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Physicochemical and nutritional properties of selected pigmented and white long grain rice varieties of Sri Lanka at different polishing rates

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Abstract

Long grain two basmati type rice varieties (RVs) having red and white pericarp color and black rice developed in Sri Lanka were used in this study. Selected rice varieties were studied for physicochemical [grain colour, size, shape and amylose contents (AC)] and nutritional properties [moisture, crude protein (CP), crude fat (CF), total ash (TA), total dietary fiber (TDF), total carbohydrate (TC) and total available carbohydrate (TAC) contents] using standard analytical techniques (n=3) for market available polishing rates (100%, 40% and 0% or whole grain). Pakistan White Basmati (PWB) was used for comparison. Physicochemical and nutritional properties varied significantly (P<0.05) among the studied RVs. Grain size and shape of all the tested RVs were long and slender respectively. CIC Red Basmati type (RBT) and CIC White Basmati type (WBT) were high amylose varieties whereas, CIC Black rice (BR) was an intermediate amylose variety. The TA, CF and TDF contents of tested RVs decreases while there were significant increases in TAC and TC contents with the increasing polishing rate (PR). At 100% PR, CP content of all the tested varieties varied between 10.16±0.06 to 11.76±0.04%. At the same PR, CIC BR exhibited the highest TA (0.86±0.03%) and CF (1.53±0.08%) contents and they were significantly higher than that of PWB rice. Further, TDF (0.45±0.01%) content of CIC BR and CP (11.76±0.04%) content of CIC RBT were comparable to PWB. In conclusion, physicochemical and nutritional properties of 100% polished BR and RBT rice of Sri Lanka were either superior or comparable to that of PWB rice.

Keywords: Physicochemical properties, nutritional properties, long grain rice varieties, Basmati type, pigmented rice, polishing rates.

Introduction

Rice is a popular cereal crop growing across the world and it is the staple food for nearly half of the world's population. The global rough rice and milled rice production in 2015 were 738.8 and 490.6 million tones, respectively[1]. Asia is the world's largest rice producer and it accounts ~ 90% to the global rice production[2].

The grain quality of rice can be evaluated by many properties including processing, physicochemical, sensory and nutritional properties and all these properties affect the consumer preference and commercial value of rice[3-5]. Grain colour, size, shape, amylose content and gelatinization characteristics are important physicochemical properties[6]. Among those, amylose content and gelatinization characteristics are key parameters that influence the cooking and eating quality of rice[3-5]. Basically amylose content acts as a key determinant of cooked rice texture. Rice with low amylose becomes cohesive, tender and glossy upon cooking whereas, rice with high amylose tends to cook dry and fluffy with grain separation[7]. Rice can be classified as long-grain, short-grain or medium-grain depending on the length of rice grain[4]. Among these, long grain rice varieties are preferred by most of the consumers[8]. In addition, there are pigmented rice types such as black, red or brown rice depending on the colour of the outer layer of the rice grain which is known as the bran[9,10]. These pigmented rice types have more phytochemicals particularly antioxidant compounds than white rice[10]. Presences of such phytochemicals are reported to provide range of health benefits. They are important in management of chronic diseases such as diabetes, cancers, cardiovascular diseases and also aging[11]. Therefore, pigmented rice is gaining attention among rice consumers who are health consciousness.

Worldwide nutritional deficiencies and non-communicable diseases are rapidly increasing and occur particularly in developing countries[12-14]. In many developing countries rice is the staple food and main source of nutrition. Therefore, apart from physiochemical properties nutritional properties of rice are also important for the rice consumers.

Rice is an important source of carbohydrates, proteins, vitamins, minerals and fiber. Except carbohydrates most of the other nutrients of rice are mainly concentrated in the bran[5,9,10]. Nevertheless, rice particularly white rice is produced by removing rice bran through milling process and it leads to loss of such nutrients[8]. Apart from that rice provides nearly 20% of the per capita energy and 13% of the per capita protein worldwide[15,16]. Further, rice supplies 40% of the dietary protein in developing countries and quality of rice protein is high due to the presence of high content of lysine an essential amino acid for humans[15,17]. Thus, whole grains of rice which are rich in nutrients and phytochemicals are important in alleviating nutritional deficiencies and non-communicable diseases particularly in widely rice consuming countries.

Sri Lanka being an Asian country has a long history of rice production and it dates back to 600 B.C. Currently Sri Lanka is cultivating mainly high yielding new improved rice varieties developed by the Department of Agriculture, Sri Lanka. The country produced 3.38 millionmetric tons of rough rice in 2014 and it accounts only for 0.46% of the world rough rice production[18]. However, up to 1950's there were merely traditional rice varieties cultivated throughout the country and about 600 traditional rice varieties had been cultivated[19]. Some of these traditional rice varieties are claimed to have medicinal properties as well as high nutritional values and important physicochemical properties[6]. In addition, these traditional and improved rice varieties are available as either red or white colour and in short, medium or long grains.

Long grain rice with 'basmati' type grain qualities is popular and highly prized in the international trade. Although fully polished long grain white rice is the most popular among rice consumers, currently there is an increasing demand for whole grain and partially polished pigmented long grain rice. In Sri Lanka, several red and white long grain rice varieties with 'Basmati' type grain quality and a black pericarp rice variety have recently been developed and commercialized. However, only limited studies have been conducted on physicochemical, nutritional and sensory properties of such varieties. The present study investigated the physicochemical, nutritional and sensory properties of recently developed selected pigmented and white long grain rice varieties of Sri Lanka at different polishing rates.

Materials and methods

Grain samples: Locally developed three long grain rice varieties namely CIC Red Basmati type, CIC White Basmati type and CIC Black rice obtained from CIC Agri Businesses (Pvt.) Ltd, Sri Lanka were used in this study. Pakistan white basmati rice purchased from local market was used for comparison.

Chemicals and reagents: Heat stable α-amylase from *Bacillus licheniformis*, pepsin from porcine gastric mucosa, pancreatin from porcine pancreas and potato amylose were obtained from Sigma-Aldrich, USA. All the other chemicals were of analytical grade.

Sample preparation: Rough rice grains were de-hulled (THU-35B, Satake, Hiroshima, Japan) and polished (TM-05C, Satake, Hiroshima, Japan) to represent the market available polishing rates (fully or 100% polished, 40% polished and 0% polished or whole grain) for the selected rice varieties. Then, rice samples were milled (0.5mm sieve) using a laboratory milling machine (Universal mill PE 402, Bauermeister, Germany) to obtain rice flour and used for nutritional composition analysis.

Physicochemical properties of selected pigmented and white long grain rice varieties: Grain color: The grain color of rice varieties were determined by visual observation as described by Juliano[15].

Grain size: As per the method described by Juliano, size of the selected rice varieties was determined[15]. Briefly, length of ten milled undamaged rice grains arranged in length wise were measured and divided by 10 to calculate the length of a rice grain. Each rice variety was replicated five times. Classification given by IRRI, Philippines was used to classify the rice grains[20].

Grain shape: For the determination of shape of the rice grain the method described by Juliano was used[15]. Briefly, cumulative measurements of ten milled undamaged rice grains arranged in length and width wise were taken using a ruler. Length, width and ratio of length to width of a grain were calculated. Each rice variety was replicated five times. Classification given by IRRI, Philippines was used to classify the rice grains[20].

Amylose content: Amylose content of selected rice varieties (100% polished rice) were determined by iodine-colorimetric method described by Juliano[15]. A sample of 100mg was weighted into an Erlenmeyer flask (100 ml). Then, 1ml of 96% ethanol and 9ml of 1N sodium hydroxide were added and boiled for 10min in a water bath. Gelatinized sample was transferred into a 100ml volumetric flask and washed two times with distilled water. Then it was diluted to 100ml using distilled water. An aliquot of 0.5ml was transferred into a 10ml volumetric flask and 0.1ml of 1N Acetic acid and 0.2ml of iodine/potassium iodide solution (2%w/v) was added. Solution was then diluted to 10ml using distilled water and mixed well. The samples were stored at 30^{o}C for 20min in a thermostatic water bath. Finally the absorbance readings were measured at 620nm. Analyses were carried out in triplicates (n=3) for each rice variety. Potato amylose was used as the standard.

Nutritional properties of selected pigmented and white long grain rice varieties: Total dietary fiber: Total dietary fiber (TDF) content was estimated by enzymatic gravimetric method described by Asp *et al*.[21]. To 1g of rice flour (nearest 0.1mg) 25 ml of 0.1M sodium phosphate buffer (pH=6) was added. Then, it was incubated in a boiling water bath for 15min by adding 100µl of heat stable α-amylase. pH was adjusted to 1.5±0.1 with

HCl and incubated with 100mg of pepsin for 1h at 40°C with agitation. After the digestion, samples were allowed to cool, pH was adjusted to 6.8±0.1 with NaOH and incubated with 100mg of pancreatin for 1h at 40°C with agitation. Finally, using HCl, pH of the digest was adjusted to 4.5. Whole digest was adjusted to 100ml with distilled water and allowed to precipitate by adding 400ml of 95% ethanol. Then, the sample was filtered through a previously dried and weighed crucible (porosity 2) containing 0.5g of celite. Residue was washed with 2×10 ml of 78% ethanol followed by 2×10ml of 95% ethanol and finally with 2×10ml of acetone. Residue was dried overnight at 105°C to obtain a constant weight. It was then incinerated in a furnace maintained at a temperature of 550°C until white ash was obtained. Nitrogen content in the residue was determined by the Kjeldhal method and converted to protein by multiplying with 6.25. Blank experiment was also performed in the same way. The TDF content of the rice samples were corrected for indigestible protein by subcontracting the protein values from TDF values. The analysis for each rice variety was carried out in triplicate (n=3).

Proximate composition: The moisture, total ash (TA) and crude protein (CP) contents of rice samples at different polishing rates were determined using methods of Association of Official Analytical Chemists (AOAC)[22]. Crude fat (CF) content was determined by submersion method using procedure described in the operating manual of Gerhardt fat extractor (Soxtherm unit). The total carbohydrate (TC) content was determined by the difference from the analysis of TA, CF and CP contents. Total available carbohydrate (TAC) content was calculated by subtracting the TDF content from TC. Analysis were carried out in triplicate (n=3).

Sensory properties of selected pigmented and white long grain rice varieties: Sensory attributes of cooked rice were evaluated using an in house trained panel at Industrial Technology Institute, Sri Lanka. Sensory attributes namely appearance (white glossy to brown dull), aroma (very weak to very strong), tenderness (very tender to very tough) and cohesiveness (very sticky to well separate) were determined.

Statistical analysis: Data were analyzed using SAS software (version 6.12) and results were given as mean ± SE. One way analysis of variance (ANOVA) was used in data analysis and for mean separation Duncan's Multiple Range Test (DMRT) was used.

Results and discussion

Present study investigated physicochemical and nutritional properties of selected pigmented and white long grain rice varieties of Sri Lanka at different polishing rates. The rice varieties used in the present study especially the CIC Red and CIC White Basmati types were consumer preferred rice varieties in the Sri Lankan market. The polishing rates used were the market available polishing rates for the selected rice varieties.

Market quality of rice depends on several factors such as grain size and shape, degree of milling, grain appearance, cooking and eating quality parameters and nutritional value[4,5,15]. Grain size and shape are important parameters that influence the consumer preference of rice[3,5]. Further, the grain size and shape are major criteria considered by breeders when developing new rice varieties for commercial production[4,5,15]. However, the preference for grain size and shape vary among consumers. Some ethnic groups prefer short bold grains, some for medium long grains and others greatly prized long slender grains[5]. In spite of that, breeders have turned their attention towards developing long grain rice varieties for commercial production[5].

The grain size and shape of selected pigmented and white long grain rice varieties of Sri Lanka and Pakistan White Basmati are presented in Table-1. All the tested rice varieties were long and slender grains according to the grain size and shape classifications used. The long, slender grains having kernel length of 6mm or more and L/B ratio of 3 or above can be characterized as basmati types[4]. Hence, the selected rice varieties in the present study can be considered as basmati types based on grain length and L/B ratio. Further, the grain size and shape of all CIC basmati type varieties were comparable to Pakistan White Basmati. Famous basmati rice varieties grown in Pakistan reported to have grain lengths of 6.6-7.7mm[23]. A study done on six basmati varieties has reported 6.61 to 7.31mm kernel length and 4.1 to 4.8 length/breadth ratio (L/B)[4]. In the present study, length and L/B ratio of tested varieties varied from 6.5±0.1 to 7.1±0.0mm and 3.6±0.1 to 4.0±0.1, respectively and were comparable to the reported values.

The amylose content of rice is an important factor use to predict the cooking and eating quality of rice[4,15,24,25]. Generally rice varieties are grouped into low (10-19%), intermediate (20-25%) and high (>25%) amylose varieties on the basis of amylose content in the rice grain[3,5,9]. Rice with intermediate amylose content is reported to cook moist and fluffy and remain soft upon cooling and widely preferred by consumers compared to high or low amylose rice[3,5,9]. Rice with high amylose becomes dry and fluffy on cooking but hard upon cooling whereas low amylose rice is moist and sticky[9,24]. Amylose content of the rice varieties used in the present study varied between 23.10% to 27.00%.

Black rice had intermediate amylose whereas, Red Basmati and White Basmati types felled under high amylose range. CIC Red Basmati type rice exhibited the highest amylose content. This is in agreement with the results of previous studies. Amylose content of 15 rice cultivars in Pakistan reported to be varied between 22.3-26.8 %[5]. Grain amylose contents ranging from 23-31% were observed among selected Sri Lankan traditional and improved rice varieties and 7.47-42.02% in pigmented rice varieties[9,25].

Moreover amylose contents found to be varied from 3.36-27.71%, 14.80-30.81% and 15-23% respectively in rice varieties[3,4,11].

Table-1: Grain size, shape and amylose content of selected pigmented and white long grain rice varieties of Sri Lanka and Pakistan white basmati rice.

Rice Variety	Pericarp color	Length (mm)	Grain size*	Width (mm)	Length: width ratio	Grain shape*	Amylose content** (%)	Amylose classification
CIC Black rice	Black	6.5 ± 0.1	Long	1.8 ± 0.1	3.6 ± 0.1	Slender	23.10± 0.00^{c}	Intermediate
CIC Red Basmati type	Red	7.1 ± 0.0	Long	1.8 ± 0.1	4.0 ± 0.1	Slender	27.00 ± 0.00^{a}	High
CIC White Basmati type	White	7.0 ± 0.0	Long	1.9 ± 0.1	3.8 ± 0.1	Slender	25.00 ± 0.37^{b}	High
Pakistan White Basmati	White	7.5 ± 0.2	Long	1.8 ± 0.0	4.2 ± 0.1	Slender	26.57± 0.50^{a}	High

Grain size and shape*: data represented as mean±SE (n=5); Size classification: <5.5mm: short, 5.5-6.3mm: medium, 6.4-7.4mm: Long; Shape classification: Length to width ratio <2.0: round, 2.0-3.0:bold,>3.0: slender. Amylose content**: data expressed as mean±SE (n=3) on % dry basis. Mean values in a column with different letters are significantly different at (P<0.05). Amylose classification: low (10-19%), intermediate (20-25%) and high (>25%).

Moisture content of the rice grain is an important factor which has an influence on the rice grain quality. It primarily affects the keeping quality of rice during storage[15]. Generally the appropriate moisture contents for safe storage of rough rice are 13% for less than six months and 12% for long-term storage[15]. Moisture content of all the tested varieties were less than 13% and thus it is within the appropriate moisture content required for safe storage of whole grain rice[15].

Nutritional value of rice is affected by several factors such as genotype, environmental conditions, storage, post-harvest processes and particularly the degree of milling[26]. The protein, fat, vitamins and minerals in the rice grain are concentrated in the germ and outer layer of the endosperm. Thus milling can lead to reduction of these nutrients[8,26]. It is reported that 7.1-8.3% proteins, 1.6-2.8% crude fat, 0.6-1.0% crude fiber and 1.0-1.5% crude ash contents present in brown rice and these values reduced to 6.3-7.1% protein, 0.3-0.5% crude fat, 0.2-0.5% crude fiber and 0.3-0.8% crude ash in milled rice at 14% moisture content[15]. However milling improves the shelf life and affects the appearance and palatability of rice[8]. Even though, fully polished long grain white rice is widely consumed in the world, whole grain or partially polished pigmented rice are also becoming popular due to health consciousness[11].

The nutritional properties of selected pigmented and white long grain rice varieties of Sri Lanka and Pakistan White Basmati rice studied at different polishing rates are presented in Table-2. At 100% polishing rate, CP content of tested varieties varied between 10.16±0.06 to 11.76±0.04%. At the same polishing rate CIC Black rice exhibited the highest TA (0.86±0.03%) and CF (1.53±0.08%) contents and those values were significantly higher (P<0.05) than that of Pakistan White Basmati rice. Further, at 100% polishing rate TDF (0.45±0.01%) content of CIC Black rice and CP (11.76±0.04%) content of CIC Red Basmati type rice were comparable to Pakistan White Basmati. Results clearly showed a decrease in TA, CF and TDF contents with the increasing polishing rate. Whole grains of CIC Black rice exhibited 1.9, 2.4 and 6.5 fold greater TA, CF and TDF contents in contrast to that of its 100% polishing rate. Similarly whole grains of CIC Red Basmati type rice showed 2.3, 2.1 and 8.7 fold greater TA, CF and TDF contents compared to that of its 100% polishing rate. For CIC Red Basmati type rice at 40% polishing rate these values were 1.7, 1.5 and 5 fold, respectively. For proteins interestingly Black rice and Red Basmati type rices showed increased CP contents with the increasing polishing rate. Further, TC and TAC contents all the tested rice varieties showed an increase with the increasing polishing rate.

The comparison of nutritional properties of tested rice varieties with the other Sri Lankan rice varieties and rice varieties worldwide are presented in Table-4.The tested rice varieties in this study had comparatively high protein content compared to the other Sri Lankan improved rice varieties and other rice varieties world over. The TA and CF contents of selected rice varieties were more or less comparable with the Sri Lankan improved rice varieties and the rice varieties world over. However, the tested rice varieties had comparatively low CP, amylose and TDF contents compared to the Sri Lankan traditional rice varieties. This may be due to varietal difference.

Sensory properties of selected pigmented and white long grain rice varieties of Sri Lanka and Pakistan White Basmati rice used in the study at different polishing rates are summarized in Table-3. Results showed that with increasing polishing rate color of the rice grains has decreased whereas tenderness of the rice grains has increased. No change in aroma has been observed with the increasing polishing rate. Decrease of cohesiveness with the increasing polishing rate was observed only in Black rice. Sensory properties of Red and White Basmati type rice were comparable to Pakistan White Basmati rice.

Considering all, selected pigmented and white long grain rice varieties of Sri Lanka had desirable physicochemical and nutritional properties. However, with the increasing polishing rate nutritional properties of the rice varieties showed a significant reduction.

Table-2: Nutritional properties of selected pigmented and white long grain rice varieties of Sri Lanka and Pakistan white basmati rice at different polishing rates.

Nutritional property	Rice variety	Polishing rate*		
		Whole grain	40%	100%
Moisture	CIC Black rice	12.35 ± 0.02[a]	-	11.77 ± 0.21[a]
	CIC Red Basmati type	12.03 ± 0.00[b]	11.90 ± 0.21	12.04 ± 0.10[a]
	CIC White Basmati type	-	-	11.57 ± 0.21[a]
	Pakistan White Basmati	-	-	11.95± 0.33[a]
Crude protein (CP)	CIC Black rice	10.45± 0.04[b]	-	10.61 ± 0.25[b]
	CIC Red Basmati type	10.76± 0.08[a]	11.44 ± 0.02	11.76 ± 0.04[a]
	CIC White Basmati type	-	-	10.16 ± 0.06[c]
	Pakistan White Basmati	-	-	11.57± 0.04[a]
Total ash (TA)	CIC Black rice	1.64± 0.02[a]	-	0.86 ± 0.03[a]
	CIC Red Basmati type	1.57± 0.03[a]	1.16 ± 0.01	0.67 ± 0.01[b]
	CIC White Basmati type	-	-	0.67 ± 0.01[b]
	Pakistan White Basmati	-	-	0.36± 0.00[c]
Crude fat (CF)	CIC Black rice	3.63± 0.03[a]	-	1.53 ± 0.08[a]
	CIC Red Basmati type	2.57± 0.01[b]	1.78 ± 0.01	1.22 ± 0.06[b]
	CIC White Basmati type	-	-	0.66 ± 0.07[c]
	Pakistan White Basmati	-	-	0.29± 0.01[d]
Total dietary fiber (TDF)	CIC Black rice	2.92± 0.10[a]	-	0.45 ± 0.01[a]
	CIC Red Basmati type	3.21± 0.12[a]	1.85 ± 0.03	0.37 ± 0.01[b]
	CIC White Basmati type	-	-	0.20 ± 0.01[c]
	Pakistan White Basmati	-	-	0.46± 0.03[a]
Total available carbohydrate (TAC)	CIC Black rice	81.36± 0.06[b]	-	86.55 ± 0.23[c]
	CIC Red Basmati type	81.88 ± 0.21[a]	83.78 ± 0.03	85.97 ± 0.04[d]
	CIC White Basmati type	-	-	88.31 ± 0.06[a]
	Pakistan White Basmati	-	-	87.32± 0.06[b]
Total carbohydrate (TC)	CIC Black rice	84.28± 0.05[b]	-	86.99± 0.25[c]
	CIC Red Basmati type	85.09 ± 0.10[a]	85.63 ± 0.02	86.35 ± 0.05[d]
	CIC White Basmati type	-	-	88.51 ± 0.07[a]
	Pakistan White Basmati	-	-	87.77± 0.04[b]

*Data expressed as mean ± SE (n=3). Crude fat, crude protein, total ash, total dietary fiber, total available carbohydrate and total carbohydrate contents are expressed as % dry basis. Mean values in a column within a nutritional property with different letters are significantly different at ($P<0.05$).

Table-3: Sensory properties of selected pigmented and white long grain rice varieties of Sri Lanka and Pakistan white basmati rice used in the study at different polishing rates.

Rice variety	Polishing rate	Appearance	Aroma	Tenderness	Cohesiveness
CIC Black rice	Whole grain	Black	No aroma	Tough	Sticky
	100%	Ash	No aroma	Tender	Separated grains
CIC Red Basmati type	Whole grain	Red-dull	Moderate	Moderate	Separated grains
	40%	Pink	Moderate	Tender	Separated grains
	100%	Light pink	Moderate	Tender	Separated grains
CIC White Basmati type	100%	White	Moderate	Tender	Well separated grains
Pakistan White Basmati	100%	White	Strong	Tender	Well separated grains

Table-4: Comparison of tested Sri Lankan rice varieties with other Sri Lankan rice varieties and rice varieties available worldwide with respect to their nutritional properties[27].

Nutritional property	Tested CIC* Rice Varieties	Other Sri Lankan rice varieties**		Rice Varieties Worldwide[15,28]
		Traditional	Improved	
Crude protein %	10.4-10.8	10.6-13.2	6.4-10.0	7.1-8.3
Total ash %	1.57-1.64	0.8-1.9	1.0-1.7	1.0-1.5
Crude fat %	2.6-3.6	2.2-4.1	2.3-4.3	1.6-2.8
Total dietary fiber %	2.9-3.2	4.9-6.9	-	2.9-4.0
Total carbohydrate %	84.3-85.1	68.6-73.3	70.4-76.3	-
Amylose content %	23.1-27.0	24.5-29.7	25.1-29.4	-

*Whole grain rice has been used, **Whole grain rice has been used.

Conclusion

Physicochemical and nutritional properties varied among the rice varieties tested in this study. There was a significant loss in nutritional properties (CF, TDF and TA contents) with the increasing polishing rate. Interestingly, physicochemical and nutritional properties of 100% polished Black rice, Red Basmati type rice and White Basmathi type rice of Sri Lanka are either superior or comparable to that of Pakistan White Basmati rice. Black rice and Red Basmati type rice which is generally consumed in the form of whole grain or as partially polished rice unlike white Basmati rice hada high nutritional value.

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