Physiochemical properties, proximate composition, and cooking qualities of locally grown and imported rice varieties marketed in Penang, Malaysia

[1]Rachel Thomas, [2]Wan-Nadiah, W. A. and [1*]Rajeev Bhat

[1]*Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, Penang 11800, Malaysia*
[2]*Bioprocess Technology Division, School of Industrial Technology, Universiti Sains Malaysia, Penang 11800, Malaysia*

Abstract

In the present study, six different rice varieties marketed in Penang, Malaysia (locally grown and imported) were evaluated for proximate composition, physiochemical properties and cooking qualities. Overall, 'Black rice' variety had the highest protein content (8.16%) with lowest fat content (0.07%). Between the various rice varieties investigated, thousand kernel weight varied between 16.97-19.43 g, length/breadth (l/b) ratio was between 2.09-3.75, while bulk density varied between 0.81-0.86 g/ml. Amylose content was highest (27.71%) in white rice (local, medium grain type) with lowest recorded for brown rice variety (3.36%). Results on minimum cooking time showed it to range between 10 to 31.67 minutes with the brown rice cooking the slowest. The water uptake ratio ranged between 2.33 to 3.95 and was low in glutinous rice (2.33), while gruel solid loss (range from 3.17 to 6.43) was lowest in Basmati rice variety (3.17%). The minimum cooking time was found to be negatively correlated with amylose content (r = -0.97). A positive correlation was recorded for both amylose content and l/b ratio in relation to elongation of cooked rice. These results highlight cooking and physiochemical properties of rice to be strongly dependent on their amylose content. Results generated in this study might be able to provide vital information's on identifying 'superior quality of rice' marketed in Penang, based on their proximate composition as well as on their physiochemical and cooking properties.

Introduction

Rice (*Oryza sativa* L.) is an important cereal grain which feeds nearly half of the world's population. Rice is usually consumed as a whole grain after cooking, and in a regular Asian diet, can contribute for 40 to 80% of the total calorie intake (Paramita *et al.*, 2002; Singh *et al*., 2005; Hossain *et al*., 2009; Cai *et al.*, 2011). Being a major cereal grain, evaluating the nutritional and cooking qualities of rice has been given highest priority (Tan *et al*., 1999; FAO, 2004; Jiang *et al.*, 2005; Dong *et al*., 2007). Consumers' preference varies based on the type of rice and their origin (Azabagaoglum *et al*., 2009; Musa *et al*.,2011). It has been opined that variations in composition and cooking quality of rice to mainly depend on the genetic as well as surrounding environmental factors where they are grown (Giri and Vijaya Laxmi, 2000; Singh *et al*., 2005). Rice grain quality is reported to be influenced by various physicochemical characteristics that determine the cooking behaviour as well as the cooked rice texture (Bocevska *et al*.,

2009; Moongngarm *et al*., 2010). Additionally, amylose content as well as gelatinization temperature and gel consistency can highly influence cooking and eating qualities of rice, which can vary based on the varieties (Juliano, 1972; Bhattacharjee *et al*., 2011). Providing adequate informations' on the quality of rice consumed by local population is important for health conscious consumer as well is expected to be useful for minimizing fuel consumption while cooking. Based on these facts, the main objective of the present study was to compare and provide details for consumers on the proximate composition, physicochemical properties, and cooking quality of different rice varieties marketed in Penang Island, Malaysia.

Materials and Method

Materials

Six popular and widely preferred different rice varieties were purchased from the local Supermarket (Tesco, Penang, Malaysia). The local rice varieties

*Corresponding author.
Email: *rajeevbhat1304@gmail.com, rajeevbhat@usm.my*
Tel: +60-4653-5212 ; Fax: +60 4657 3678

from Malaysia were the white rice (Medium grain type), unpolished brown rice and Bario rice (of Sarawak origin). Whereas, imported rice varieties included: Black rice (Short grain type) and glutinous rice (Short grain type) from Thailand and Basmati rice (Long grain type) from Pakistan. Only whole rice grains without any physical damage or insect infestation was selected for analysis. Further, after bringing to the laboratory, rice samples were individually ground to a fine powder (30 mesh size), packed in air tight polyethylene plastic bags and were stored at 4°C until further analysis.

Physical properties

Thousand (1000) kernel weight, length–breadth ratio (L/B) and bulk density

One thousand rice kernels were randomly selected and weighed separately. For analyzing length-breadth ratio, the cumulative measurements of rice were measured in mm (n=10) and the value of L/B was recorded by dividing length by breadth. For bulk density, 50 g of rice grains was weighed and were dropped into a graduated glass measuring cylinder from a constant height (approximately 30 cm). The volume occupied by rice samples were recorded and bulk density was calculated as g/ml ratio (Seena and Sridhar, 2005; Singh et al., 2005).

Proximate Composition

Determination of moisture, crude protein, fiber, lipid, and ash were done based on AOAC (2000) standard method. Carbohydrate content was determined by difference.

$$\text{Carbohydrate (\%)} = 100\% - (\% \text{ moisture} + \text{fat} + \text{protein} + \text{ash})$$

Whereas, Gross energy was calculated based on the formula reported by (Ekanayake et al., 1999):

$$\text{Gross energy (kJ per 100 g dry matter)} = (\text{crude protein} \times 16.7) + (\text{crude lipid} \times 37.7) + (\text{crude carbohydrates} \times 16.7)$$

Amylose Content

Amylose content in rice samples were determined based on the Iodine-binding procedure as described by Juliano (1971). In brief, for 100 mg of rice flour, 1 ml of ethanol (95%) and 9 mL of 1 N NaOH were added in a volumetric flask (100 ml) followed by thorough mixing. Further, samples were heated on a boiling water bath for 10 min to gelatinize the starch and later on cooled to room temperature. Five millilitre of gelatinized starch solution was then transferred to a 100 ml volumetric flask followed by addition of 1 mL of 1N acetic acid and 2 ml of iodine solution,

with the volume adjusted to 100 mL with distilled water. All the contents were thoroughly vortex mixed and allowed to stand for 20 min. The absorbance was measured at 620 nm using a UV-Spectrophotometer (Model AA-6650, Shimadzu Co. Japan). The amylose content in samples was determined based on the standard curve prepared using potato amylose.

Cooking properties

Cooking properties of the rice samples were determined based on the available standard procedures (Batcher et al., 1956; Singh et al., 2003, 2005).

Minimum cooking time

Rice samples (2 g) were individually taken and cooked around 90°C in distilled water (20 ml) in a boiling water bath. The minimum time required for cooking was estimated by pressing the cooked rice samples between two glass slides (till no white core was left) by removing a few cooked kernels at regular time intervals.

Elongation ratio and length–breadth ratio

To determine elongation ratio, randomly selected cooked rice samples were measured for length and were divided by length of uncooked raw samples. Results were reported as elongation ratio.

The length-breadth ratio was determined by dividing the cumulative length by the breadth of cooked kernels. A mean of 10 replicates were taken for measurement.

Water uptake ratio

Two grams of rice samples were cooked in 20 ml of distilled water for a minimum cooking time in a boiling water bath. After this, the contents were drained and the adhering superficial water present on cooked rice was removed by pressing the samples between filter papers. Cooked rice samples were weighed and the water uptake ratio was calculated (determined as increase in weight of rice samples after cooking).

Gruel solid loss

To measure the gruel solid loss, approximately 2 g of rice grains were cooked in 20 ml of distilled water for minimum cooking time. The gruel obtained was transferred to beakers (50 ml) after few washing (3-5 times), and the volume was made up with distilled water. Further, the aliquot was evaporated in a vacuum oven (at 110°C) until it was completely dried. The solid obtained were weighed and the percentage of gruel solid loss was calculated.

Statistical analysis

All the analysis were performed in triplicates (unless stated otherwise) and presented as mean ± standard deviation. Statistical significance of the data obtained was analysed by One-way analysis of variance (ANOVA) followed by Tukey's HSD post-hoc test by using SPSS version 17.0 (SPSS Inc., Wacker Drive, Chicago, IL, USA). The level of significance was considered at $P < 0.05$.

Results and Discussion

Physiochemical properties

Physiochemical properties of a rice variety are evaluated to provide important facts in determining their appropriate uses (Majzoobi *et al.*, 2008). Results on the 1000-kernel weight of different rice varieties analysed in this study showed significant differences (see Table 1). Glutinous rice had highest 1000-kernel weight (19.43 g) followed by Bario rice (19.23 g) and brown rice (18.66 g), respectively. The lightest 1000-kernel weight was recorded for the white rice variety (16.97 g). There were no significant differences in the l/b ratio for Bario, black, glutinous and basmati rice. Overall, highest l/b ratio was recorded for the local white rice (3.75), whereas, the lowest ratio was recorded for brown rice (2.09). This analysis (l/b ratio) was performed to determine the shape of individual rice grains. A length to breadth ratio of above 3 is generally considered as slender (IRRI, 1980). In this study, except for Basmati and brown rice (classified as bold), all other rice samples can be judged as slender. Determining the rice grain shape and width are highly essential as both, cooking and eating properties are strongly influenced by these (McKenzie *et al.*, 1983). Among the different varieties, bulk density was observed to be highest in brown rice (0.86 g/ml), followed by glutinous rice (0.83 g/ml) and Bario rice (0.82 g/ml).

Proximate composition

The results obtained for proximal composition of different rice varieties investigated in this study are depicted in Table 2. Significant differences were recorded in the proximal composition between different varieties of rice evaluated. Moisture content, which plays a significant role in determining the shelf-life (Webb, 1985) was recorded to vary between 10.04-12.88%. The ash content was high in black rice (0.90%) and low in white rice (0.39%). The amount of ash present in a food sample plays an important role while determining the levels of essential minerals (Bhat and Sridhar, 2008). Protein content for all the rice varieties evaluated ranged between 5.96% to 8.16%, while fat content ranged

between 0.07% up to 1.74%. Overall, low fat content was recorded in black rice variety (0.07%).There were no significant differences recorded for crude fiber content among brown and black rice varieties. For crude fiber, the values were in the range of 7.07 to 8.47% among the samples analyzed. Black rice is also known to be a good source of fiber and it was the highest in this study. Carbohydrate content was high in all varieties (> 70%) and hence can be considered to be a good source of carbohydrate. Energy value measures the available amount of energy obtained from food via cellular respiration. In this study, white rice provided the highest energy per 100g among all the samples analyzed (1523.57 kJ). The data obtained is comparable with (Saunders *et al.*, 1979).

Amylose content

Amylose content can play a significant role in determining the overall cooking, eating and pasting properties of a rice variety (Adu-Kwarteng *et al.*, 2003, Asghar *et al.*, 2012). Apart from the amylose content, the cooking quality of rice can also be influenced by components such as: proteins, lipids or amylopectin (Cai *et al.*, 2011). In our present study, a positive correlation was observed wherein, rice varieties which had higher amylose content, required a shorter cooking time (Table 1). These results are on par with the observation made earlier by Singh *et al.* (2005). Rice with intermediate amylose content (20-25%) has been reported to cook moist and remain soft (when cool) and is widely preferred than rice with high (20-25%) or low amylose contents (10-20%) (IRRI, 1985). In this study, among the different rice varieties, brown rice had the lowest amylose content of 3.36% followed by black rice (5.11%). Bario rice was the only variety which fell under the intermediate amylose content range. High amylose content rice is known to cook dry and fluffy, but can become hard on cooling. This has been attributed to the retrogradation of the amylose molecules (Adu-Kwarteng *et al.*, 2003), which was evident and holds true with regard to the white rice variety (27.71%) as recorded in this study. Earlier, a strong positive correlation has also been reported between amylose content and elongation of rice (Nayak *et al.*, 2003).

Cooking properties

The cooking properties are important as rice is consumed almost immediately after cooking. Rice being a major staple food in most of the developing countries, reduced cooking time can be beneficial especially when fuel consumption is of concern. Results obtained for cooking properties are depicted in Table 3. The Pearson correlation coefficients for

Table 1. Physiochemical properties and amylose content of different rice varieties investigated in this study (n = 3 for amylose content and for others n = 10 ± s.d.)

Rice samples	1000 Kernel Weight	l/b Ratio	Bulk Density (g/ml)	Amylose Content (%)
White (local)	16.97 ± 0.5[a]	3.75 ± 0.1[c]	0.81 ± 0.1[a]	27.71 ± 1.2[e]
Brown	18.66 ± 0.2[c]	2.09 ± 0.5[a]	0.86 ± 0.0[d]	3.36 ± 0.6[a]
Bario	19.23 ± 0.1[d]	3.19 ± 0.2[b]	0.82 ± 0.5[b]	22.63 ± 0.9[d]
Black (Imported)	17.03 ± 0.3[a]	3.13 ± 0.4[b]	0.81 ± 0.2[ab]	5.11 ± 0.2[b]
Glutinous	19.43 ± 0.6[d]	3.10 ± 0.5[b]	0.83 ± 0.2[c]	8.44 ± 1.3[c]
Basmati	17.3 ± 0.0[b]	2.99 ± 0.1[b]	0.81 ± 0.2[a]	9.43 ± 0.2[c]

Same letter in the same column are not significantly different from each other.

Table 2. Proximate composition of rice varieties investigated in this study (n = 3 ± s.d.)

Rice samples	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Total Dietary Fibre (%)	Energy (kJ per 100 g)
White (local)	12.08 ± 0.1[e]	0.39 ± 0.4[a]	5.96 ±0.2[a]	1.24 ± 0.0[e]	80.14 ± 1.1[d]	7.07 ± 0.6[a]	1523.57 ± 0.9[e]
Brown	12.88 ± 0.0[f]	0.55 ± 0.0[c]	6.48 ± 0.0[c]	1.74 ± 0.1[f]	78.21 ± 0.9[a]	8.37 ± 0.1[d]	1487.90 ± 0.3[b]
Bario	10.55 ± 0.2[b]	0.63 ± 0.0[d]	6.35 ± 0.6[b]	0.26 ± 0.2[b]	82.23 ± 0.5[e]	7.17 ± 0.1[a]	1495.22 ± 0.5[c]
Black (Imported)	11.07 ± 0.2[c]	0.90 ± 0.2[f]	8.16 ±0.3[e]	0.07 ± 0.2[a]	78.26 ± 0.6[a]	8.47 ± 0.2[d]	1457.72 ± 0.7[a]
Glutinous	10.04 ± 0.1[a]	0.82 ± 0.1[e]	8.14 ± 0.1[e]	1.12 ± 0.2[d]	78.89 ± 0.6[b]	7.47 ± 0.4[b]	1502.65 ± 0.2[d]
Basmati	11.23 ± 0.0[d]	0.48 ± 0.2[b]	7.75 ±0.1[d]	1.02 ± 0.1[c]	79.34 ± 0.1[c]	8.09 ± 0.2[c]	1498.46 ± 0.2[c]

the relationship between physiochemical and cooking properties of different rice varieties used in this study is depicted in Table 4. Cooking time of a rice grain is usually ascertained when an opaque center is no longer visible by 90% of the starch in the grain (Dipti *et al.*, 2003). In this study, white rice variety required minimum cooking time of 10 minutes followed by Bario rice (12.67 min.). Brown rice took longest 'minimal cooking time' of 31.67 min. This could be due to the fact that the fibrous bran layer might have not yet been removed, and hence it requires longer time for the starchy endosperm to cook (Juliano and Bechtel, 1985). Differences in the observed amylose content between different rice varieties can also affect the cooking properties (Singh *et al*., 2005), which holds true in this study. Additionally, the minimum cooking time was found to be negatively as well as significantly correlated with amylose content (r = -0.97, P ≤ 0.01). The relationship between amylose content and cooking time of various rice varieties investigated in this study is depicted in Figure 1.
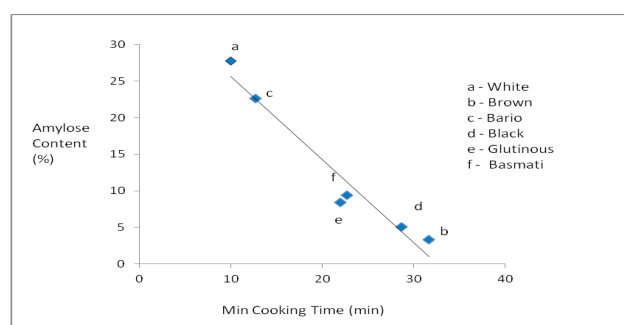
Figure 1. Relationship between amylose content and cooking time of various rice varieties investigated in this study

Water uptake ratio is an important parameter while cooking rice. If the bulk density is higher, then correspondingly water uptake ratio will also be high. This has been attributed to the compact structure of a rice variety (Bhattacharya *et al.*, 1971; Horigane *et al.*, 2000). When a disorganized cellular structure is present in the grain, soft cooked grains can be obtained (Lisle *et al*., 2000). Also, according to Juliano *et al.* (1987) for rice, high amylose and long chain amylopectin can lead to hard texture, while the vice-versa can have a softer texture on cooking. Disorganized cellular structure can enhance the probabilities for high water absorption during cooking and can contribute to longer cooking time. In this study, it was observed water uptake ratio to be highest for brown rice (3.95) and lowest for glutinous rice (2.33). A positive correlation between water uptake ratio and l/b ratio was also found in this study (r = 0.66). Similar findings have also been reported by Yadav *et al.* (2007).

Among the various rice varieties evaluated in this study, highest l/b ratio was observed in white rice (3.75). Increase in either length or breadth can occur depending on the increase in volume during cooking as and when water is absorbed. Generally, breadth wise increase on cooking of rice is considered undesirable trait, while high quality rice varieties are characterized and preferred based on increase in length during cooking (Danbana *et al.*, 2011). Elongation of rice can be influenced by both the l/b ratio and the amylose contents (Singh *et al*., 2005; Danbana *et al*., 2011). Additionally, a positive correlation was also recorded by both amylose content and l/b ratio in

Table 3. Cooking properties of rice varieties investigated in this study (n=3 ± s.d.)

Rice samples	Min Cooking Time (min)	Elongation	Cooked l/b (mm)	Water Uptake Ratio	Gruel Solid Loss (%)
White (local)	10.00 ± 0.0^a	1.43 ± 0.0^b	3.27 ± 0.1^b	2.44 ± 0.3^a	6.43 ± 0.0^f
Brown	31.67 ± 0.6^d	1.68 ± 0.3^d	2.25 ± 0.4^a	3.95 ± 0.3^d	3.37 ± 0.6^b
Bario	12.67 ± 0.6^b	1.37 ± 0.2^a	3.07 ± 0.2^b	2.75 ± 0.2^b	5.46 ± 0.3^d
Black (Imported)	22.66 ± 0.6^c	1.57 ± 0.1^c	3.45 ± 0.3^c	2.73 ± 0.1^b	4.22 ± 0.4^c
Glutinous	22.67 ± 0.0^c	1.41 ± 0.1^b	3.17 ± 0.4^b	2.33 ± 0.8^a	5.76 ± 0.2^e
Basmati	22.00 ± 0.6^c	1.77 ± 0.0^d	4.18 ± 0.1^d	3.77 ± 0.6^c	3.17 ± 0.2^a

Same letter in the same column are not significantly different from each other at $P \leq 0.05$.

Table 4. Correlation coefficient for the relationship between physiochemical and cooking properties of milled rice from white, black, brown, Bario, Basmati and glutinous rice cultivars

	1000 Kernel Weight	L/B ratio	Bulk Density	Amylose Content	Min Cooking Time	Elongation	Cooked L/B	Water Uptake	Gruel Solid Loss
1000 kernel weight	1.00								
L/B ratio	-0.29	1.00							
Bulk Density	-0.56*	-0.83**	1.00						
Amylose Content	-0.11	0.23	-0.52*	1.00					
Min Cooking Time	0.02	-0.38	-0.59*	-0.97**	1.00				
Elongation	-0.29	0.23	0.44	0.71**	-0.77**	1.00			
Cooked L/B	-0.5*	0.95**	-0.82**	0.11	-0.23	-0.01	1.00		
Water uptake	0.52*	0.66**	-0.28	0.01	0.27	-0.37	0.46	1.00	
Gruel solid loss	-0.37	0.62**	-0.50*	0.03	-0.17	0.01	0.72**	0.27	1.00

*$P \leq 0.05$; ** $P \leq 0.01$

relation to elongation of rice. In this study, maximum elongation ratio was observed in Basmati rice 1.77, followed by brown rice 1.68.

With regard to gruel solid loss, it ranged from 3.17 in Basmati rice up to 6.43 in white rice variety. Low solid contents in the cooking gruel can be attributed to the fact that the surface area in contact with water is smaller, resulting in a lower l/b ratio. These observations are comparable to the report of Hirannaiah *et al.* (2001) who have also observed minimum gruel solid loss in Basmati rice. Rice varieties with higher amylose content are more prone to leaching out into the cooking water as starch grains expand during cooking (Juliano, 1971). Gruel solid loss has been reported to exhibit a positive correlation with cooked l/b ratio of rice. Our results are on par with the observations of Usha *et al.* (2012).

Conclusion

Investigations conducted on six rice varieties (local and imported and marketed in Penang Island, Malaysia) indicated differences in the physiochemical, proximate and cooking properties. The physiochemical properties were either negatively or positively correlated with the cooking properties. There were low, intermediate and high amylose content containing rice varieties too. White rice with high amylose content had shortest minimum cooking time. Basmati rice had the highest elongation ratio,

while water uptake ratio was high in brown rice. Among all the samples studied, it can be concluded by indicating Basmati rice to possess fairly good cooking and eating characteristics, based on its amylose content, grain elongation and gruel solid loss during cooking and water uptake. Results obtained in this study are expected to be useful for preparation of novel rice based food products, based on the individual requirements.

References

AOAC International. 1990. Official methods of analysis Washington DC: Association of Official Analytical Chemists.

AOAC International. 2000. Official Methods of Analysis, 17th Ed., Washington DC.

Adu-Kwarteng, E., Ellis, W. O., Oduro, I. and Manful, J. T. 2003. Rice grain quality: A comparison of local varieties with new varieties under study in Ghana. Food Control 14: 507–514.

Asghar, S., Anjum, F.M., Amir, M.R. and Khan, M. A. 2012. Cooking and eating characteristics of Rice (*Oryza sativa* L.)-A review. Pakistan Journal of Food Sciences 22: 128-132

Azabagaoglum, O. and Gaytancioglu, O. 2009. Analyzing

consumer preference to different rice varieties in Turkey. Agricultural Tropica et Subtropica 42: 118-125.

Batcher, O.M., Helmintoller, K. F. and Dawson E.H. 1956. Development and application of method for evaluating cooking and eating quality of rice. Rice Journal 59:4-8, 32.

Bhat, R. and Sridhar, K.R. 2008. Nutritional quality evaluation of electron beam-irradirated lotus (*Nelumbo Nucifera*) seeds. Food Chemistry 107: 174-184.

Paramita, B., Singhal, R.S. and Kulkarni P.R. 2002. Review Basmati Rice: a review. International Journal of Food Science and Technology 37: 1-12.

Bhattacharya, K.R. and Sowbhagya, C.M. 1971. Water uptake by rice during cooking. Cereal Science Today 16: 420-424.

Bocevska, M., Aldabas, I., Andreevska, D. and Ilieva, V. 2009. Gelatinization behavior of grains and flour in relation to physiochemical properties of milled rice (*Oryza Sativa* L.). Journal of Food Quality 32:108–124.

Cai, Y., Liu, C., Wang, W. and Cai, K. 2011. Differences in physicochemical properties of kernels of two rice cultivars during grain formation. Journal of Science of Food and Agriculture 91: 1977–1983.

Danbaba, N., Anounye, J.C., Gana A.S., Abo, M.E. and Ukwungwu, M.N. 2011. Grain quality characteristics of Ofada rice (*Oryza sativa* L.): Cooking and eating quality. International Food Research Journal 18: 629-634.

Dipti, S.S., Bari, M.N. and Kabir, K.A. 2003. Grain quality characteristics of some beruin rice varieties of Bangladesh. Pakistan Journal of Nutrition 2: 242-245.

Dong, M-H., Sang, D-Z., Wang, P., Wang, X-M. and Yang, J-C. 2007. Changes in cooking and nutrition qualities of grains at different positions in a rice panicle under different nitrogen levels Rice Science 14: 141-148.

Ekanayake, S., Jansz, E.R. and Nair, B. M. 1999. Proximate composition, mineral and amino acid content of mature Canavalia gladiate seeds. Food Chemistry 66: 115-119.

Food and Agriculture Organization (FAO). 2004. Rice is Life. Italy: FAO.

Giri, C.C. and Vijaya, G. 2000. Production of transgenic rice with agronomically useful genes: an assessment. Biotechnology Advances 18: 653-683.

Hirannaiah, B. V., Bhashyam, M. K. and Ali, S. Z. 2001. An improved cooking quality test for Basmati rice. Journal of Food Science and Technology 38: 116–119.

Horigane, A. K., Engelaar, W. M. H. G., Toyoshima, H., Ono, H., Sakai, M., Okubo, A. and Nagata, T. 2000. Differences in hollow volumes in cooked rice grains with various amylose contents as determined by NMR micro-imaging. Journal of Food Science 65: 408–412.

Hossain, M. S., Singh, A.K. and Fasih-uz-Zaman. 2009. Cooking and eating characteristics of some newly identified inter sub-specific (*indica/japonica*) rice hybrids. Science Asia 35: 320-325.

IRRI International Rice Research Institute. 1980. Annual report for 1980. Los Banos, Laguna, Philippines. p 25-38.

IRRI International Rice Research Institute. 1985. Rice quality training manual.

Jiang, G-H., Hong, X-Y, Xu, C-G, Li, X-H. and He, Y-Q. 2005. Identification of quantitative trait loci for grain appearance and milling quality using a doubled-haploid rice population. Journal of Integrative Plant Biology 47: 1391−1403.

Juliano, B.O. 1971. A simplified assay for milled rice amylose. Cereal Science Today 16: 334-338.

Julino, B.O. 1972. Physicochemical properties of starch and protein in relation to grain quality and nutritional value of rice. In IRRI Rice Breeding. IRRI: 389-405.

Juliano, B. O., Perez, C. M., Blakeney, A. B., Castillo, D.T, Kongseree, N., Laignelet, B., Lapis, E.T., Murty, V.V.S. and Webb, B.D. 1981. International cooperative testing on the amylase content of milled rice. Starch 33:157–162.

Juliano, B. O. and Bechtel, D. B. 1985. The rice grain and its gross composition. In B. O. Juliano (Ed.), Rice chemistry and technology. St. Paul, Minnesota, USA: American Association of Cereal Chemists.

Juliano, B.O., Villareal, R. M., Perez, C. M., Villareal, C. P., Takeda,Y. and Hizukuri, S. 1987. Varietal differences in properties among high amylose rice starches. Starch 39: 390–393.

Lisle, K. J., Martin, M. and Fitzgerald, M. A. 2000. Chalky and translucent rice grains differ in starch composition and structure and cooking properties. Cereal Chemistry 77: 627-632.

Majzoobi M. and Farahnaky A. 2008. The physiochemical properties of starch components of six Iranian rice cultivars. Iran Agricultural Research 27: 113-122.

McKenzie, K. S. and Ruther J. N. 1983. Rice grain shape and rice grain quality. Crop Science 23: 306–313.

Moongngarm, A. 2010. Influence of Germination Conditions on Starch, Physicochemical Properties, and Microscopic Structure of Rice Flour. International Conference on Biology, Environment and Chemistry. IPCBEE 1: 78-82.

Musa, M., Othman N. and Fatah, F.A. 2011. Determinants of Consumers Purchasing Behavior for Rice in Malaysia. American International Journal of Contemporary Research 1: 159-163.

Nayak A.R., Chaudhury D. and Reddy J.N. 2003. Inter-relationship among quality characters in scented rice. Indian Journal of Agricultural Research 37: 124-127.

Ong, M. H. and Blanshard, M. V. 1995. Texture determination in cooked, parboiled rice. 1: Rice starch amylose and the fine structure of amylopectin. Journal of Cereal Science 21: 251–260.

Saunders, R. and Betschart, A. 1979. In Inglett, G.E. and Charalambous, G. eds. Tropical foods: chemistry and nutrition, USA, Academic Press: 191-216.

Seena, S. and Sridhar, K. R. 2005. Physichochemical, functional and cooking properties of under explored legumes, Canavalia of the southwest coast of India.

Food Research International 38: 803–814.

Singh, N., Kaur, L., Singh, S.N. and Sekhon, K.S. 2005. Physicochemical, cooking and textural properties of milled rice from different Indian rice cultivars. Food Chemistry 89: 253–259.

Singh, N., Sodhi, N.S., Kaur, M. and Saxena, S.K. 2003. Physico-chemical, morphological, thermal, cooking and textural properties of chalky and translucent rice kernels. Food Chemistry 82: 433–439.

Tan, Y.F., Li, J.X, Yu, S.B., Xing, Y.Z. and Xu, C.G. 1999. The three important traits for cooking and eating quality of rice grains are controlled by a single locus in an elite rice hybrid, Shanyou 63. Theory Applied Genetic 99: 642-648.

Usha, R., Menon, L., Gomathy, G., Parimala, C. and Rajeshwari, R. 2012. Quality analysis of indigenous organic Asian Indian rice variety - Salem Samba. Indian Journal of Traditional Knowledge 11:114-122.

Webb, B.D. 1985. Criteria of rice quality in the U.S. In: Juliano. B., ed., Rice: Chemistry and technology. St. Paul, Minnesota, Association of Cereal Chemistry Inc., 774.

Yadav, R.B., Khatkar, B.S. and Yadav B.S. 2007. Morphological, physicochemical and cooking properties of some Indian rice (*Oryza sativa* L.) cultivars. Journal of Agricultural Technology 203-210.