \qquad (1)$$

Starch Content

Starch content of the rice seeds was extracted using alkaline steeping method as described by Wang and Wang (2001) and (2004). Rice samples were ground into flour and the flour (10 g, dry basis) was soaked in 20 mL of 0.1% sodium hydroxide (NaOH) for 18 h. Then the samples were blended using a high-speed blender for two minutes. The solution was then passed through a 63 µm screen and centrifuged at 1,400 x g for 10 min. The yellow top layer was carefully removed, and the underlying starch layer was re-slurred with 0.1% sodium hydroxide (NaOH) and centrifuged at 4,200 × g for 10 min. This process was carried out at least three times until there was no yellow layer. The starch layer was washed with distilled water and centrifuged at 4,200 × g for 10 min. The starch was re-slurred, neutralized to pH 6.5 with 1 M hydrochloric acid (HCl) and centrifuged again at 4,200 x g for 10 min. The neutralized starch was washed with distilled water thrice. After drying at 45 °C for 48 h, the starch was passed through a 100 mesh sieve. The starch obtained (starch content) was weighed using an electronic balance. The starch yield was the recovered starch weight divided by the starch content of rice flour.

Starch Swelling Power

Starch swelling power (SSP) of the rice was determined according to the method of Wang *et al*. (2010). A 2% w/v starch suspension of rice was heated in a water bath at 90 ℃ for 30 min. The starch samples were centrifuged at 1,500 x g for 15 min. The supernatant was then removed and the sediment was weighed. Aliquots of the supernatant were dried in an oven at 105 ℃ to constant weight. The swelling power (g/g on a dry weight basis) was calculated using the equation (2):

Starch swelling power = Sediment weight /Mass of dry starch x (100% - % of total mass of dried supernatant) (2)

Amylose Content

Amylose content (AC) of the rice was determined based on the method described by Juliano (1971). 100 mg of rice powder was mixed with 1 mL of 95% ethanol and 9 mL of 1 M NaOH. The mixture was heated for 10 min to gelatinize the starch. Distilled water was added to bring up to 100 mL after cooling and mixed well. A starch solution of 5 mL was mixed with 1 M acetic acid and 2 mL of iodine solution. The distilled water was added to bring up to 100 mL. The mixture was left for 20 min and then absorbance value was measured at 620 nm. The AC of rice samples was determined from a standard curve. A standard curve was generated by preparing potato amylose solution with a known concentration of anhydrous amylose. The absorbance values of potato amylose solutions were plotted at 620 nm.

(B) Cooking properties

Minimum Cooking Time

Rice samples (2 g) were placed in a test tube with 20 mL of distilled water and cooked in a boiling water bath. A few kernels of the cooked rice samples were removed at different time intervals during cooking and pressed between two glass plates. The cooking time was determined as the time when no white core remained while pressing with the glass plates (Singh *et al*., 2003; Singh *et al*., 2005).

Water Uptake Ratio

Rice samples (2 g) were placed in a test tube with 20 mL distilled water and cooked for a minimum cooking time in a boiling water bath. After cooking, the water was drained out and the superficial water left on the rice kernels were sucked by pressing the cooked rice in filter paper sheets. The weight of cooked rice samples was measured accurately and the water uptake ratio was calculated (Singh *et al*., 2003; 2005).

Elongation Ratio

Grain elongation was determined according to the method of Khush *et al*. (2000). Whole milled grains (25 grains) having the same length were selected after measuring with a vernier micrometer. The selected grains were soaked in 20 mL distilled water for 30 min. The samples were placed in a boiling water bath for 10 min. The cooked rice samples were transferred to a petri dish lined with filter paper. Ten cooked whole grains were selected and the final length measured. The grain elongation of rice was obtained from the average of 10 rice grain lengths.

Gruel Solid Loss

Rice samples (2 g) were placed in a test tube with 20 mL distilled water and cooked for a minimum cooking time in a boiling water bath. The gruel was transferred to 50 mL beakers and washed several times with distilled water and made to volume. The aliquot having leached solids was evaporated at 110˚C in an oven until completely dry. The solids were weighed and percentage gruel solids were recorded (Singh *et al*., 2005).

Statistical Analysis

Data obtained was analyzed statistically (one way - ANOVA) using SPSS 17.0 software package and the statistical significance was $p \leq 0.05$. All analyses were carried out using three replicates. Person correlation coefficients (r) were calculated for relationships between the different parameters for all the variety.

RESULT AND DISCUSSION

(A) Physicochemical characteristics

Grain appearance is considered an important characteristic for understanding the physical properties of rice (Deepa *et al.*, 2008). Brown rice is light yellow-brown in colour while white rice and aroma rice are white in colour. Red rice is dark purple red pigmented and black rice is gray pigmented. The length-breadth (L/B) ratio, thousand grains weight (TGW), moisture content, starch content, starch swelling power (SSP) and amylose content (AC) of the rice obtained for the five varieties differed significantly (Table 1). L/B ratio was highest for red rice (3.33) and black rice showed the lowest L/B ratio (2.96). Black rice and brown rice had L/B ratios less than 3.0 are considered as medium grain while white, red and aroma rice with L/B ratios greater than 3.0 were categorized as slender grained. White rice showed the highest TGW (20.90 g), followed by brown rice (20.50 g), aroma rice (19.90 g), and red rice (17.20 g). Black rice showed the lowest TGW (15.30 g). TGW is a measure of seed size and a range of 20 – 30 g is acceptable (Adu-Kwarteng *et al.*, 2003; Sujatha *et al.*, 2004; Yadav *et al.*, 2007). The moisture content of the five rice varieties ranged between 12.30% and 16.40%. The recommended MC for optimum storage of rice seeds is between 12 – 14% (no more than 15%) (Luh, 1991; Owen, 2003; Golob *et al.*, 2004; Randall *et al.*, 2009). Starch content, SSP, and AC of the five rice varieties ranged between 33.73-64.98%, 9.31-13.01 g/g and 10.83-14.93% respectively. Aroma rice with the highest amount of starch content (64.80%) resulted in the highest SSP value (13.01 g/g). The differences in rice swelling capacity may be attributed to the differences in amylose content, viscosity patterns and weak internal organization which resulted from negatively charged phosphate groups within the rice starch granules (Jane *et al.*, 1996; Jane *et al.*, 1999; Singh *et al.*, 2006).

Table 1. Physicochemical characteristics of the five rice varieties.

Variety	Appearance	L/B ratio	TGW (g)	Moisture content (%)	Starch content (%)	SSP (g/g)	Amylose content (%)
White	White, long, slender	3.12^{bc}	20.90^{a}	14.25^{bc}	56.17^{c}	11.47^{ab}	14.93^{c}
Red	Dark purple red and gray, medium, slender	3.33^{d}	17.20^{b}	12.30^{a}	52.37^{b}	9.92^{ab}	12.90^{b}
Black	Grey, medium, medium	2.96^{b}	15.30^{b}	13.98^{b}	52.90^{b}	9.93^{ab}	13.04^{bc}
Brown	Light yellow brown, medium, medium	2.18^{a}	20.50^{a}	16.40^{d}	33.73^{a}	9.31^{a}	13.23^{bc}
Aroma	White, long, slender	3.21^{bc}	19.90^{a}	14.40^{c}	64.80^{d}	13.01^{b}	10.83^{a}

*Mean of three replications ± standard deviation

*Figure followed by the same alphabet in the same column showed no significant different at 0.05.

L/B ratio: length-breadth ratio; TGW: 1000-grains weight; SSP: starch swelling power

(B) Cooking characteristics

Table 2 shows the cooking characteristics of the five rice varieties. Cooking time for different rice varieties ranged from 21.97 to 47.20 min, with the highest for brown rice and the lowest for black rice. It has been reported previously that cooking time for brown rice is generally higher than other milled rice or polished rice (Gujral and Kumar, 2003; Deepa *et al*., 2008). This may be due to the presence of a thick aleurone and the pericarp on brown rice. Water uptake ratio for the rice varieties was significantly different ($p \leq 0.05$). Black rice showed the highest water uptake ratio (3.51 g/g), followed by aroma rice (3.38 g/g), red rice (3.20 g/g), white rice (2.99 g/g), and brown rice which showed the lowest water uptake ratio of 2.30 g/g. There was a significant difference ($p \leq 0.05$) in elongation ratio between the rice varieties. The black rice showed the highest elongation ratio (1.65) and the brown rice showed the lowest (1.25). Gruel solid loss ranged from 6.02 to 13.62% for cooked rice for the five varieties. Black rice lost more gruel solid (13.62%) as compared to others. Aroma rice showed the lowest gruel solid loss value (6.02%).

Table 2. Cooking characteristics of the five rice varieties

Variety	Cooking Time (min)	Water Uptake Ratio (g/g)	Elongation Ratio	Gruel Solid Loss (%)
White	32.43^{b}	2.99^{b}	1.62^{c}	11.11^{c}
Red	32.30^{b}	3.20^{bc}	1.42^{b}	11.56^{c}
Black	21.97^{a}	3.51^{c}	1.65^{c}	13.62^{c}
Brown	47.20^{c}	2.30^{a}	1.25^{a}	8.83^{b}
Aroma	23.30^{a}	3.38^{c}	1.60^{c}	6.02^{a}

*Mean of three replications ± standard deviation
*Figure followed by the same alphabet in the same column showed no significant different at 0.05.

Cooking time of the rice varieties showed a strong negative correlation with water uptake ratio (r=-0.960, $p \leq 0.05$) (Figure 1) and elongation ratio (r=-0.990, $p \leq 0.05$) (Figure 2). Meanwhile, Figure 3 shows the correlation for the relationship between L/B with water uptake ratio (*r=0.811, p≤0.05*) and Figure 4 shows the relationship between L/B ratio and elongation ratio (r=0.692, $p \leq 0.05$). The results indicate that L/B ratio and cooking time have a dominant effect on water uptake ratio and elongation ratio. The results of this study are consistent with those reported earlier by Bhattacharya and Sowbhagya (1971); Khan and Ali (1985); Singh *et al.* (2005) and Yadav *et al.* (2007).

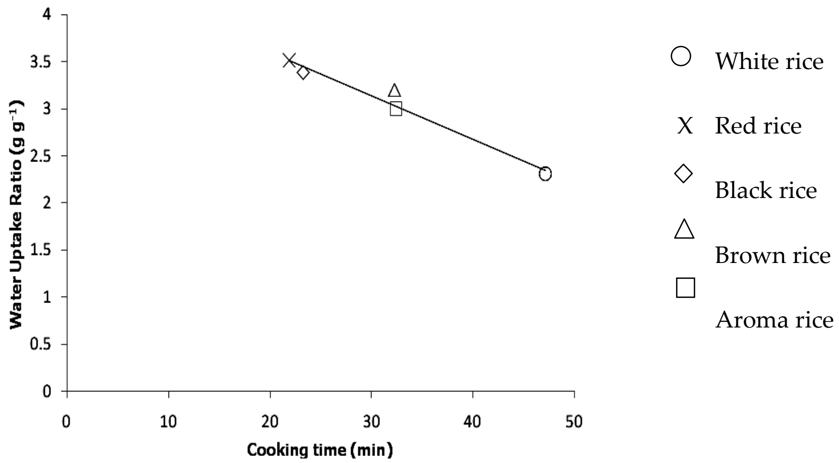

Figure 1. The relationship between cooking time and water uptake ratio of the five rice varieties (r=-0.960, $p \leq 0.05$).

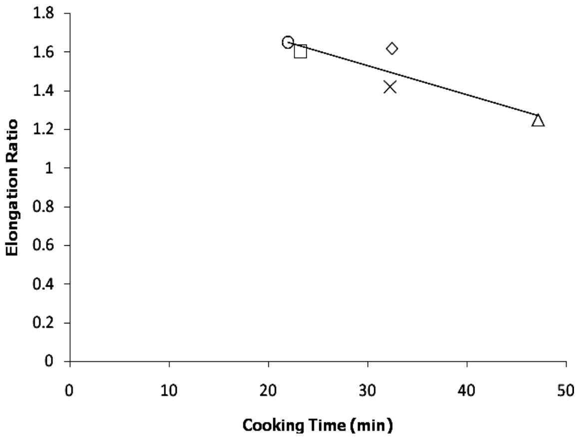

Figure 2. The relationship between cooking time and an elongation ratio of the five rice varieties (r=-0.990, p≤0.05).

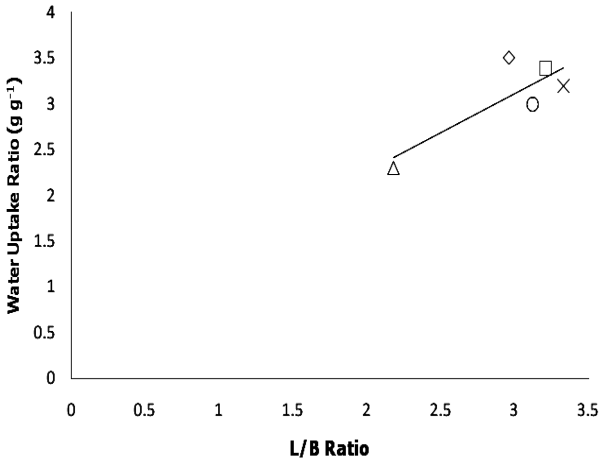

Figure 3. The relationship between L/B ratio and water uptake ratio of the five rice varieties (*r=0.811, p≤0.05*).

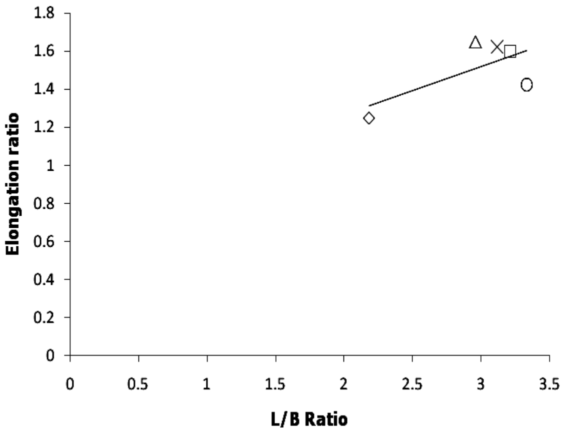

Figure 4. The relationship between L/B ratio and an elongation ratio of the five rice varieties (r=0.692, p≤0.05).

CONCLUSION

There were significant differences between the five varieties for all the parameters studied. The cooking parameters of rice correlated well with each other and the elongation and water uptake ratios correlated positively with the L/B ratio. The rice varieties can serve as gene sources in rice breeding programmes for grain quality.

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