Oryza Vol. 53 No.1, 2016 (63-73)

Extra long, long, medium and short grain rices- biochemical and nutritional traits

G Kaur, N Sharma*, S Sharma, P Singh and GS Mangat

Punjab Agricultural University, Ludhiana, Punjab, India

****Email: neerjasharma@pau.edu***

Received : 04 January 2016 Accepted : 20 March 2016 Published : 15 June 2016

ABSTRACT

Nineteen rice genotypes involving four extra long grain, five long grain, seven medium grain and three having short grain sizes were employed in this study to evaluate the biochemical and nutritional properties of varying sizes rice genotypes. The fat content was found to be highest in extra long grain genotypes in brown fraction while in milled fraction, it was found to be highest in long grain rice genotypes. Crude fibre and ash content was found to be highest in extra long grain genotypes in both brown and milled rice fractions. The content of total sugars, reducing sugars and total phenol was found to be highest in extra long grain genotypes in both brown and milled rice fractions. Total amino acids, crude protein and phytate content were found to be highest in medium grain genotypes in both brown and milled fractions. Starch content was found to be higher in milled rice than in brown rice. In brown rice protein fractions, prolamin was found to be in lowest amount while glutelin was found to be in highest amount in all nineteen rice genotypes. Principal component analysis extracted four principal components that explained 78.2% and 80.9% of the total variances in brown and milled rice grains respectively. Therefore, it can be concluded that the grain sizes are fairly good indicators of biochemical and nutritional characters and can be useful in indirect selection of rice genotypes having desired grain composition.

Key words: *rice, grain size, biochemical composition, nutritional composition, protein fractionation*

Rice is the main staple food for two third of the world’s population providing 21% of global dietary energy, 14% of protein and 2% of fat (Kennedy and Burlingame, 2003). It is primarily utilized for its starch content which is approximately 90% of dry grain weight. Among the major cereal grains, rice is the only grain that is widely eaten as a whole grain after cooking. Rice grain generally consists of three major regions, the pericarp, embryo and endosperm. Brown rice is the least processed form; only the hull has been removed, but still retains the germ and several bran layers which contribute a brown colour. Further milling to remove the pericarp, seed coat, testa, aleurone layer and embryo to yield milled or white rice results in a disproportionate loss of lipid, protein, fiber, reducing sugars, total sugars, ash, and minor components including vitamins, free amino acids and free fatty acids. Milled rice is the most common form of rice consumed and has a longer shelf life than brown rice.

Starch is the most abundant storage polysaccharide in rice grains and is the major dietary source of carbohydrates. Rice starch has neutral taste and hence does not affect the final flavour of the product. Protein is the second most abundant constituent of rice; with content ranging from 4 to 15%. Rice protein is superior in nutritional quality because it contains 60% essential amino acids. Rice has a trace amount of fat and no cholesterol which makes it an ideal healthy food for people from all age groups. Brown rice has two times more fiber as white rice provides, but it is not an especially rich source of fiber. Rice grains also contain trace amount of minerals. In addition, rice contains phytic acid, which is the most important anti-nutritional factor that forms complexes with divalent mineral ions like Fe^{2+} and Ca^{2+} and impede their bioavailability.

Grain quality in rice is a complex trait and is difficult to define with precision as preference for quality varies from country to country and within the country from region to region and between ethnic groups. Grain size and shape are usually the first criteria of rice quality that breeders consider when developing new varieties for commercial production. Rice grains can be classified into various categories on the basis of their length *i.e.* extra long (>7.5 mm), long (6.61-7.5 mm), medium (5.51-6.60 mm) and short (<5.51 mm) (Cruz and Khush, 2000). Geographical variations in the preferences for grain size are well described with long grain rice being preferred on the Indian sub-continent, medium grains in Southeast Asia, while short grain rice is consumed in many parts of north Asia (Cruz and Khush, 2000). It is difficult to identify and characterize large number of varieties or genotype on the basis of morphological characters because they are non-stable and originate due to environmental and climatic conditions and therefore phenotypic plasticity is an outcome of adaptation. In such cases, it is important to develop some stable markers, which could help to identify and characterize the required genotype for cultivation as well as breeding programme.

The physicochemical and textural properties of rice grains or the basic food quality and palatability of the cooked product are majorly dependent upon the starch properties. The amylose content, gelatinization temperature, gel consistency and pasting characters are the significant starch properties that influence the cooking and eating characteristics of rice grains. The longer grain types are usually associated with a higher amylose content, higher gelatinization temperature and dry fluffy cooked rice, while the typical short grain types are moist and sticky when cooked. The consumers are interested to get rice which possesses good cooking and eating qualities. Therefore, the present study is planned with the aim to compare the biochemical and nutritional properties of rice genotypes belonging to different grain size.

MATERIALS AND METHODS

A total of nineteen rice genotypes having different sizes *viz.*, four having extra-long grain size (>7.5 mm length), five having long grain size (6.61-7.5 mm length), seven having medium grain size (5.51-6.60 mm length) and three having short grain size (< 5.51 mm length) were used in the present study (Table 1). These rice genotypes were grown in the experimental ûelds of Punjab Agricultural University (Ludhiana, India) following the recommended agronomic practices and were harvested at maturity. They were then air dried until their moisture content was reduced to approximately 14% and were stored at room

Table 1 Designation and size classification of 19 rice genotypes

Rice variety	Designation	Size classification
RYT-BT-10	CSR-30	Extra long grain
RYT-BT-8	Kernel Bas	Extra long grain
RYT-BT-7	CR-2007	Extra long grain
RYT-BT-6	SRB-1617	Extra long grain
RYT-3179	PAU-3739-5-4-1-1	Long grain
RYT-3261	PAU-3762-3-3-2-2-2	Long grain
IHRT-E-23	PR-115	Long grain
RYT-1-14	2K6-Ctk-2871-304-3-2-0	Long grain
RYT-3222	PAU-3832-196-4-1-3	Long grain
RYT-Mutant-3207	PAU-2769-20-2-3-3-2-1-2-M	Medium grain
RYT-3269	2K3-322-5-1-1-1-1-1-1	Medium grain
RYT-3316	2K3-322-5-1-1-9-1-1-1-1-1	Medium grain
RYT-3285	2K6-Ctk-2871-30-2	Medium grain
RYT-3284	2K6-Ctk-2871-30-1	Medium grain
RYT-1-19	UPR-3330-9-1-2	Medium grain
RYT-1116	PR-113	Medium grain
AVT-2-IM-1411	OR-1895-2	Short grain
AVT-IME-1207	CRK-27	Short grain
AVT-2-IME-1104	CRR-624-207-B-1-B	Short grain

temperature for 3 months. Paddy samples of the genotypes under study were cleaned to free them from extraneous matter. Cleaned paddy was dehulled on a Satake (Hiroshima, Japan) THU 35B rice dehusker to obtain brown rice and then milled in a Satake TMO5C testing mill to obtain milled rice with approximately 10% degree of milling. Head rice was obtained using a Satake test rice grader. Brown rice and head rice were ground to pass through a 150 µm sieve on a Cyclotec 1093 mill (Foss, Hoganas, Sweden). The moisture content was determined by keeping the grain sample (2 g) in a hot air oven at 130+1°C for 1 h and then it was calculated in percent from loss in weight of sample. For determination of ash content, rice grain sample (5 g) was incinerated on hot plate until there were no more fumes. Afterwards, kept in muffle furnace at 550°C for 5 hrs; cooled to room temperature, weighed and results were expressed in percentage form. Crude fat and crude fibre content was determined by AACC (2000) and AOAC (1990) methods, respectively.

For determination of soluble sugars and reducing sugars, rice grain powdered sample (0.1 g) was extracted with 15 ml of 80% ethanol followed by 70% ethanol on a water bath within the temperature range of 80-85°C. The supernatants were pooled and concentrated using flash evaporator and then made to volume with distilled water. From this supernatant, soluble sugar content was measured using method described by Dubois *et al*. (1956) while reducing sugar content was measured using method described by Nelson. (1944). For determination of starch content, residues obtained after the extraction of soluble sugars were dried in an oven at 80°C, 2 ml of distilled water was added and kept in boiling water bath for 15 minutes. After cooling, 2 ml of 9.2 N $HClO_4$ was added and stirred the solution occasionally for 15 minutes. Filtered it and collected the filtrate in a test tube. Further 2 ml of 4.6 N $HClO_4$ was added to the residue and again the solution was stirred for 15 minutes. Filtered it, pooled the filtrate and made volume upto 10 ml with distilled water. The total sugars formed were estimated in the extract thus obtained using the procedure of Dubois *et al*. (1956). The amount of starch was calculated by multiplying the content of total sugars by a factor of 0.9.

The percent nitrogen content was determined using method described by AOAC (2000). Protein content was calculated by multiplying percent nitrogen content with a factor of 5.95. The amino acids content was estimated from the aqueous extract obtained during the extraction of soluble sugars using the method described by Lee and Takahashi. (1966). For determination of total phenol content, dried rice powder (0.5 g) was reûuxed with 5 mL of 800 mL L^{-1} methanol for 1 h at 70^0C in a water bath. The reûuxed sample was ûltered and the volume was made to 10 mL with 800 mL L^{-1} methanol. The resulting extract was used for the estimation of total phenols using method described by Swain and Hillis (1959). The phytate content was determined by extracted the one gram of finely ground rice sample with 25 ml of 0.2 N HCl for three hours with continuous shaking in a shaker. After proper shaking, it was filtered through Whatman No. 1 filter paper and volume was made 25 ml with 0.2 N HCl. From this extract, phytate content was measured using method described by Haugh and Lantzch. (1983).

Five gram of rice powder was extracted with 50 ml of petroleum ether with continuous stirring for one hour, and then centrifuged at 15000g for 15 minutes at 4°C and the residue re-extracted twice with petroleum ether. The defatted sample was air-dried overnight at room temperature. From 0.5 g of defatted rice powder, different protein fractions *i.e.* albumin, prolamin, globulin and glutelin were extracted by using method described by Cagampang *et al*. (1966). Further, the protein content in these fractions was estimated by using the method of Lowry *et al.* (1951).

Data were reported as mean ± standard deviation for triplicate determinations of each sample. Analysis of variance and Duncan's Multiple Range Test (DMRT) were performed using SPSS 16.0 (SPSS Inc., Chicago, IL, USA) to identify diûerences between values. Statistical signiûcance was deûned at a level of P d" 0.05 unless speciûed otherwise.

RESULTS AND DISCUSSION

A comparison of the proximate composition *i.e.* moisture, ash, crude fat and crude fibre of rice grains of varying sizes in both brown and milled rice fractions is given in Table 2. It was found that the contents were higher in the brown rice as compared to the milled rice fraction. Moisture content was found to be comparable in milled rice fractions (9.76-11.45%) and brown rice fractions (9.58-11.08%). The proximate composition of

Table 2 Proximate composition of rice genotypes of different sizes

	Moisture (%)		Ash (%)		Crude Fat (%)		Crude Fiber (%)	
Rice variety	Brown Rice	Milled Rice	Brown Rice	Milled Rice	Brown Rice	Milled Rice	Brown Rice	Milled Rice
Extra long grain genotypes								
RYT-BT-10	9.84 cde ± 0.15	9.90 hij ± 0.05	1.42 ef ± 0.02	0.60 c ± 0.02	1.35 j ± 0.01	0.44 d ± 0.01	1.07 a ± 0.03	0.50 a ± 0.02
RYT-BT-8	10.47 b ± 0.45	10.05 fg ± 0.04	1.56 d ± 0.01	0.54 d ± 0.01	1.13 k ± 0.07	0.36 f ± 0.02	1.00 b ± 0.05	0.45 ab ± 0.03
RYT-BT-7	9.84 cde ± 0.06	9.82 jk ± 0.09	1.64 c ± 0.06	0.88 a ± 0.02	3.16 a ± 0.02	0.45 d ± 0.02	0.92 c ± 0.04	0.45 ab ± 0.04
RYT-BT-6	10.04 c ± 0.10	10.01fgh ± 0.08	1.69 b ± 0.02	0.84 b ± 0.03	2.05 d ± 0.04	0.25 h ± 0.03	1.00 b ± 0.06	0.44 b ± 0.04
Mean	10.05	9.95	1.58	0.72	1.92	0.38	1.00	0.46
Long grain genotypes								
RYT-3179	9.77 cde ± 0.02	9.87 ijk ± 0.03	1.34hi ± 0.02	0.37 h ± 0.03	1.74 ef ± 0.07	0.54 c ± 0.02	0.91 c ± 0.03	0.36 cd ± 0.02
RYT-3261	9.58 e ± 0.09	9.76 k ± 0.04	1.20 l ± 0.04	0.36 hi ± 0.02	1.13 k ± 0.02	0.33 g ± 0.03	0.90 c ± 0.05	0.35 cde ± 0.05
IHRT-E-23	9.85 cde ± 0.04	9.91 hij ± 0.06	1.29j ± 0.06	0.41 g ± 0.03	1.65 hi ± 0.03	0.44 d ± 0.01	0.87 cd ± 0.02	0.31 cdef ± 0.02
RYT-1-14	9.73 cde ± 0.06	9.89 hij ± 0.07	1.39 efg ± 0.06	0.51 e ± 0.01	1.76 e ± 0.04	0.66 a ± 0.04	0.86 cde ± 0.04	0.35 cde ± 0.04
RYT-3222	9.80 cde ± 0.02	10.00 fgh ± 0.06	1.22 l ± 0.04	0.46 f ± 0.02	2.08 d ± 0.08	0.68 a ± 0.05	0.87 cd ± 0.07	0.37 c ± 0.04
Mean	9.75	9.89	1.29	0.42	1.67	0.53	0.88	0.35
Medium grain genotypes								
RYT-Mutant-3207	10.00 cd ± 0.13	10.11 f ± 0.05	1.35 gh ± 0.02	0.37 h ± 0.02	1.76 e ± 0.01	0.58 b ± 0.02	0.80 de ± 0.02	0.30 efg ± 0.02
RYT-3269	10.68 b ± 0.05	10.88 d ± 0.09	1.09 m ± 0.07	0.31 j ± 0.03	1.13 k ± 0.02	0.35 f ± 0.03	0.79 e ± 0.04	0.24 ghij ± 0.04
RYT-3316	9.89 cde ± 0.13	10.69 e ± 0.07	1.30 ij ± 0.09	0.39 g ± 0.06	1.70 fg ± 0.05	0.41 e ± 0.05	0.86 cd ± 0.03	0.26 fghi ± 0.03
RYT-3285	9.75 cde ± 0.17	10.69e ± 0.06	1.21 l ± 0.05	0.34 i ± 0.08	2.27 c ± 0.06	0.53 c ± 0.02	0.82 de ± 0.04	0.28 fgh ± 0.01
RYT-3284	9.63 de ± 0.09	10.61e ± 0.06	1.27 jk ± 0.09	0.36 hi ± 0.05	2.82 c ± 0.07	0.52 c ± 0.01	0.86 cd ± 0.03	0.30 def ± 0.02
RYT-1-19	9.67 cde ± 0.05	9.93 ghij ± 0.09	1.40 ef ± 0.08	0.59 e ± 0.03	1.68 gh ± 0.04	0.43 de ± 0.05	0.79 e ± 0.04	0.29 efgh ± 0.04
RYT-1116	9.86 cde ± 0.07	9.98 fghi ± 0.11	1.23 kl ± 0.01	0.29 j ± 0.03	1.16 k ± 0.03	0.25^{h} ± 0.03	0.79^{e} ± 0.05	0.24 ghij ± 0.04
Mean	9.93	10.41	1.26	0.37	1.78	0.44	0.82	0.27
Short grain genotypes								
AVT-2-IM-1411	10.80 ab ± 0.54	11.45 a ± 0.10	1.75 a ± 0.03	0.84 b ± 0.05	2.22 c ± 0.02	0.36 f ± 0.02	0.66 f ± 0.02	0.22 ij ± 0.03
AVT-IME-1207	11.02 a ± 0.16	11.14 c ± 0.07	1.43e ± 0.05	0.56 d ± 0.01	1.14 k ± 0.02	0.22 i ± 0.01	0.71 f ± 0.03	0.23 hij ± 0.04
AVT-2-IME-1104	11.08 a ± 0.18	11.27 b ± 0.02	1.38 fgh ± 0.02	0.48 f ± 0.02	1.62 i ± 0.04	0.36 f ± 0.04	0.70 f ± 0.05	0.20 j ± 0.04
Mean	10.96	11.29	1.52	0.63	1.66	0.31	0.69	0.21
Overall Mean	10.07	10.31	1.38	0.50	1.77	0.43	0.85	0.32

Values are mean ± SD of three replicates. Values with diûerent letters in the same column are signiûcantly diûerent at P d” 0.05.

rice grains includes moisture, ash, crude fat and crude fibre. Moisture content is the most important criterion for rough rice. Its effects are of primary importance as far as keeping properties of rice during storage are concerned. This is because under practical storage conditions, moisture level is usually the factor most responsible for controlling the rate of deterioration of the grain. Moisture is dependent on genetic makeup of varieties and agronomic as well as climatic conditions. The moisture content of rice prior to cooking affects its texture. The samples with lower moisture have tendency of cracking during cooking and hence a poorer cooking texture. Ash content was found to be higher in brown rice fractions (1.09- 1.75%) as compared to milled rice fractions (0.29-0.88%). Mineral content is measured as "ash" after incineration at >550°C. The minerals (ash) are concentrated primarily in the outer layers of rice or in the bran fraction. The mineral content of the rice grain is also affected by the mineral content of the soil and irrigation water. Fibre, especially that found in whole grains are not digested by enzymes in the human intestinal tract. Increase in fibre content in rice may improve the human health by lowering the plasma cholesterol. Crude fibre content in brown rice fraction possessed an average mean value of 0.85% as compared to milled fraction which has an average mean value of 0.32%. The ash and crude fibre content was found to be highest in extra long grain genotypes in both brown and milled fractions (Table 2). About 3% of dietary fibre can be obtained from brown rice while only 0.5% from milled rice (OECD Environment, 2004). Brown rice has two times more fiber as white rice provides. The foods rich in fiber augment the functions of digestive system and also reduce the risk of intestinal disorders. Average mean value of crude fat content was of 1.77% as compared to milled fraction which has an average mean value of 0.43%. Crude fat content was found to be highest in extra long grain genotypes (1.92%) in brown fraction while in milled rice fraction was found to be highest in long grain genotypes (0.53%). Juliano and Bechtel (1985) have reported that the crude fat content in brown and milled rice fractions were in the range between 1.6-2.8% and 0.3-0.5%, respectively. The fat content of rice is low and most of it is removed in the process of milling and is contained in the bran. So, brown rice contains more fat as compared to milled rice varieties. The higher fat content in the brown rice makes it susceptible to rancidity due to lipase activity on the oil, so milled rice is mainly consumed. Overall, the ash, crude fat and crude fibre contents were found to be higher in the brown rice fraction as compared to the milled rice fraction of the genotypes under study (Table 2).

A comparison of the biochemical constituents, *i.e.* total sugars, reducing sugars, starch, crude proteins, total amino acids, total phenols and phytate of rice grains of varying sizes in both brown and milled rice fractions is given in Tables 3 and 4. Significant differences were observed in carbohydrate content *i.e.* soluble sugars, reducing sugars and starch in rice grains of varying sizes (Table 3). The carbohydrates of rice grains include soluble sugars, reducing sugars and starch. Carbohydrates are known to contribute the greatest quota of energy required by man and animal. The soluble sugars and reducing sugars contents were found to be higher in brown rice as compared to milled rice. Soluble sugars and reducing sugars content were found to be highest in extra long grain genotypes in both brown and milled rice fractions. Among all 19 genotypes, a short grain genotype (IM-1411) was found to have the highest soluble sugar and reducing sugar content in both brown and milled fractions. Juliano (1972) has reported that the soluble sugars content varied from 8.3-13.6 mg g^{-1} and 2.5-5.3 mg g^{-1} in brown and milled rice respectively, and the reducing sugars content varied from 0.9-1.3 mg g^{-1} and 0.50-0.80 mg g^{-1} in brown and milled rice, respectively. The major non-reducing sugar of the rice grain is sucrose, with small amounts of raffinose, while glucose and fructose are major reducing sugars. The sugar concentration in rice grains decreases towards the center of the kernel. So, brown rice contained more amounts of sugars as compared to milled rice. Sugar concentration is affected by variety, degree of milling and processing. The content of starch was found to be higher in the milled rice (75.21-79.97%) as compared to brown rice fraction (64.71-68.15%). Starch content was found to be highest in short grain genotypes in both milled and brown fractions. These results are in accordance with those reported by Juliano and Bechtel (1985). Starch constitutes 90% of the dry weight of milled rice. Main role of starch is providing the major calories in the diet; it is also used in food manufacture to improve the functional properties of food. Starch is the only constituent of rice that increases in concentration from periphery to the centre of the kernel (Burell, 2003)

Table 3 Carbohydrate Content of rice grains of varying sizes

Variety	Soluble sugars(mg/g)		Reducing sugars (mg/g)		Starch (g/100g)	
	Brown Rice	Milled Rice	Brown Rice	Milled Rice	Brown Rice	Milled Rice
Extra long grain genotypes						
RYT-BT-10	11.34 d ± 0.10	3.30 d ± 0.09	3.13 c ± 1.34	1.38 def ± 0.62	66.83 abc ± 1.01	77.06 dc ± 0.61
RYT-BT-8	9.76 h ± 0.19	2.49 g ± 0.10	2.28 e ± 1.09	1.55 cd ± 0.71	64.98 de ± 0.61	76.27 e ± 0.53
RYT-BT-7	10.59 f ± 0.11	2.91 e ± 0.13	3.09 c ± 1.37	1.21 f ± 0.55	64.71 e ± 1.02	77.86 c ± 0.53
RYT-BT-6	11.31 d ± 0.18	3.31 d ± 0.11	2.95 cd ± 1.33	1.71 bc ± 0.77	66.83 abc ± 1.59	79.18 ab ± 0.61
Mean	10.75	3.00	2.86	1.46	63.84	77.59
Long grain genotypes						
RYT-3179	8.29 i ± 0.16	1.81 i ± 0.12	1.60 f ± 0.74	0.59 h ± 0.28	66.83 abc ± 0.53	77.06 cd ± 0.61
RYT-3261	11.73 c ± 0.37	3.03 e ± 0.05	3.51 b ± 1.58	1.55 cd ± 0.71	67.89 ab ± 0.53	77.33 cd ± 0.54
IHRT-E-23	10.65 ef ± 0.27	2.61 fg ± 0.12	2.79 cd ± 1.27	0.72 h ± 0.33	66.30 bcd ± 0.59	76.27 de ± 0.49
RYT-1-14	12.15 b ± 0.24	3.45 c ± 0.14	3.50 b ± 1.63	1.84 b ± 0.83	67.09 abc ± 0.61	79.44 a ± 0.52
RYT-3222	10.11 g ± 0.11	2.03 h ± 0.06	2.79 cd ± 1.27	0.59 h ± 0.27	67.36 abc ± 1.01	79.86 c ± 0.57
Mean	10.59	2.59	2.84	1.06	65.09	77.99
Medium grain genotypes						
RYT-Mutant-3207	6.95 k ± 0.20	1.27 k ± 0.09	1.03 h ± 0.48	0.36 i ± 0.17	66.56 abc ± 0.87	75.74 e ± 0.57
RYT-3269	8.50 i ± 0.23	1.95 h ± 0.13	1.55 fg ± 0.73	0.67 h ± 0.30	65.77 cde ± 0.53	75.21 e ± 0.49
RYT-3316	10.29 g ± 0.15	2.67 f ± 0.06	2.63 d ± 1.19	0.98 g ± 0.45	68.15 a ± 0.61	78.12 bc ± 0.61
RYT-3285	7.82 j ± 0.23	1.51 j ± 0.06	1.24 gh ± 0.57	0.59 h ± 0.28	65.77 cde ± 0.59	77.59 c ± 0.87
RYT-3284	9.69 h ± 0.17	2.07 h ± 0.06	1.97 e ± 0.91	0.75 h ± 0.35	66.30 bcd ± 0.48	77.06 cd ± 0.61
RYT-1-19	6.89 k ± 0.25	0.98 l ± 0.11	0.46 i ± 0.23	0.21 i ± 0.22	67.09 abc ± 0.61	78.12 bc ± 0.61
RYT-1116	10.12 g ± 0.23	1.25 k ± 0.06	2.68 d ± 1.62	0.64 h ± 0.17	68.15 a ± 0.37	77.57 c ± 0.48
Mean	8.61	1.67	1.65	0.60	66.83	77.06
Short grain genotypes						
AVT-2-IM-1411	12.75 a ± 0.11	4.01 a ± 0.08	3.95 a± 1.78	2.07 a ± 0.94	67.88 ab ± 0.33	77.06 cd ± 0.61
AVT-IME-1207	10.89 e ± 0.23	1.97 h ± 0.05	3.15 c ± 1.43	1.34 ef ± 0.62	67.36 abc ± 0.59	79.18 ab ± 0.36
AVT-2-IME-1104	8.39 i ± 0.06	1.54 j ± 0.08	0.98 h ± 0.45	0.33 i ± 0.19	67.09 abc ± 0.37	79.97 a ± 0.59
Mean	10.68	2.51	2.70	1.25	67.44	78.74
Overall Mean	10.16	2.44	2.51	1.09	64.79	77.85

Values are mean ± SD of three replicates. Values with different letters in the same column are significantly different at P d” 0.05.

and is essentially composed of two glucose polymers, amylose and amylopectin. Starch also determines the physical and cooking properties of rice grains.

Rice is mainly a carbohydrate staple food, but is often the most important source of protein in people's diet. Protein is only a secondary factor of rice eating quality but it makes a fundamental contribution to nutrition. The protein quality is determined by amino acid composition and by its digestibility. Protein plays role in both nutritional and functional properties of rice grain. Rice proteins are colorless and having a bland taste. They are non allergenic and possess cholesterol reducing properties (Chrastil, 1992). Greater protein content of rice is found in the bran and periphery of the endosperm. During milling and polishing, these layers are removed and polished rice always contains less protein than brown rice (Juliano, 1985). The crude protein content was found to be higher in brown rice fraction with an average mean value of 9.51% as compared to milled fraction which has an average mean value of 6.92%. Crude protein content was found to be highest in medium grain genotypes in both brown and milled fractions with average values 10.84% and 8.62% respectively (Table 4). Protein content is correlated with cooking texture (Hamaker and Griffin, 1990). Rice varieties with low protein have more flavour, and were more tender and cohesive than high protein samples (Onate *et al.*, 1964) whereas high protein varieties displayed lower water absorption and restricted starch granule swelling (Martin and Fitzgerald, 2002). Despite the negative influence on the texture of cooked rice, high protein content rice is considered to be nutritious. The protein content of rice differs according to the variety grown and is affected by growing conditions such as early and late maturing, soil fertility and water stress as well as degree of milling and polishing (OECD

Table 4 Biochemical composition of rice grains of varying sizes

	Crude Protein (g/100g)		Total Amino Acids (mg/g)		Total Phenols (mg/g)		Phytate (mg/g)	
Rice variety	Brown Rice	Milled Rice	Brown Rice	Milled Rice	Brown Rice	Milled Rice	Brown Rice	Milled Rice
Extra long grain genotypes								
RYT-BT-10	12.49 a ± 0.34	10.24 a ± 0.16	0.25 abcd ± 0.01	0.19 bcd ± 0.02	0.95 a ± 0.01	0.33 a ± 0.06	2.15 g ± 0.05	0.30 h ± 0.02
RYT-BT-8	10.32 e ± 0.15	7.58 fg ± 0.34	0.27 a ± 0.02	0.24 a ± 0.01	0.71 bcde ± 0.09	0.24 ab ± 0.03	2.54 e ± 0.06	0.59 cd ± 0.03
RYT-BT-7	10.08 efg ± 0.18	7.75 ef ± 0.33	0.19 gh ± 0.03	0.17 de ± 0.02	0.89 ab ± 1.00	0.27 ab ± 0.09	2.37 f± 0.04	0.45 f ± 0.04
RYT-BT-6	10.33 e ± 0.24	7.59 fg ± 0.17	0.21 defgh ± 0.02	0.17 de ± 0.03	0.71 bcde ± 0.09	0.25 ab ± 0.02	2.13 g ± 0.06	0.33 h ± 0.08
Mean	10.81	8.29	0.23	0.19	0.82	0.27	2.30	0.42
Long grain genotypes								
RYT-3179	5.75 l ± 0.56	3.50 k ± 0.20	0.20 efgh ± 0.02	0.15 ef ± 0.02	0.80 abcd ± 1.00	0.30 ab ± 1.00	1.58 lm ± 0.04	0.17 j ± 0.02
RYT-3261	6.50 k ± 0.24	4.58 j ± 0.18	0.19 gh ± 0.01	0.17 de ± 0.02	0.71 bcde ± 0.18	0.22 ab ± 0.06	1.67 kl ± 0.03	0.21 ij ± 0.06
IHRT-E-23	6.84 j ± 0.19	3.75 k ± 0.32	0.22 defg ± 0.02	0.20 bcd ± 0.03	0.71 bcde ± 0.27	0.28 ab ± 0.07	1.74 j ± 0.04	0.29 h ± 0.04
RYT-1-14	6.92 j ± 0.17	3.67 k ± 0.27	0.17 h ± 0.02	0.13 f ± 0.02	0.66 cde ± 0.11	0.20 b ± 0.02	1.66 k ± 0.08	0.23 i ± 0.06
RYT-3222	8.08 i ± 0.21	5.08 i ± 0.16	0.21 defg ± 0.02	0.20 bcd ± 0.01	0.75 abcd ± 0.06	0.21 ab ± 0.03	1.54 m ± 0.05	0.18 ij ± 0.05
Mean	6.82	4.12	0.20	0.17	0.73	0.24	1.63	0.22
Medium grain genotypes								
RYT-Mutant-3207	9.83 g ± 0.20	7.83 ef ± 0.21	0.26 abc ± 0.02	0.22 ab ± 0.02	0.71 bcde ± 0.18	0.33 a ± 0.10	2.57 de ± 0.06	0.60 cd ± 0.02
RYT-3269	9.92 fg ± 0.17	8.66 c ± 0.28	0.24 bcdef ± 0.01	0.19 bcd ± 0.02	0.62 de ± 0.09	0.23 ab ± 0.11	2.64 cd ± 0.05	0.65 b ± 0.04
RYT-3316	10.24 ef ± 0.42	8.66 c ± 0.32	0.23 cdefg ± 0.02	0.20 bcd ± 0.03	0.66 cde ± 0.10	0.23 ab ± 0.09	2.74 b ± 0.04	0.74 a ± 0.05
RYT-3285	11.99 b ± 0.27	9.58 b ± 0.38	0.27 ab ± 0.02	0.20 bcd ± 0.04	0.71 bcde ± 0.09	0.30 ab ± 0.09	2.85 a ± 0.06	0.76 a ± 0.08
RYT-3284	11.49 cd ± 0.20	8.24 d ± 0.16	0.24 abcde ± 0.03	0.19 bcd ± 0.01	0.76 abcd ± 0.01	0.25 ab ± 0.12	2.57 de ± 0.09	0.62 bc ± 0.03
RYT-1-19	11.58 c ± 0.25	8.75 c ± 0.35	0.22 defg ± 0.02	0.20 bcd ± 0.03	0.52 e ± 0.09	0.26 ab ± 0.08	2.66 c ± 0.02	0.53 e ± 0.03
RYT-1116	11.16 d ± 0.18	8.00 de ± 0.27	0.20 fgh ± 0.02	0.17 cde ± 0.02	0.75 abcd ± 0.15	0.25 ab ± 0.06	2.67 bc ± 0.08	0.56 de ± 0.08
Mean	10.89	8.53	0.24	0.20	0.68	0.26	2.67	0.64
Short grain genotypes								
AVT-2-IM-1411	10.24 ef ± 0.20	7.24 g ± 0.14	0.20 fgh ± 0.04	0.13 f ± 0.02	0.71 bcde ± 0.18	0.21 b ± 0.03	1.95 h ± 0.05	0.41 fg ± 0.02
AVT-IME-1207	8.24 i ± 0.24	5.67 h ± 0.28	0.18 h ± 0.02	0.13 f ± 0.03	0.75 abcd ± 0.15	0.23 ab ± 0.04	1.87 i ± 0.03	0.40 g ± 0.03
AVT-2-IME-1104	8.67 h ± 0.15	5.67 h ± 0.32	0.24 abcde ± 0.03	0.19 bcd ± 0.01	0.85 abc ± 0.11	0.28 ab ± 0.07	1.86 i ± 0.06	0.32 h ± 0.05
Mean	9.04	6.19	0.21	0.15	0.77	0.24	1.89	0.38
Overall Mean	9.51	6.92	0.22	0.18	0.75	0.26	2.20	0.44

Values are mean ± SD of three replicates. Values with different letters in the same column are significantly different at P d” 0.05.

Environment, 2004). Rice is not rich source of protein but the protein quality of rice is far superior to other cereals. The composition of the rice essential amino acids *i.e.* histidine, proline, and threonine varied widely. The variation in the amino acid content was probably due to the genetic and environmental factors. Amino acids are building blocks of proteins. The total amino acid content was found to be higher in brown rice (0.17-0.27 mg g^{-1}) as compared to milled rice (0.13-0.24 mg g^{-1}). However, a relatively low variation in total amino acid content was found between the brown and milled genotypes. Houston *et al*. (1969) also reported a low variation in amino acid content in milled rice. Rice protein is a good source of essential amino acids for human nutrition.

Phenols are compounds possessing one or more aromatic rings with one or more hydroxyl groups. The results of this study suggested that the concentration of total phenols increased from endosperm to the periphery of grain. The difference in the phenolic content may be due to the difference in the genotypes under study and the age of samples at the time of estimation. Storage of rice grains has been reported to decrease the total phenols content in rice grains (Zhou *et al*., 2004). Significant differences were found in the total phenolic content of brown and milled rice fractions. The total phenolic content and phytate contents were found to be higher in brown rice as compared to milled rice. The extra long grain genotype, RYT-BT-10 was found to have the highest total phenolic content in brown rice fraction (0.95 mg g^{-1}) as well as in milled fraction (0.33 mg g^{-1}). Hodzic *et al*. (2009) reported that brown rice is richer in phenols than white rice. Phytic acid (myo-inositol-1,2,3,4,5,6-hexakisphosphate) is the most abundant form of phosphorus in cereal grains and is important to grain nutritional quality. In mature rice grains, the bulk of phytic acid is found in the germ and aleurone layer of rice grains. So, phytate content was observed higher in brown rice than in milled rice. Phytic acid is an anion at physiological pH (7.35-7.45), and forms insoluble complexes by chelating minerals. As a result, the bioavailability of these micronutrients will be decreased. The medium grain genotype, RYT-3285 was found to have the highest phytate content in brown rice fraction (2.85 mg g^{-1}) as well as in milled fraction (0.76 mg g^{-1}) (Table 4).

The content of different classes of proteins in brown rice based on their solubility is represented in Table 5. Albumin was found to be present in the range of 4.02-8.07%, prolamin varied from 1.18-5.36% while globulin was 9.64-14.24%. Albumin, prolamin and globulin were found to be highest in extra long grain genotypes with the average mean values of 7.88%, 5.10% and 14.16%, respectively. However, glutelin content was highest among all the protein classes (mean range of 79.61%) and was found to be highest in short grain genotypes with the average mean value of 84.17%. Thind and Sogi, (2003) reported the content of albumin (4.6-7.4%), prolamin (0.9-2.5%), globulin (9.4-12.5%) and glutelin (54.9-70.5) in medium, long and extra long rice grains. The rice proteins are composed of 5% albumin, 10% globulin, 5% prolamin and 80% glutelin (Takaiwa *et al*., 1999). Ratio of albumin, globulin, prolamin, and glutelin for brown rice are reported as 5-17: 4-12: 2-5: 73-86 (mean, 9:7:4:80) (Mitra and Das, 1975). In our results, the major fraction of storage proteins was glutelin (79.61%) while prolamin (2.90%) was minimal in all 19 genotypes.

Pairwise correlation between grain size, 1000-grain weight and proximate constituents, carbohydrates, amino acid, total phenols and phytate content among rice genotypes of varying sizes was done at 1% and 5% level of significance. In brown and milled rice grains, length and length:breadth ratio of grains positively correlated with fibre content while breadth of grains was negatively correlated with fibre content at 1% level of significance. In brown rice, breadth was found to be positively correlated with starch content at 1% level of significance while 1000-grain weight of paddy was negatively correlated with ash content of milled rice at 5% level of significance. Correlations were done among grain size, 1000-grain weight of paddy and nutritional constituents among the genotypes under study. For the ease of breeding, the indirect selection approaches are often used. One of the indirect selection methods is to use the grain size which can be easily measured with dial guage/vernier calliper. The length and l/b ratio of brown and milled grains are positively correlated with fibre content. So, in rice breeding programmes, high fibre content of breeding lines could be indirectly selected with higher grain length and higher l/b ratio of grains while higher starch content could be indirectly selected with broader grains.

Principal component analysis was performed

Table 5 Content of Protein classes in brown fraction of genotypes of different sizes

Variety	Albumin	Prolamin	Globulin	Glutelin
Extra long grain genotypes				
RYT-BT-10	7.66 d ± 0.07	5.36 a ± 0.04	14.21 a ± 0.05	72.76 o ± 0.06
RYT-BT-8	7.93 b ± 0.04	4.96 c ± 0.08	14.24 a ± 0.06	72.87 n ± 0.05
RYT-BT-7	8.07 a ± 0.03	5.08 b ± 0.06	14.16 b ± 0.10	72.70 p ± 0.05
RYT-BT-6	7.86 c ± 0.05	4.98 c ± 0.09	14.03 c ± 0.06	73.14 m ± 0.09
Mean	7.88	5.10	14.16	72.87
Long grain genotypes				
RYT-3179	5.39 h ± 0.05	1.43 l ± 0.04	11.21 j ± 0.06	81.94 d ± 0.05
RYT-3261	5.64 g ± 0.04	1.69 jk ± 0.09	11.17 k ± 0.05	81.50 e ± 0.04
IHRT-E-23	5.69 f ± 0.06	1.87 i ± 0.03	11.30 i ± 0.08	81.15 g ± 0.03
RYT-1-14	5.84 e ± 0.06	1.72 j ± 0.04	11.07 l ± 0.03	81.37 f ± 0.06
RYT-3222	5.82 e ± 0.03	1.87 i ± 0.05	11.18 jk ± 0.02	81.14 g ± 0.08
Mean	5.68	1.72	11.19	81.42
Medium grain genotypes				
RYT-Mutant-3207	4.16 m ± 0.05	3.51 e ± 0.07	12.31 d ± 0.05	80.02 k ± 0.06
RYT-3269	4.25 l ± 0.06	3.59 d ± 0.04	12.17 f ± 0.06	79.99 k ± 0.05
RYT-3316	4.62 j ± 0.05	3.44 f ± 0.04	12.10 g ± 0.04	78.85 l ± 0.03
RYT-3285	4.46 k ± 0.03	3.23 h ± 0.05	12.09 g ± 0.05	80.12 i ± 0.04
RYT-3284	4.02 n ± 0.09	3.25 h ± 0.03	12.04 h ± 0.04	80.73 h ± 0.05
RYT-1-19	4.26 l ± 0.03	3.39 g ± 0.06	12.23 e ± 0.05	80.12 i ± 0.06
RYT-1116	4.48 k ± 0.06	3.43 f ± 0.05	12.03 h ± 0.08	80.07 j ± 0.08
Mean	4.32	3.41	12.14	79.99
Short grain genotypes				
AVT-2-IM-1411	4.59 j ± 0.06	1.18 n ± 0.04	9.64 o ± 0.03	84.59 a ± 0.04
AVT-IME-1207	4.70 i ± 0.04	1.67 k ± 0.06	9.99 m ± 0.04	83.64 c ± 0.06
AVT-2-IME-1104	4.73 i ± 0.08	1.29 m ± 0.05	9.72 n ± 0.06	84.27 b ± 0.09
Mean	4.67	1.38	9.78	84.17
Overall Mean	5.64	2.90	11.82	79.61

Values are mean ± SD of three replicates. Values with different letters in the same column are significantly different at P d” 0.05.

on the eleven variables including total sugars, reducing sugars, starch, amylose, crude protein, amino acid, phenols, phytate, fat, fibre and ash contents of brown and milled rice grains (Tables 6 and 7). All the eleven principal components and their corresponding eigen values and variances of brown and milled grains are listed in Table 8. In brown grains, the results indicated that first four principal components could explain 78.2% of the total variance. The first principal component (PC1) was the most important one, explaining 38.9% of total variance. The PC1 represented the proximate constituents, carbohydrates, phenols, amino acid and phytate parameters (Table 9). The 38.9% variation in the first PC was mainly due to the variation in total sugars, reducing sugars, amylose, amino acid and fibre contents, for which the eigen values were 0.432, 0.427, 0.431, -0.386 and -0.389, respectively. This proved that first principal component (PC1) positively correlated with total sugars, reducing sugars and amylose contents while it correlated negatively with amino acid and fibre content. The second principal component (PC2) accounted for an additional 18.6% of total variance, which was mainly attributed to starch and ash contents with the eigen values of -0.422 and 0.415, respectively. The third principal component (PC3) accounted for the 11.9% of total variance. The variation was mainly attributed to phytate and fat contents. The fourth principal component (PC4) accounted for the 8.7% of total variance. This variation was mainly generated by crude protein and phenols contents with the eigen values of 0.493 and -0.667, respectively.

In case of milled grains, its results also indicated that the first four principal components explain 80.9% of total variance. The first principal component explaining 36.1% of total variance, accounted due to variation in the reducing sugars, and amino acid contents, for which eigen values are 0.384 and -0.364, respectively (Table 7). This indicated that the first principal component positively correlated with the reducing sugars and negatively correlated with amino

Table 6. Principal component analysis for eleven parameters in brown and milled rice grains

	Brown rice grains			Milled rice grains		
Component	Eigenvalue	Variance (%)	Cumulative variance (%)	Eigenvalue	Variance (%)	Cumulative variance (%)
1	4.282	38.9	38.9	3.970	36.1	36.1
2	2.046	18.6	57.5	2.012	18.3	54.4
3	1.314	11.9	69.5	1.657	15.1	69.4
4	0.962	8.7	78.2	1.262	11.5	80.9
5	0.752	6.8	85.1	0.787	7.2	88.1
6	0.712	6.5	91.5	0.552	5.0	93.1
7	0.340	3.1	94.6	0.292	2.7	95.8
8	0.319	2.9	97.5	0.203	1.8	97.6
9	0.218	2.0	99.5	0.131	1.2	98.8
10	0.041	0.4	99.9	0.090	0.8	99.6
11	0.014	0.1	100.0	0.042	0.4	100.0

Table 7 Sources of variation for the first four principal components (PC) in brown and milled grains

	Brown rice grains				Milled rice grains			
	PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4
Total sugars	0.432	0.048	-0.232	-0.104	0.369	-0.373	0.073	-0.223
Reducing sugars	0.427	0.043	-0.198	-0.167	0.384	-0.359	-0.078	-0.245
Amylose	0.431	0.081	0.098	0.240	0.364	0.232	-0.189	0.438
Crude proteins	-0.138	0.427	-0.271	0.493	-0.229	-0.395	-0.356	0.339
Amino acids	-0.386	0.219	-0.219	0.030	-0.364	-0.170	0.138	0.213
Phenols	0.123	0.348	0.053	-0.667	-0.275	-0.140	0.278	0.351
Starch	0.222	-0.422	-0.147	0.250	0.299	0.360	-0.059	0.475
Phytate	0.075	0.372	-0.608	-0.074	-0.328	-0.182	-0.451	0.033
Fibre	-0.389	-0.001	-0.101	-0.091	0.116	-0.428	0.463	0.261
Ash	0.237	0.415	0.260	0.371	0.325	-0.329	-0.082	0.343
Fat	-0.017	0.386	0.552	-0.033	-0.075	0.137	0.549	0.046

acid content. The second principal component accounted for (PC2) for an additional 18.3% of total variance, which was mainly due to total sugars and crude protein contents. The third principal component accounted for 15.1% of total variance, contributed by phytate, fibre and fat contents. The fourth principal component mainly representing the amylose, phenols, starch and ash contents explained the 11.5% of total variance.

We can conclude that extra long grain genotypes possessed highest content of biochemical constituent's namely crude fat, crude fibre, crude proteins, ash, total soluble sugars, total reducing sugars and total phenols in both brown and milled rice fractions. The medium sized genotypes possessed highest crude protein (equivalent to extra long genotypes), total amino acids and phyate content in brown and milled rice fractions. They possessed the lowest amount of ash and total soluble sugars in their brown and milled rice fractions, while lowest starch content was also present in the milled rice fraction of medium grain genotypes. Short grain genotypes possessed the lowest crude fat and crude fibre and highest starch and amylose contents. In the long grain genotypes, no particular trend was observed in biochemical and nutritional characters. Rice breeders can further increase the content of fibre by indirect selection of breeding lines with greater length and higher l/b ratio. However, a study involving a higher number of genotypes is required to give conclusive results.

REFERENCES

AACC 2000. American Association of Cereal Chemists. Approved laboratory methods. St. Paul, Minnesota, USA.

AOAC 1990. American Association of Cereal Chemists. Official methods of analysis. Washington, D.C.

AOAC 2000. American Association of Cereal Chemists. Official methods of analysis. Washington, D.C.

Burrell MM 2003. Starch: the need for improved quality or quantity-an overview. Journal of Experimental Botany 54: 451-456.

Cagampang GB, Cruz LJ, Espiritu SG, Santiago RS and Juliano BO 1966. Studies on the extraction and composition of rice Prolamins. Cereal Chemistry 43: 145.

Charstil J 1992. Correlation between the physico-chemical and functional properties of rice. Journal of Agricultural and Food Chemistry 40: 1683-1686.

Cruz ND and Khush GS 2000. Rice grain quality evaluation procedures. In: Singh R K, Singh U S, Khush G S (ed) Aromatic Rices. Oxford and IBH Publishing, New Delhi.

Dubois M, Gills KA, Hamilton JK and Robers PA 1956. Colorimetric method for the determination of sugars and related substances. Analytical Chemistry 28: 350-356.

Hamaker BR and Griffin VK 1990. Changing the viscoelastic properties of cooked rice through protein disruption. Cereal Chemistry 67: 261-264.

Haug W and Lantzsch H 1983. Sensitive method for the rapid determination of Phytate in cereals and cereal products. Journal of the Science of Food and Agriculture 34: 1423-1426.

Hodzic Z, Pasalic H, Memisevic A, Srabovic M, Saletovic M and Poljakovic M 2009. The influence of total phenols content on antioxidant capacity in the whole grain extracts. European Journal of Science Research 28: 471-477.

Houston DF, Allis ME and Kohler GO 1969. Amino acid composition of rice and rice by-products. Cereal Chemistry 46: 527-537.

Juliano BO and Bechtel DB 1985. The Rice grain and its Gross composition. In: Juliano B O (eds) Rice: Chemistry and Technology. American Association of Cereal Chemists, St Paul, Minneosta, USA.

Juliano BO 1972. The rice caryposis and its composition. In: Huston D F (ed) Rice: Chemistry and Technology. American Association of Cereal Chemists, St Paul, Minneosta.

Juliano BO 1985. Criteria and tests for rice grain qualities. In: Juliano B O (ed) Rice: Chemistry and Technology. American Association of Cereal Chemists, St Paul, Minnesota.

Kennedy G, Burlingame B 2003. Analysis of food composition data on rice from a plant genetic resources perspective. Food Chemistry 80: 589-596.

Lee YP and Takahashi T 1966. An improved colorimetric determination of amino acids with the use of ninhydrin. Analytical Biochemistry 14: 71-77.

Lowry OH, Rosebrough NJ, Farr AL and Randall RJ 1951. Protein measurement with folin-phenol reagent. Journal of Biological Chemistry 193: 265-275.

Martin M and Fitzgerald MA 2002. Proteins in rice grains influence cooking properties. Journal of Cereal Science 36: 285-294.

Mitra GN and Das B 1975. Nutritive value of some rice varieties grown in Orissa; Protein content and composition of protein. Journal of Research Orissa University of Agriculture and Technology 5: 51-57.

Nelson N 1944. A photometric adaption of the somogyi method for determination of glucose. Journal of Biological Chemistry 153: 375-380.

OECD 2004. Organisation for Economic Co-operation and Development. Series on the safety of novel foods and feeds. Paris, France.

Onate TU, Del Mundo AM and Juliano BO 1964. Relationship between protein content and eating quality of milled rice. Philippine Agriculturist 47: 441.

Swain T and Hillis WE 1959. Phenolic constituents of *Prunus domestica*. The qualitative analysis of phenolic constituents. Journal of the Science of Food and Agriculture 10: 63-68.

Takaiwa F, Ogawa M and Okita T W 1999. Rice glutelins. In: Shewry P R, Casey R (ed) Seed Proteins. Kluwer Academic Publishers. Norwell MA, USA.

Thind GK and Sogi DS 2003. Identification of coarse, fine and superfine rice cultivars. Food Chemistry 37: 55-61.

Zhou K and Yu L 2004. Effects of extraction solvent on the wheat bran antioxidant activity estimation. LWT-Food Science and Technology 37**:** 717-721.