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Characterization of red and purple-pericarp rice (*Oryza sativa* L.) based on physico-chemical and antioxidative properties of grains

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ABSTRACT

In the preset study range of variations in physico-chemical, cooking characteristics and antioxidant properties of six pigmented rice (four purple and two red) cultivars from north east India were evaluated. Significant variation ($P<0.05$) was detected among the cultivars for all the traits evaluated except for volume expansion ratio (VER). All the genotypes had long slender grain. Hulling and milling % for all the genotypes were more than 74 and 61%, respectively. Head rice recovery (HRR) was more than 50% in Manipuriblack, Kalobhat and Assambiroin. The range of amylose content (AC) varied from 2.19 to 24.87% where as Mornodoiga was found with highest AC. All the genotypes except Manipuriblack elongated more than 9mm after cooking. Most of the genotypes were found with soft gel consistency (GC). Similarly, all the genotypes except Assambiroin had water uptake (WU) value $\leq$ 100ml/100g rice. The concentration of total anthocyanin content (TAC), total phenolic content (TPC) and antioxidant activity (ABTS) differed significantly among the genotypes with highest concentration of these parameters were observed for the purple grain (Mamihunger) whereas no significant difference between the colour groups (red and purple) was observed for total flavonoid content (TFC), gamma-oryzanol and phytic acid content which envisages that value of these parameters depends on genotypes and not on kernel colour. A high correlation of TAC with TPC and ABTS suggest that the major phytochemicals responsible for the tested antioxidant activities are phenolic acids and anthocyanin.

Key words: *Pigmented rice, antioxidants, grain quality, physico-chemical characteristics*

Rice (*Oryza sativa* L.) is consumed as a staple food by more than half of the world's population with approximately 95% of production in Asia (Bhattacharjee *et al*. 2002). It is the only cereal crop cooked and consumed mainly as whole grains, and quality considerations are much more important than for any other food crops (Hossain *et al*. 2009). Grain quality has always been an important consideration in rice variety selection and development. It is the primary determinant for market place and consumer acceptability. The Kernel appearance, size, shape, nutritional value and cooking characteristics are important for judging the quality and preference of rice from one group of consumer to another (Kanchana *et al*. 2012). In particular, the cooking and eating qualities are very important determinants of cooked rice grain quality (Ge *et al*. 2005). The content of amylose in rice is considered the principal determinant of rice quality. However, rice varieties with similar amylose content have shown to possess different rice characteristics on cooking which indicated that secondary differences exist among varieties with similar amylose content.

Most of the rice crops grown and consumed throughout the world have the white pericarp but there are many special cultivars of rice known as pigmented rice characterized by red, black and purple pericarp. This pigmentation depends on the kinds of deposition of phenolic compounds such as anthocyanin and proanthocyanidin in the aleurone layer of the grain

(Finocchiaro *et al*. 2010; Pereira- Caro *et al*. 2013a, 2013b). Great interest has been shown in the polyphenols in rice for their multiple biological activities. These phenolic compounds include ferulic acid and diferulates, anthocyanins, anthocyanidins and polymeric proanthocyanidins (condensed tannins) (Chun *et al*. 2005). Phenolics have free radical scavanging activity which protect cell against oxidative damage.

Free radicals have been claimed to play an important role in affecting human health by causing many diseases (*e.g*., heart diseases, cancer, hypertension, diabetes and atherosclerosis). In the past decade, antioxidants have shown their relevance in the prevention of various diseases, in which free radicals are implicated. This coloured rice are known source of antioxidant compounds including flavonoid, anthocyanin, phytic acid, proanthocyanidin, tocopherols, tocotrienols, γ-oryzanol, and phenolic compounds (Butsat and Siriamornpun 2010; Goufo and Trindade 2014) which can decrease oxidative stress in vivo, highly effective in reducing cholesterol levels in the human body and exert beneficial effects on human health (Santos-Buelga and Scalbert 2000; Ghie and Walton 2007; Lee *et al*. 2008). Major anthocyanins such as peonidin, peonidin 3-glucoside and cyanidin 3-glucoside extracted from black rice, also reported to exert an inhibitory effect of cell invasion on various cancer cells (Chen *et al*. 2006).

Considering health protecting and promoting effect of pigmented rice, the objective of this study was to compare physico-chemical, cooking properties and antioxidant potentials of the six pigmented rice cultivars native to the North-east India *viz*., Mamihunger, Manipuri black, Chakhao, Kalobhat, Mornodoiga and Assambiroin.

MATERIALS AND METHODS

Pigmented paddy varieties were collected from the sub-station of NRRI, Gerua, Assam and multiplied in the NRRI experimental field, Cuttack, India. All the paddy samples were from the recent harvest of *Kharif*, 2015. The agronomic data were collected from the field time to time. The paddy samples were sun-dried (moisture up to 12-13%) and cleaned for foreign materials, packed in polyethylene bags and kept inside cloth bags, and stored at 4°C. The samples were dehulled through laboratory rice huller, Satake, Japan make. The kernels were ground by a grinding machine (Glen mini grinder) and sheaved through 100 mesh size and then stored at 4°C for further experiments.

Anthocyanin content of rice samples was measured in UV-V is spectrophotometrically according to Swain and Hillis (1959) with alcoholic extract.

Gamma-oryzanol content (GOC) was determined with RP-HPLC. γ-oryzanols extraction by HPLC was performed according to Chen *et al*. (2005) with simplification. Briefly, 0.5 grams of samples (Brown rice flour) were mixed with 5 ml of HPLC-grade isopropanol, vortexed for 2 min at 25°C, centrifuged at 4500 g for 10 min and the supernatant was collected. After 2-3 times repetition, supernatant fractions were evaporated under hot water bath and then extracts were dissolved in 5 ml of HPLC-grade isopropanol. After filtration through a 0.45 μm membrane, 20 μl aliquots were injected into the column (C18- Phenomenex Column). It was separated by an analytical Shimadzu High Performance Liquid Chromatography (RP-HPLC) system equipped with an LC-20AT pump and PDA detector (Shimadzu, Kyoto, Japan). The composition of the mobile phase was 35% acetonitrile, 55% methanol and 10% isopropanol and operated in low pressure gradient mode.

Total phenolic content (TPC) was determined by modified protocol of Zilic *et al*. 2011. About 0.3 g of brown rice flour sample and 10 ml 70% acetone were mixed thoroughly in a centrifuge tube at room temperature. After centrifugation for 20 minutes at 15000g, aliquots (0.2 ml) of aqueous acetone extracts were transferred into test tubes and their volumes made up to 0.5 ml with distilled water. After addition of the Folin-Ciocalteu reagent (0.25 ml) and 20% aqueous sodium carbonate solution (1.25 ml), tubes were vortexed. After 40 min, the absorbance was recorded at 725 nm against a reagent blank. The total phenolic content of each sample was determined by means of a calibration curve prepared using catechol and expressed as mg catechol equivalents (CE) per gram of brown rice flour.

Total flavonoid content was determined according to Eberhardt *et al*. (2000). One gram rice grain was extracted in 10 ml of 40% (v/v) ethanol for 30 min at room temperature. The supernatant, after centrifugation for 20 min at 15,000g was used in experiments. Briefly, 0.075 ml of 5% $NaNO_2$ was mixed with 0.5 ml of the sample (ethanolic extract diluted with 1 ml of water). After 6 min, 0.15 ml of a 10% $AlCl_3$ solution was added, and the mixture was allowed to stand for another 5 min. Then, 0.5 ml of 1 M NaOH was added, and the volume was made up to 2.5 ml with distilled water. The absorbance was measured at 510 nm immediately after mixing, against the blank containing the extraction solvent instead of a sample. The results are expressed as mg CE (catechine equivalent) per 100g of dry matter.

ABTS radical scavenging was assayed by modified protocol of Serpen *et al*. 2008. In this methodology, both soluble and insoluble fraction of antioxidant compounds come into contact with the ABTS radical. The ABTS+ reagent was prepared by reacting a 7 mmol/l aqueous solution of ABTS with 2.45 mmol l^{-1} potassium persulfate and further dissolved in the mixture of ethanol: water (50:50, v/v) so that 1: 5: 28 (V/V) ratio of ABTS, potassium persulphate and ethanol-water was maintained and final OD at 734 nm will be 0.70 + .02. Six milliliters of ABTS+ reagent was added to 10 mg of brown rice flour and the mixture was vortexed for 1.5 min to perform the surface reaction. Following centrifugation at 9200 g for 2 min, the absorbance of the optically clear supernatant was measured at 734 nm exactly 30 min and 60 min of sample mixing with the ABTS reagent. The antioxidant capacity was expressed as percent inhibition.

Phytic acid content was determined by modified protocol of Gao *et al*. 2007. Extraction of PA was done by taking 1g brown rice flour sample in 10ml 2.4% HCl in the 100ml conical flask and the flasks containing the samples were shaken at 220 rpm for 16h in an incubator Shaker at 50°C (Rivotek, India) and centrifuged at 10,062 g in a table-top centrifuge (Remi, India) at 25°C for 20 min. The supernatant was then collected and after adding 1g NaCl, it was shaken for 20 min at 350 rpm. After keeping for 20 min at -20°C, these tubes were again centrifuged at 3000 g for 20 min. After 25 times dilution of supernatant with double distilled water, 3 ml sample and 1 ml wade reagent (0.03% $FeCl_3$, $6H_20$+0.3% Sulpho-salicylic acid) were mixed thoroughly by vortexing and after keeping it for 1 hour OD was measured in 500nm. Standard curve was prepared by sodium phytate so that the blank OD will be 0.453+ 0.002. PA concentration was determined by using the following formula: PA% = {(0.463-OD) x 25 V} / (22.05 x M). Here OD is absorbance; V=final volume (ml); M=weight of sample (g).

For physical traits, 100 g of rice seeds were de-hulled and milled using a standard de-husker and miller, respectively and the milling, head recovery ratio (HRR), kernel length (KL), kernel breadth (KB) and length/breadth (L/B) were calculated. For the gel consistency (GC), 100 mg of rice flour was taken in test tube (13 x100 mm), 0.2 ml of ethanol containing 0.03% thymol blue and 2.0 ml of 0.2 N of KOH were added and kept in boiling water-bath for 8 min, cooled, mixed well and kept in ice bath for 20 min. Later, the test tubes were laid horizontally on the flat base, graph paper for one hour and length of gel spreading of those tubes were measured (mm).

For chemical traits, six number milled rice grains were taken in petriplates and 10 ml of 1.7% of KOH was added and kept in an incubator at 27-30 °C for 23 hours to measure alkali spreading value (ASV). Whereas, the amylose content (AC) was measured using a spectrophotometer (Thermo spectronic USA) as per Juliano *et al*. (2009).

Cooking properties were determined by taking 15 ml of water in 50 ml graduated centrifuge tubes and 5 g of rice samples were added in it. Rice samples were cooked for 20 min in a water bath. Length of ten cooked rice kernels was measured using graph paper for computing the kernel length after cooking (KLAC). Volume expansion ratio and elongation ratio were calculated after cooking as per established methods.

Statistical analysis

All experiments were carried out in triplicates and presented as mean±standard deviation of mean using SAS version 9.2. The data were statistically analysed by Duncan's multiple range tests at 5% significance level.

RESULTS AND DISCUSSIONS

Wide variation in the physico-chemical and cooking properties were observed in the pigmented rice (Table 1). The hulling percentage was more than 74% in all the pigmented rice with higher value (78%) observed

Table 1. Physico-chemical and cooking characteristics of pigmented rice.

	HUL(%)**	MIL(%)**	HRR(%)**	L/B**	AC(%)**	ASV*	KLA**	VER**	GC**	WU**
Mamihunger (purple grain)	^{A}78.00±2.0	^{B}69.67±1.50	^{D}49.50±1.0	^{B}4.22±0.04	^{B}15.60 ±0.20	^{A}6.00	^{B}9.27±0.11	4.00±0.50	^{D}43.00±1.0	^{E}104.67±0.57
Manipuriblack (purple grain)	^{B}75.00±2.0	^{C}61.33±1.15	^{A}59.50±1.00	^{C}3.30±0.15	^{F}2.19±0.10	^{A}6.00	^{C}8.47±0.12	3.75±0.05	^{A}75.00±1.0	^{B}195.33±0.55
Chakhao (purple grain)	^{B}74.50±1.0	^{C}62.50±1.00	^{D}48.83±0.57	^{A}4.36±0.10	^{D}5.84 ±0.05	^{B}5.00	^{AB}9.67±0.28	3.77±0.07	^{A}75.00±1.0	^{C}134.67±0.57
Kalobhat (purple grain)	^{B}75.00±2.0	^{A}73.00±1.32	^{B}56.83±1.15	^{D}3.15±0.05	^{E}4.57±0.11	^{B}5.00	^{AB}9.50±0.50	3.75±0.25	^{B}65.33±0.57	^{D}110.50±0.51
Mornodoiga (red grain)	^{B}75.33±0.57	^{C}61.83±1.15	^{E}35.50±1.0	^{D}3.04±0.07	^{A}24.87± 0.57	^{D}3.00	^{B}9.33±0.26	3.75±0.25	^{B}66.33±1.15	^{F}82.33±0.28
Assambiroin (red grain)	^{B}74.50±1.0	^{C}62.50±1.00	^{C}55.00±1.0	^{D}3.08±0.06	^{C}11.13±0.33	^{C}4.00	^{A}9.87±0.30	3.75±0.25	^{C}48.33±1.15	^{A}332.50±0.50

Note- Values are presented as mean ± Standard daviation (n=3), Mean with different letters (A-F) within the same column are significantly different ($P < 0.05$), * Standard daviation in ASV is zero, ** no significance difference among genotypes for VER, ASV-alkali spreading value, AC-amylose content(%), GC-gel consistency in mm, HRR=Head rice recovery(%), HUL-hulling(%), KLA-kernel length after cooking, L/B-length/breadth ratio, MIL-Milling(%), VER-volume

in Mamihunger. The milling percentage was in the range of 61.33 (Manipuri black) to 73.00 (Kalobhat). Head rice recovery, one of the major criteria that determine the grain quality varied from 35.50 (Mornodoiga) to 59.50% (Manipuri black). This important grain quality varies depending on variety, grain type, cultural practices and post harvest conditions (Razavi and Farahmandfar 2008; Emadzade *et al*. 2009). HRR of more than 55% was found in Manipuri black, Kalobhat and Assambiroin. In this study, HRR was found positively correlated (r=0.819;Table 3) with ASV, L/B ratio or axial ratio which provide information about the grain type. All the pigmented rice were found to have long slender grain as the axial ratio was more than 3.0 and varied from 3.04 to 4.36.

Cooking quality of rice mainly depends on amylose content and gelatinization temperature. Amylose content (AC), an important grain quality character which determines the texture of cooked rice varied from 2.19 to 24.87%. Manipuriblack was nonwaxy type (>2%), very low amylose content was observed in Chakhao and Kalobhat (within 2- 9%) and low amylase content (within 10-20%) was observed in Mamihunger and Assambiroin where as Mornodoiga had moderate level (within 20-25%) and preferred amylose content. Cultivar with high amylose level are associated with lower blood glucose level and slower emptying of the human gastrointestinal tract compared to those with low levels of this macromolecule (Frei and Becker 2003). In this study, high significant negative correlation of AC with ASV (-0.961) and HRR (- 0.887) was observed (Table 3).

The alkali spreading value was in the range of 3-6 for all the genotypes. Mornodoiga had high intermediate ASV (3) and Assambiroin, chakhao and kalobhat had intermediate ASV (4-5) where as Mamihunger and Manipuri black had low ASV (6). It signifies that the intermediate group requires high gelatinization temperature (70-74^{0}C) and low gelatinization temperature (<70^{0}C) is required for mamihunger and manipuriblack. It was reported that the gelatinization temperature affects water uptake, volume expansion ratio and kernel elongation (Vanaja and Babu 2003).

Length-wise expansion without a corresponding increase in girth is considered a highly had desirable long grain after cooking (> 9mm). There was no significant difference among genotypes for VER which was 3.75 for all the genotypes except Mamihunger (4.0). VER was found significant positive correlation with HUL (r=0.958; Table 3).

Gel consistency (GC) ranged from 43.00 to 75.00. Based on GC classification, moderate GC was observed in Mamihunger and Assambiroin (within 41-60) where as other genotypes has soft and desirable GC (within 61-100). When cooked, rice types with hard gel consistency harden faster than those with a soft gel consistency. Rice with soft gel consistency cook more tenderly and remain soft even upon cooling (Oko *et al*. 2012). The correlation between percentage amylose and gel consistency was negative in direction though not significant (Table 3), suggesting the unlikelihood of correlated responses in selecting for these traits.

The WU value was in the range of 82.33 to 332.50. Mornodoiga required less than 100ml water / 100g rice where as for rest of the genotypes it was more than 100. Highest water uptake was observed in Assambiroin (332.50ml/100g rice). The appearance in the quality of cooked rice grains is associated with the amount of water uptake during cooking process (Tan *et al.* 2000). It is worthy to note that high water uptake ratio affects the palatability of the cooked rice negatively (Oko *et al*. 2012).

Different antioxidant parameters like, total anthocyanin content, flavonoid, gammaoryzanol, and total phenolics, phytic acid and ABTS antioxidant assay are shown in Table 2. The phenolics, flavonoids and anthocyanins, are known to act as electron donors that are capable of reacting with free radicals and convert them to stable compounds, and thus the radical chain reaction is terminated (Laokuldilok *et al*. 2011). The concentration of TACs, TPC and ABTS differed significantly among the genotypes. Highest concentrations of TACs were observed for the grains with purple pericarp color (Mamihunger-96.71 and Manipuri black-96.22 mg/100g), which were more than 25 times higher than the TACs concentrations of grains with red pericarp color (Assambiroin and Mornodoiga). Similar results were also obtained by other researchers (Abdel-Aal *et al*. 2006; Laokuldilok *et al*. 2011) who reported that purple-pigmented rice having a higher level of anthocyanin than red-pigmented rice. The higher concentration of TAC in purple rice may be due to the deposition of both anthocyanin and proanthocyanidin pigment in the aleurone layer where as only proanthocyanidin present in the red rice. Highest concentration of TPC was detected in the purple grain (955.28mg/100g) and lowest in the red grain (191.35mg/100g). These results is in agreements with findings of Choi *et al*. 2007, Shen *et al*. 2009, Goffman and Bergman 2004 for red and black rice varieties. Significant correlation of TAC with TPC (r=0.971) envisages its higher content in the purple pericarp (Table 3). The higher total phenolics contents of purple pericarp appear to be attributable to their higher anti-oxidative activities. The evaluation of the antioxidant properties of cereals is getting more importance because of their free radical scavenging activity. Highest ABTS assay

Table 2. Antioxidant properties and ABTS assay in pigmented rice.

	TAC (mg/100g)	TFC (mg CE/100g)	Gammaoryzanol (mg/100g)	TPC (mg /100g)	Phyticacid (g/100g)	Antioxidant (AAE/g)
Mamihunger (purple grain)	^{A} 96.71±0.98	^{F}146.34±0.58	^{A} 98.10±0.74	^{A} 955.28±0.92	^{C}0.11±0.01	^{A}3187.24±0.39
Manipuriblack (black grain)	^{B} 96.22±0.98	^{D}223.76±1.16	^{D} 65.21±1.0	^{B}621.25±0.85	^{B}0.23 ±0.02	^{B}3127.45±0.38
Chakhao (purple grain)	^{C} 88.55±1.24	^{A}289.20±1.11	^{E}52.65±0.86	^{C}555.80±0.93	^{B}0.20 ±0.02	^{C}3119.34±0.72
Kalobhat (purple grain)	^{C} 89.21±0.98	^{B}284.21±0.83	^{C}67.46±0.98	^{D}491.50±0.51	^{B}0.23 ±0.01	E3061.91±0.27
Mornodoiga (red grain)	^{D} 5.10±0.66	^{C} 272.51±0.63	^{B}80.71±1.01	^{E}355.27±0.97	^{A} 0.32±0.03	^{F}3044.22±0.60
Assambiroin (red grain)	^{D} 3.33±0.63	^{E}211.22±0.96	^{E}52.92±0.68	^{F}191.35±1.05	^{B} 0.20±0.01	^{D}3105.23±0.38

Note- Values are presented as mean ± Standard daviation (n=3); Mean with different letters (A-F) within the same column are significantly different (P < 0.05); CE- Catechine Equivalent; AAE-Ascorbic Acid Equivalent; TAC= Total anthocyanin content; TFC= Total flavonoids content; TPC= Total phenolics content

Table 3. Correlation of physico-chemical and antioxidant properties of pigmented rice.

	WU	VER	KLA	AC	ASV	GC	HUL	MIL	HRR	LB	TAC	GAM	TPC	TFC	PHY	ABTS
WU	1.000															
VER	-0.304	1.000														
KLA	0.215	-0.064	1.000													
AC	-0.298	0.268	0.225	1.000												
ASV	0.083	-0.209	-0.445	**-0.961**	1.000											
GC	-0.267	-0.670	-0.378	-0.405	0.512	1.000										
HUL	-0.433	**0.958**	-0.210	0.387	-0.272	-0.623	1.000									
MIL	-0.395	0.437	0.169	-0.138	0.170	-0.365	0.465	1.000								
HRR	0.512	-0.086	-0.234	**-0.887**	**0.819**	0.015	-0.181	0.251	1.000							
LB	-0.313	0.619	0.088	-0.137	0.149	-0.064	0.436	0.108	-0.047	1.000						
TAC	-0.421	**0.814**	-0.336	-0.251	0.364	-0.236	0.763	0.548	0.278	0.705	1.000					
GAM	-0.608	0.779	-0.307	0.572	-0.397	-0.465	**0.922**	0.420	-0.393	0.180	0.567	1.000				
TPC	-0.530	**0.819**	-0.454	-0.109	0.268	-0.160	0.805	0.419	0.108	0.700	**0.971**	0.665	1.000			
TFC	-0.246	-0.790	0.216	-0.164	0.167	0.773	-0.755	-0.129	-0.197	-0.242	-0.537	-0.557	-0.526	1.000		
PHY	-0.158	-0.752	-0.114	0.322	-0.251	0.577	-0.567	-0.436	-0.473	-0.669	-0.769	-0.213	-0.641	0.688	1.000	
ABTS	0.117	0.782	-0.222	-0.211	0.210	-0.434	0.634	0.088	0.333	0.717	0.781	0.318	0.751	-0.797	**-0.882**	1.000

Number in bold indicates significance at p=0.05level. ASV-alkali spreading value, AC-amylose content (%), GC-gel consistency, HRR=Head rice recovery (%), HUL-hulling (%), KLA-kernel length after cooking, L/B-length/breadth ratio, MIL-Milling (%), VER-volume expansion ratio, WU-water uptake (ml/100g rice). ANTH-anthocyanin (mg/100g), GAM-gammaoryzanol (mg/100g), PHE-phenol (mg/100g), TFC- total flavonoid content (mgCE/100g), PHY-phytic acid (g/100g), ABTS-2, 2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt

was observed for purple rice (Mamihunger-3187.24 AAEg-1foll) and lowest ABTS value was observed for red grain (Assambiroin-3105.23 $AAEg^{-1}$). Positive correlation of ABTS with TAC (r = 0.781) and TPC (r = 0.751) clarifies that higher ABTS scavanging assay in purple grain may be due to higher TAC and TPC content (Table 3). These results suggest that the major phytochemicals responsible for the tested antioxidant activities are phenolic acids and anthocyanin.

Gamma-oryzanol is another one of the phytochemicals that found at high concentration in rice bran has been reported to exhibit more antioxidant activity than vitamin E as six fold and their important bioactivities include anti- and inflammatory activity, enhancement of the immune system, heart disease, cardiovascular disease, glycemic control, diabetes and inhibit tumor promotion (Saenjum *et al*. 2012). Recently, polyphenolic compounds including flavonoids is known as safe and non-toxic antioxidants. Many studies have shown that a high dietary intake of natural phenolics is strongly associated with longer life expectancy, reduced risk of developing some chronic diseases, various types of cancer, diabetes, obesity, improved endothelial function and reduced blood pressure (Halliwell 2007; Yan and Asmah 2010; Jonathan and Kevin 2006). Furthermore, phytic acid which complexes with iron, zinc considered as another antioxidant as it bring about a favorable reduction in the formation of hydroxyl radicals in the colon (Graf and Eaton 1993). Total flavonoid content among the pigemted rice ranged from 146.34 to 289.20 mg/100g and the gamma-oryzanol content ranged from 52.65 to 98.10 mg/100g. Higher flavonoid and gamma-oryzanol content was observed in purple grain (Chakhao and Kalobhat; > 200 mg/100g and Mamihunger; 98.10 mg/100g, respectively. Gammaoryzanol content was found positively correlated with TAC (r=0.567) and TPC (r=0.665) though correlation is not significant (Table 3). Similarly, lowest phytic acid content was found in purple grain Mamihunger (0.11%). Though significant differences were observed among the genotypes for flavonoid, gammaoryzanol and phytic acid content but no significant difference was observed between the colours. It envisages that content of gammaoryzanol and flavonoid content accumulated in bran parts of pigmented rice grain depends on rice genotype and not on the kernel colour.

Traditional rice breeding has been mainly focused on improving agronomic traits, such as yield and disease and insect-resistance, as well as improvement of grain quality, such as milling quality, grain appearance, and cooking quality. Recently, there has been an interest in developing rice varieties rich in one or more phytochemical fractions to potentially contribute to improved human health and develop new market opportunities. In this study, purple rice was found with higher antioxidant properties compared to red rice and most of the pigmented rice was observed with desirable grain quality. The knowledge generated could be used in future breeding programmes for the development of a variety with high antioxidant properties combined with valuable grain quality traits. Also the correlation of variables studied will help in carefully selecting the variables.

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