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Assessment of nutritive and antioxidant properties of some indigenous pigmented hill rice (*Oryza sativa* L.) cultivars of Assam

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ABSTRACT

Fourteen pigmented hill rice cultivars along with a non-pigmented one were studied for ascertaining the extent of their nutritional and genetic diversity. Moisture contents of the fourteen pigmented hill rice cultivars ranged from 7.49 to 10.10 % along w.ith the contents (% dry weight) of nutrients *viz*., crude fat (4.37 – 5.27) and crude protein (9.27 - 11.42). The corresponding range of values for the contents (mg/100g dry weight) of microminerals Zn and Fe were form 3.42 to 4.28 and from 3.21 to 4.18 respectively. The pigmented germplasm had anthocyanin content (mg cyanidine 3-*O* glucoside /100g) ranging from 3.58 to 7.86, total phenolic content (mg GAE/100 g)from 67.89 to 89.43, flavonoid content (mg QE/100g)from 57.75 to 78.74 and antioxidant activity from 19.56 to 29.29 %. Analysis of variance indicated that the varietal effect on each of the parameters studied was highly significant. There was significant correlation amongst the different parameters of the rice genotypes analysed. Results of the biochemical screening of these cultivars may lead to selection of promising candidates that can be used for developing improved lines in future breeding programmes.

Key words: Antioxidant, Assam, Hill, Pigmented, Rice.

INTRODUCTION

Pigmented rice (*Oryza sativa* L.) has been consumed since time immemorial, in most of the countries of Southeast Asia (Tananuwong and Tewaruth 2010). Nowadays, whole grain pigmented rice has been categorized as one of the potent functional foods since it contains high amounts of phenolic compounds (Yawadio *et al*, 2007). The phenolic compounds have been found as a major active component for antioxidation. Anthocyanins have been recognized as health-promoting functional food ingredients due to their antioxidant activity (Philpott *et al*., 2006), anticancer (Zhao *et al*., 2004), hypoglycemic (Tsuda *et al*., 2003), and anti-inflammatory effects (Tsuda *et al*., 2002). Rice is also a good source of various essential minerals and vitamins. Microminerals *viz*.,zinc and iron present in rice play important roles in body regulatory functions. Identification of rice cultivars with a high anthocyanin level, good agronomic traits and nutritional quality may facilitate rice breeding. Nutritional quality of rice has received more attention in the developing countries, where monotonous consumption of rice may lead to deficiencies of essential minerals, vitamins, phytochemicals and other nutritional compositions.

Rice can be grown practically any where, even on a steep hill or mountain. In Assam, the Hill zone constitutes 20% of the geographical area of the state with 1.24 lakh ha area and 1.74 lakh tonnes production for rice (Baishya *et al*, 2010). The Hill zone constitutes only 5% of the total rice area in the state. A traditional method of cultivation practiced by hill community of Northeast India is called "*jhum*" cultivation. For this type of cultivation, the forest land is usually cleared in December to January by slashing shrubs and cutting trees. The slashed vegetation is then allowed to dry for two months before burning the tract of land in March. In addition to clearing the land, the burning of the leftover vegetation enriches the soil with mineral nutrients present in the ash and destroying pests leading to enhanced yield of the succeeding crop i.e., rice, the seeds of which are then sown. The practice is usually driven by groups of villages. A large number of traditional cultivars of rice with either red or black coloured outer layer of the grains are grown in hill region of Assam. However, there is lack of systematic investigations aiming at ascertaining the biochemical composition of those cultivars. This led the authors to undertake the present project involving nutritive and phytochemical evaluation of a few selected hill rice genotypes with good agronomic traits for providing improved materials to be used in future rice breeding programmes.

MATERIALS AND METHODS

For the present study, a total of 15 numbers of hill rice cultivars were collected including 14 pigmented *viz*., Bairing Gurmu, Joradhan, Miren, Maibee ,Maichukik ,Dimrou, IRAT-141, Bairing, Sakbothung, Buarcha, Sakcharap, Vijoy Bijor and Pakai and one non-pigmented

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hill rice cultivar 'Vandana' from Regional Agricultural Research Station (RARS), Diphu, Assam, during 2014 (Table 1).The rice grains were stored at 4°C. Around 200g of rice sample of each cultivars were collected, duhusked and then ground using a mechanical grinder to make it fine powder dried in a oven at 100°C For few hours.

Nutritive quality

Protein content was estimated by method of Scales and Harrison (1920). Crude fat was estimated from oven dried sample using a Soxhlet apparatus (AOAC, 1970).The mineral solution was prepared according to the method as described by AOAC (1970). This solution was used for the estimation of zinc (Zn) and iron (Fe) using a double beam atomic absorption spectrophotometer (Chemito, model AA203D).

Phytochemicals and antioxidant activities

Sample extraction : Finely powdered dehusked grain samples of hill rice cultivars were extracted following the method of Atala *et al*. (2009) for subsequent analysis of phytochemicals and antioxidant activity. Briefly, 10 g of rice powder sample was extracted with 100 ml of extraction solvent (75:25 v/v, acetone: water). Extracts were shaken in a water bath at 25°C for 2.5 hours and then centrifuged at10, 000 rpm for 10 min (Sigma laboratory centrifuge, 3K30). The supernatant was then stored at "20°C until further analysis of total phenolics, flavonoids, anthocyanins and antioxidant activity.

Determination of total anthocyanin content: The sample extracts were used to determined total anthocyanin content. It was determined by the pH differential method (Giusti and Wrolstad, 2005). To measure the absorbance at pH 1.0 and 4.5, the crude extract was diluted 20 times with pH 1.0 potassium chloride buffer and pH 4.5 sodium acetate buffers, respectively. The total anthocyanin content of crude extract was calculated in terms of cyanidin3-*O*-glucoside (CG). The concentration of monomeric anthocyanin pigment was calculated by the following equation.

$$\textbf{Monomeric anthocyanin pigment (mg/L)} = [\text{A diff} \times \text{MW} \times \text{DF} \times 1000]/\varepsilon$$

where MW represents molecular weight of cyanidin-3-glucoside (449.2), DF is the dilution factor ε is molar absorptivity of cyanidin-3-glucoside (26,900 l/mol cm) and A diff was calculated from the following equation:

$$\text{A diff} = (A_{513} - A_{700})\text{pH}1.0 - (A_{513} - A_{700})\text{pH}4.5.$$

Determination of DPPH activity : The DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging activity of the extracts was measured according to the method of Brand-Williams et al., (1995). Precisely, 100 µL of extracts were added to 1.4 mL DPPH radical methanolic solution (10^{-4} M). The absorbance at 517 nm was measured at 30 min against blank (100 µL methanol in 1.4 mL of DPPH radical solution). The results were expressed in terms of radical scavenging activity using the following equation:

$$\text{Radical scavenging activity (\%)} = \frac{(A_0 - A_S)}{A_0} \times 100$$

Where, $A_0$is the absorbance of control blank, and $A_S$is the absorbance of sample extract.

Determination of total phenolic content : A modified version of the Folin–Ciocalteu assay (Slinkard & Singleton, 1977) was used to determine the total phenolic content in the extracts from the rice samples. Gallic acid standard curve was made with appropriate concentrations of aqueous gallic acid solution. For the analysis, 20 µL each of extract, gallic acid standard or blank were taken in separate test tubes and to each 1.58 mL of distilled water was added, followed by 100 ìL of Folin–Ciocalteu reagent, mixed well and within 8 min, 300 ìL of sodium carbonate was added. The samples were vortexed immediately and allowed to incubate in dark for 30 min at 40°C. The absorbance was measured at 765 nm. The phenolic content was expressed in mg GAE/100 g.

Determination of total flavonoid content: The method of Dewanto *et al* (2002) with slight modification was followed for estimation of the flavonoid content. Briefly, to 0.5 mL of the extract in a test tube, 2.25 mL of distilled water and 0.15 mL of 5% sodium nitrite solution were added and the contents were mixed well and kept for 6 min. To this, 0.3 mL of a 10% aluminium trichloride hexahydrate solution was added and contents were mixed well and allowed to stand for 5 min followed by addition of 1 mL of 1 M sodium hydroxide. The mixture was vortexed and the absorbance was measured immediately at 510 nm. Results were expressed as quercetin equivalent (mg QE/ 100 g) of sample.

Physical properties

Colour value of rice grain: The colour of different rice grain sample was measured using Colour Measurement Spectrophotometer (Hunter Color Lab Ultrascan Vis). Color measurements were expressed as tristimulus parameters, L*, a*, and b*.where 'L*' indicates degree of lightness or darkness (L*=0 indicates perfect black and L*=100 indicates most perfect white); 'a*' indicates degree of redness (+) and greenness (-); whereas 'b*' indicates degree of yellowness (+) and blueness (-). Hue angle and Chroma were determined using respective formula as shown below.

$$\textbf{Chroma} = \sqrt{a^2+b^2}$$

$$\textbf{Hue angle}(\theta) = \tan^{-1} b/a$$

RESULTS AND DISCUSSION

Nutritive quality : The nutritive quality parameters were shown in the Table 1. The fat content values ranged from 4.37 % ('Buarcha') to 5.27%('Vijoy') with an average 3.91 % as compared to 'Vandana' (3.50 %).A slightly higher fat

Table-1: Contents of different nutritional and phytochemical principles, antioxidant activity and colour properties of hill rice cultivars

Rice Cultivar	Moisture (%)	Crude protein (%)	Crude fat (%)	Zn (mg/ 100 g)	Fe (mg /100 g)	Anthocyanin mg/100g C3G	Antioxidant activity % DPPH	Total Phenol mg GAE/ 100 g	Flavonoid mg QE/100g	L*	a*	b*	Hue	Chroma
Bairing Gurmu	10.1	9.88	4.99	3.73	3.49	4.7	24.34	78.56	67.12	48.69	7.47	8.14	56.13	11.04
Joradhan	7.49	10.67	5.15	3.94	3.76	6.96	29.29	89.43	71.24	46.26	6.86	7.76	57.83	10.35
Miren	8.3	11.06	5.06	4.23	3.21	6.18	22.11	81.11	69.21	46.36	6.19	7.87	61.44	10.01
Maibee	8.87	11.15	5.04	3.91	3.29	3.58	20.68	76.56	59.22	50.27	9.09	9.87	54.46	13.41
Maichukik	9.45	10.06	4.97	3.97	3.98	4.5	19.56	67.89	57.75	49.58	9.2	9.57	53.47	13.28
Dimrou	8.96	10.75	5.18	4.23	3.72	7.23	26.47	78.76	70.47	47.47	7.98	8.02	53.67	11.3
IRAT-141	9.29	9.8	5.19	3.94	4.18	4.27	21.43	71.34	58.34	49.78	8.84	9.76	55.22	13.22
Bairing	8.96	11.02	5.1	3.42	3.88	6.35	23.69	79.46	69.61	50.93	10.11	10.24	52	14.36
Sakbothung	8.64	11.42	4.82	3.86	3.48	7.86	25.64	85.23	78.74	46.11	6.83	7.85	58.15	10.52
Buarcha	8.65	10.49	4.37	3.53	3.46	6.23	26.73	80.16	70.76	49.25	8.17	8.77	55.03	12.02
Sakcharap	8.29	11.19	4.76	3.97	3.59	5.45	20.43	77.94	68.23	49.02	7.87	8.59	55.77	11.7
Vijoy	9.05	10.75	5.27	3.46	3.81	6.44	26.61	86.48	69.89	48.58	8.16	8.06	53.06	11.44
Bijor	8.5	9.27	4.75	4.14	3.94	4.23	22.43	78.9	63.87	49.23	9.13	9.06	52.21	12.82
Pakai	7.7	11.06	4.84	4.28	3.56	6.56	23.79	86.45	70.48	49.47	8.54	9.79	56.3	13.07
Vandana	9.47	10.84	3.5	2.58	2.67	0.98	ND	33.23	24.58	84.78	3.67	6.89	61.74	8.1
MEAN	8.78	10.63	4.87	3.81	3.60	5.43	23.80	76.77	64.63	51.05	7.87	8.68	55.77	11.76
	(8.73)†	**(10.61)**	**(4.96)**	**(3.90)**	**(3.67)**	**(5.75)**	**(23.80)**	**(79.88)**	**(67.50)**	**(48.64)**	**(8.17)**	**(8.81)**	**(55.34)**	**(12.04)**
C.V.	1.893	0.605	1.185	2.536	1.192	3.218	0.123	0.069	0.096	0.117	0.770	0.486	0.123	0.406
S.E.M.	0.096	0.037	0.033	0.056	0.025	0.101	0.016	0.030	0.036	0.034	0.035	0.024	0.040	0.028
C.D. 5%	0.279	0.107	0.096	0.161	0.072	0.293	0.046	0.088	0.104	0.100	0.101	0.071	0.115	0.080

†Values in the parentheses represent the mean value of 14 pigmented hill rice cultivars excepting non-pigmented 'Vandana'.

content was reported by Bhagabati (2000), who found the range of crude fat content varying from 3.34%to 3.51%in glutinous rice genotypes of Assam. Saikia *et al*. (2012) also found higher amounts of fat in pigmented rice as compared tothe non pigmented rice varieties, which is ingood agreement with the results of the present investigation. This might be due to the concentration of phenols, polyphenols, anthocyanins and other fatty substances (Pantindol *et al.,*2006). The highest protein content was recorded in 'Sakbothang' (11.42%) and lowest in 'Bijor' (9.27 %) with a mean 10.61%against 'Vandana' (10.84 %). The similar findings were also reported by of Bhagabati (2000). The variation in the protein content of rice grains may primarily be ascribed to cultivar differences, genetic makeup of the cultivars, climatic condition, and nutrient status of the soil as well as the analytical methods used (Baishya *et al*, 2010). Effects of such factors on protein content of rice was observed by Juliano *et al.* (1964).The highest (4.28 mg/100g) Zn content was found in 'Pakai' and lowest (3.42 mg/100g) in 'Bairing' with an average 3.90 mg/100 g whereas 'Vandana' contained 2.58 mg/100g. The highest Fe content was recorded in 'IRAT-141' (4.18 mg/100g) and the lowest in 'Miren'(3.21 mg/100 g) with an averageof 3.67 mg/100 g as against 'Vandana' (2.67 mg/100g).The Fe content of the cultivars as recorded in the present study was found to be similar with the findings of Borua et al.(2004) but higher than the findings of Yodmanee *et al.* (2011). The pigmented cultivars in the present study were having higher Zn and Fe contents than the non-pigmented hill rice cultivar 'Vandana' and similar results were also reported by several researchers (Pathak, 2015).The red rice has approximately eight times the amount of zinc contained in the polished rice, as reported by Juliano (1985). Milling of rice generally decreases the mineral content in rice. The complete milling and polishing that converts brown rice into white rice destroy 60 % of the iron content (Oko *et al*., 2012).

Phytochemicals and antioxidant activity

Total phenolic content : The range of total phenolic content of 14 pigmented hill rice cultivars was 67.89–89.43 mg GAE/100 g with a mean value of 79.88 mg GAE/100 g against 'Vandana'(33.23 mg GAE/100 g) scoring much less than 50%(Table 1). Yodmanee *et al.* (2011) observed the polyphenol content of eight pigmented rice varieties of Thailand ranging from 58-329 mg GAE/100 g sample. Lum *et al.* (2012) and Saikia et al. (2012) reported higher amount oftotal phenolic acids in some pigmented rice. Tananuwong and Tewaruth (2010) found 188 mg GAE/ 100g total phenolic content in the crude extract of one black glutinous rice 'Kam Doi Saked' of Thailand. The total phenolic content of present investigation was found to be higher than that of white rice as reported by Saikia *et al.* (2012). Bordiga *et al.* (2014) reported the phenolic content of six pigmented rice varieties ranging from 140.4 to 1187.2 mg GAE/100 g of rice.

Flavonoid content : The range of flavonoid content (Table 1) of the14 pigmented hill rice cultivars under the present study was 57.75–78.74 mg QE/100g with an average 67.50 mg QE/ 100g, whereas 'Vandana'contained 24.58 mg QE/100 g. The range of flavonoid content is lower than the findings of the Saikia *et al.* (2012They reported that the flavonoid content of two pigmented rice varieties were 220.50 mg QE/100 g ('Chak-hao-amubi') and 123.75 mg QE/100 g ('Poreiton chakhao'). This might be because of the differences in the rice genotypes used for the studies (Pathak 2015).

Anthocyanin content : The range of anthocyanin content of 14 pigmented hill rice cultivars was 3.58 ('Maibee') - 7.86 mg Cyanidine 3-*O* glucoside /100 g ('Sakbothnag') with a mean value of 5.75 mg Cyanidine 3-*O* glucoside /100 g as compared to much lower value in 'Vandana' (0.98 mg Cyanidine 3-*O* glucoside /100 g) (Table 1),].Saikia *et al.* (2012) reported the anthocyanin contentof 'Poreiton chakhao'to be 35.87 mg cyanidin-3-glucoside equivalent 100/ g whereas the variety'Chak-hao-amubi contained' 1.81 mg (cyanidin-3-glucoside equivalent 100/ g).The anthocyanin content in brown rice having lower in non pigmentd rice than the pigmented rice, which is also a good agreement with the outcome of present investigation.The red pigmented rice is having mean content of 5.75 mg Cyanidine 3-*O* glucoside / 100 g Similare results were also reported earlier by few workers [Shen *et al*., 2009; Yodmanee *et al*., 2011 and Pathak, 2015]

Antioxidant activity (Radical DPPHÿ scavenging activity) : The range of radical DPPH scavengingactivity of 14 pigmented hill rice cultivars was 19.56 ('Maichukik')–29.29 ('Joradhan') %with an average value of 23.80 %whereas no DPPH activity has been detected in non-pigmented rice cultivar 'Vandana' (Table 1The range of DPPH activity was lower than the findings of Saikia *et al.* (2012), Lum *et al.* (2012) which might be because of differences in the genetic makeup of the materials and extraction procedure used for the study. Bordiga *et al.* (2014) reported that pigmented rice showed higher contents of phenolics, flavonoids, and anthocyanins showing higher antioxidant activity as compared to white rice.

Physical properties

Colour value of rice grain: : The value of the colour parameters were shown in the Table 1. The L* values, which expresses the brightness of 14 pigmented hill rice cultivar was in the range of 46.11 ('Sakbothang') - 50.93 ('Bairing') with a mean value 48.64 against 'Vandana' (84.78). It indicated that the 'Sakbothang' is darker in nature among the 14 pigmented hill rice genotypes. Saikia *et al.* (2012) reported that L* value of pigmented rice ranged from 48.58 to 62.12 which is in a good agreement with the results of the present investigation.The a* value of 14 pigmented hill rice

Table-2: Correlation among different parameters studied

	Moisture	Crude protein	fat	Zn	Fe	Anthocyanin	Antioxidant	Total activity	Flavonoid Phenol	L*	a*	b*	Hue	Chroma
Moisture	1	-0.65966 *	-0.79814 *	-0.51094	0.0661	-0.72762 *	- 0.54588 *	-0.71754 *	-0.51650 *	0.68746 *	0.4846	0.39485	-0.53609 *	0.44379
Crude protein		1	0.54395 *	0.58495 *	-0.60668 *	0.14692	-0.03692	0.36463	0.11087	-0.22589	-0.19601	0.05236	0.4284	-0.07916
Crude fat			1	0.28714	-0.07397	0.65548 *	0.64935 *	0.76704 *	0.56646 *	-0.59328 *	-0.46008	-0.41039	0.46715	-0.45088
Zn				1	-0.23005	0.41479	-0.20496	0.082	0.16455	-0.47955	-0.37264	-0.15485	0.62008 *	-0.28069
Fe					1	0.08712	0.13303	-0.25834	-0.23432	0.113	0.3654	0.16443	-0.50758	0.26954
Anthocyanin						1	0.75798 *	0.77977 *	0.87483 *	-0.97113 *	-0.84670 *	-0.86032 *	0.76559 *	-0.86493 *
Antioxidant activity							1	0.89577 *	0.82288 *	-0.67371 *	-0.61401 *	-0.74127 *	0.39042	-0.68910 *
Total Phenol								1	0.88782 *	-0.77109 *	-0.75965 *	-0.76072 *	0.65140 *	-0.77558 *
Flavonoid									1	-0.90898 *	-0.95012 *	-0.96926 *	0.82147 *	-0.97390 *
L*										1	0.93472 *	0.90815 *	-0.88678 *	0.93106 *
a*											1	0.95484 *	-0.94443 *	0.98730 *
b*												1	-0.81173 *	0.98630 *
Hue													1	-0.89071 *
Chroma														1

* represent the significant value of correlation

cultivar ranged from 6.19 ('Miren') to 10.11 ('Bairing') with a mean value of 8.17 as compared to 'Vandana' (3.67) and was similar with the findings of Mir *et al.* (2013) who found the range of a* from 4.23 to 7.73 in brown rice.The b* value of 14 pigmented hill rice cultivar ranged from 7.76 ('Joradhan') to 10.24 ('Bairing') with an average of 8.81 against 'Vandana' (6.89). A slightly wider range of b* values 3.30-15.71 was reported for pigmented rice by Yodmanee *et al.* (2011). The Hue angle of 14 pigmented hill rice cultivar ranged from 52 to 61.44 as compared to non-pigmented 'Vandana' (61.74).The chroma of 14 pigmented rice ranged from 10.01 to 14.36 as compared to non-pigmented 'Vandana' (8.1).Saikia *et al.* (2012) reported slightly lower but with wider range of Hue values (35.62 – 63.35) and a lower value of Chroma (3.04-9.83) for some pigmented rice varieties.

CORRELATION

The correlation values of different parameters were shown in the Table 2. Moisture was found to be negatively correlated with Protein, fat, anthocyanin content, antioxidant activity, total phenol, flavonoid and hue and positively correlated with only L* value. A positive correlation was observed in between protein and fat content. The crude fat content was found to be positively correlated with anthocyanin, antioxidant activity, total phenol and flavonoid content. There was a negative correlation between fat and L* value. Zn was found to be positively correlated with hue. The anthocyanin content was positively correlated with antioxidant activity, total phenol and flavonoid content. The anthocyanin content was negatively correlated with all the colour value like L*, a*, b* and chroma. Yodmanee *et al.* (2011) also reported that rice grain color parameters (L*, a* and b*) had negative correlations ($p<0.01$) with polyphenol (r = -0.893, -0.851 and -0.928) and antioxidant capacity (r = -0.794, -0.629 and -0.770). Similarly, phenol was found to be positively correlated with flavonoid content and negatively correlated with all the colour values like L*, a*, b* and chroma except Hue. Jin *et al.* (2009) reported that the phenolic content was positively correlated with the flavonoid content. A significant correlation among the different colour parameters was also observed. Jin *et al.* (2009) also reported that these color parameters were interrelated. The correlation value among different parameters will be useful for breeder to go for simultaneous improvement of pigmented hill rice cultivars.

The pigmented rice cultivars analysed in the present study appear to be a good source of phytochemicals like anthocyanin, phenol, flavonoid and found to have antioxidant activity. These genotypes are also rich in important minerals like Fe and Zn as compared to the other common rice cultivars grown in the plane region of Assam. No single genotype was found to be superior over the other in terms of all the parameters studied.

The genetic diversity found in the cultivars under the present investigation may be considered as a need to select the best performers amongst themselves with respect to the contents of nutritive and antioxidant principles as well as the antioxidant activity. Promising candidates thus selected, may be utilized for developing improved lines in future breeding programmes.

REFERENCES

AOAC. (1970).Official methods of analysis 10thEd Association of Official Analytical Chemists Washington D C.

Atala, E., Vásquez L., Speisky, H., Lissi, E. and Lopez-Alarcon C. (2009).Ascorbic acid contribution to ORAC values in berry extracts: An evaluation by the ORAC-pyrogallol red methodology. *Food Chem.***113**: 331–335.

Baishya, S., Pathak, K., Baruah, A.M. and Rathi, S. (2010). Starch and protein profile of hill rice cultivars of Assam. *Oryza* **47**:237-242.

Bhagabati, R.K. M. (2000). Biochemical and isozyme analysis of some glutinous and non-glutinous rice (*Oryza sativa* L.) varieties of Assam. M.Sc. (Agri.) Thesis, Assam Agricultural University, Jorhat.

Bordiga, M., Gomez-Alonso, S., Locatelli, M., Travaglia, F., Coïsson, J. D., Hermosin-Gutierrez, I. and Arlorio M. (2014).Phenolics characterization and antioxidant activity of six different pigmented *Oryza sativa* L. cultivars grown in Piedmont (Italy). Food Res. Intern.(Article in press) www.elsevier.com/locate/foodres.

Borua,, I.; Ahmed, S.A.; Sarkar, C.R. and Das, D. (2004). Biochemical evaluation of scented rice of northeastern India. Bioprospecting of commercially important plants. Proc. of the national symposium on "Biochemical approaches for utilization and exploitation of commercially important plants. Indian Society of Agricultural Biochemists, Jorhat, India, pp. 79-85.

Brand-Williams, W., Cuvelier, M. E. and Berset, C. (1995). Use of free radical method to evaluate antioxidant activity. *Lebensm Wiss Technol.* **28**: 25–30.

Dewanto, V., Wu, X., Adom, K.K. and Liu, R.H. (2002). Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. *J. Agril. Food Chem.* **50**: 3010–3014.

Giusti, M.M. and Wrolstad, R.E. (2005). Characterization and measurement of anthocyanins by UV-visible spectroscopy. *Handbook of Food and Analytical Chemistry*.19-31.Jin L., Xiao P., Lu Y., Shao Y. F., Shen Y. and Bao J.S. (2009). Quantitative trait loci for brown rice color, phenolics and, flavonoid contents and antioxidant capacity in rice grain. *Cereal Chem*. **86**: 609-615.

Jin.L., Xiao, P, Lu. Y., Shao, Y.F., Shen, Y and Bao, J.S. (2009). Quantitative trait loci for brown rice color, phenoics flavonoid contents and antioxidant capacity in rice grain. *Cereal Chem* **86**:609-615

Juliano, B.O. (1985). Criteria and test for rice grain quality. In: *Rice Chemistry and Technology*. Juliano, B.O. (ed.) American Association of Cereal Chemists, Inc., St. Paul, Minnesota, USA, pp. 443-513.

Juliano, B. O., Banitista, G.M., Dugay, J.C. and Reyes, A.C. (1964).Studies on the physiochemical properties of rice. *J. Agril. Food Chem.* **12**:131-138.

Lum, M.S. and Chong, P.L. (2012). Potential antioxidant properties of pigmented rice from Sabah, Malaysia. Intern. *J. .Appl. Nat. Sci.***1:** 29-38.

Mir, S.A., Bosco, S, J.D and Sunooj, K.V (2013). Evaluation of physical properties of rice cultivators grwon in the temperate region of India. *International Food Res. J.* **20**(4): 1521-1527

Oko A.O., Ubi B.E., Efisue A.A. and Dambaba N. (2012).Comparative analysis of the chemical nutrient composition of selected local and newly introduced rice varieties grown in Ebonyi State of Nigeria. Intern. *J. Agri. Forestry* **2**: 16-23.

Pantindol, J., Flowers, A., Kuo, M., Wang, Y. and Gealy, D. (2006).Comparison of physicochemical properties and starch structure of red rice and cultivated rice. *J. Agril. Food Chem.* **54**: 2712-2718.

Pathak, K. (2015). Bioprospecting of glutinous rice of Assam. A PhD (Agri.) Thesis, Assam Agricultural University, Jorhat.

Philpott, M., Gould, K.S., Lim, C. and Ferguson, L.R. (2006). In situ and in vitro antioxidant activity of sweetpotato anthocyanins. *J. Agril. Food Chem.* **54**: 1710–1715.

Rathore, V. S., Singh, J.P., Meel, B. and Nathawat, N.S. (2014**).** Agronomic and economic performances of different cropping systems in a hot arid environment: A case study from North-western Rajasthan *J. Arid Environ*. **105**: 75 -90

Saikia, S., Dutta, H., Saikia, D. and Mahanta, C.L. (2012). Quality characterisation and estimation of phytochemicals content and antioxidant capacity of aromatic pigmented and non-pigmented rice varieties. *Food Res. Intern*. **46**: 334-340.

Scales, F.M. and Harrison, A.P. (1920). Boric acid modification of the Kjeldahl method for crop and soil analysis. *J Industry Engin. Chem*. **12**: 350-352.

Shen, Y., Jin, L., Xiao, P., Lu,Y. and Ba, J. (2009). Total phenolics flavonoids antioxidant capacity in rice grain and their relations to grain color size and weight. *J. Cereal Sci***. 49**:106-111.

Slinkard, S. and Singleton, V. L. (1977). Total phenol analysis: automation and comparison with manual methods. *American J. Enol.Viti*. **28:** 49–55.

Tananuwong, K. and Tewaruth, W. (2010).Extraction and application of antioxidants from black glutinous rice. *Food Sci. Technol.***43:**476-481.

Tsuda, T., Horio, F. and Osawa, T. (2002). Cyanidin 3-*Î-â*-glucoside suppresses nitric oxide production during a zymosan treatment in rats. *J. Nutr. Sci. Vitamin*. **48**: 305–310.

Tsuda, T., Horio, F., Uchida, K., Aoki, H. and Osawa, T. (2003).Dietary cyanidin 3-*Î-â-D*-glucoside-rich purple corn color prevents obesity and ameliorates hyperglycemia. *J. Nutr*. **133**: 2125–2130.

Yawadio, R., Tanimori, S. and Morita, N. (2007). Identification of phenolic compounds isolated from pigmented rice and their aldose reductase inhibitory activities. *Food Chem*.**101**:1616–1625.

Yodmanee, S., Karrila, T. T. and Pakdeechanuan, P. (2011). Physical chemical and antioxidant properties of pigmented rice grown in Southern Thailand. *Intern.Food Res. J*. **18:**901-906.

Zhao, C., Giusti, M.M., Malik, M. and Moyer, M.P. (2004).Magnuson BA Effects of commercial anthocyanin-rich extracts on colonic cancer and nontumorigenic colonic cell growth. *J. Agril. Food Chem.* **52**: 6122–6128.