

Original Research Article

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## A Study on Phytochemicals and Mineral Content of Indigenous Red Rice of Assam, India

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### ABSTRACT

Considering nutraceutical potentiality of phytochemicals, a few indigenous red rice germplasm of Assam, India were analysed for various phytochemicals, antioxidant activities and a few mineral contents. Among the sixteen germplasm analysed in their brown form, the total phenol content, total flavonoid content, and the anthocyanin content per 100 gm dry matter ranged from 752.89 mg±18.12 ('Ranga Dariya') to 2223 mg±33.48 ('Amana Bao'), 252.12±15.40mg ('Ixojoy') to 1000.75±86.93mg ('Dal Bao') and 76.05±0.32 µg ('Kolaguni') to 159.42±15.97 µg ('Betu'), respectively. For the polished form of rice, the same in 100 gm dry matter ranged from 76.51 mg±1.46 in 'Ranga Dariya' to 1409 mg±100.88 in 'Kolaguni', from 32.09± 7.17 mg in 'Ranga Dariya' to 374.46± 2.05mg in 'Negheribao' and from 17.91±5.08µg ('Biroi') to 115.42±11.72µg ('Hurupibao'), respectively. The antioxidant activities were observed to be the highest 96.00±0.26% in 'Negheribao' (for brown form of rice) and 86.35± 3.88% in 'Kenukubao' (for polished form of rice) and the lowest 81.54±0.23% in 'Betu'(for brown form of rice) and 59.65±4.64 % in 'Ranga Dariya' (polished rice), respectively. In brown rice, on dry weight basis, the iron, zinc and manganese content ranged from 2.12-54.40 mg per 100 gm, 2.42 mg to 26.57mg per 100 gm and 0.04 mg per 100 gm to 25.13 mg per 100 gm, respectively. The study revealed some indigenous rice germplasm of Assam, India which are significant considering phenolic compounds and mineral content.

#### Keywords

Colored rice, Red rice, Germplasm, Total phenols, Total flavonoids, Anthocyanins, Antioxidant activity, Minerals

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### Introduction

Rice (*Oryza sativa* L.) is the most important cereal worldwide. Traditionally, it has been the staple food and main source of income for more than 50% of the world's population. Besides being the main source of calories, rice is an important cereal because it has the

highest digestibility, biological value and protein efficiency ratio among all cereal (Kaul, 1973). Rice starch mainly differs in amylose content; amylose molecule determines the grain's gelatinization temperature, pasting behavior and visco-elastic properties (Tavares *et al.*, 2010) and has been an important component to be

considered in quality breeding of rice (Zhang *et al.*, 2007 and Bhattacharya, 2009).

Rice is generally consumed as white rice with the husk, bran, and germ removed. However, consumption of brown rice (hulled rice) is increasing in recent years, due to the increased awareness about its health benefits and good nutritional properties due to higher amounts of proteins, minerals and also phytochemicals (Tan *et al.*, 2009 and Mohan *et al.*, 2010). Whole grain consumption is associated with the prevention of chronic diseases, such as cancer and cardiovascular disease

Although, white rice is widely popular in South Eastern Asia, there are also some red, purple and black colored rice cultivars available. The color of rice results from the high content of anthocyanins located in the pericarp layers (Abdel-Aal and Hucl, 1999). Anthocyanin pigments have been reported to be highly effective in reducing cholesterol levels in the human body (Lee *et al.*, 2008) and also due to aldose reductase inhibitory activities, they are beneficial for diabetic prevention (Yawadio *et al.*, 2007). Colored rices are reported as potent sources of antioxidants and functional food because of its high polyphenols and anthocyanin content (Yawadio *et al.*, 2007). Colored rice is more nutritious than white rice, as it is good source of fiber, vitamins, minerals, and several important amino acids (Itani *et al.*, 2002). Attention is currently being given to the antioxidant and radical scavenging properties of colored rice cultivars because of their potential to provide and promote human health by reducing the concentration of reactive oxygen species and free radicals (Nam *et al.*, 2006 and Oki *et al.*, 2002).

Apart from genotypic differences, grain micronutrient content is also dependent on location (Rao *et al.*, 2014). It was reported

that that heavy metal concentrations in rice straw and grains were negatively correlated with soil pH value, but positively correlated with soil organic matter content, except grain Pb and Zn concentrations (Zeng *et al.*, 2011). Bhuyan *et al.*, 2014 reported that in Lakhimpur district of Assam, India, soils were strongly acidic to near neutral in reaction (pH 4.60–6.61) with organic carbon (OC) content ranging from low to high (1.20–18.3 g kg<sup>-1</sup>) and diethylene tri amine penta acetic acid (DTPA) extractable Fe, Zn, and Mn varied from 36.4 to 224.1, 0.10 to 1.68, and 4.60 to 131.3 mg kg<sup>-1</sup>, respectively (Bhuyan *et al.*, 2014). It was reported earlier (Neelamraju *et al.*, 2012) that large genetic variation exists for grain iron and zinc in rice germplasm including wild species and deep water rices. They reported that ‘Madhukar’ and ‘Jalmagna’ are deep-water rice varieties with high grain iron and zinc and overall, Fe concentration ranged from 0.2 to 224 ppm (or 0.02 to 22.4 mg per 100gm) and Zn concentration from 0.4 to 104 ppm (or 0.04 to 10.4mg per 100gm).

Several varieties of colored rice, particularly red and black rice, have been cultivated in North Eastern part of India. Rice is principal food crop of the region and is extensively cultivated in upland, lowland and deepwater conditions. Among these, the state Assam is particularly rich in rice germplasm with extreme physicochemical properties. Traditionally, it has been the staple food and main source of income for the people of Assam. The state has its climatic and physiographic features favourable for rice cultivation and the crop is grown in a wide range of agro-ecological situations. The release of high yielding varieties replaces the traditional landraces, which leads to gradual erosion of the rice genetic diversity. It was found that the indigenous varieties were relatively superior with respect to demand, resistance to pest and diseases and eating

quality, although their yield is low as compared to commercial white rice varieties. But there is important point that these varieties are invariably grown organically. These varieties are yet to be investigated for their nutritional and phytochemical properties. Therefore, the present study was undertaken to find out the phyto-chemical composition of a few indigenous colored rice cultivars of Assam. Earlier, the proximate composition and amylose content of some indigenous coloured rice germplasm of Assam, India was reported by the present authors (Mudoj and Das, 2018).

## **Materials and Methods**

### **Collection of red rice samples**

The details of indigenous colored rice germplasm, analysed in the present study and the place of collection are mentioned at Table 1. The non-pigmented variety 'Ranjit' was collected from Assam Agricultural University, Jorhat, Assam, India.

### **Processing of rice grains**

Rice grains were de-husked using a de-husker (Satake Corporation, Hiroshima, Japan) and then polished (4%) using a polisher (Satake Corporation, Hioroshima, Japan). The brown and polished rice grains were ground to flour and used for further analysis.

### **Extraction of rice samples for total phenols, total flavonoid content and antioxidant activity**

The rice flour (1.5 g) was extracted (1:20 w/v) at room temperature with 85% aqueous methanol under agitation for 30 min using a magnetic stirrer. The mixtures were centrifuged at 2500 g for 10 min and the supernatants were collected. The residues were re-extracted twice under the same

conditions, resulting finally in 50 ml crude extract.

### **Determination of total phenolic content (TPC)**

The TPC of extracts was determined using the Folin–Ciocalteu reagent (Singleton *et al.*, 1999). Extract (120 µl) was added to 600 µl of freshly diluted (10-fold) Folin–Ciocalteu reagent. 7.5% Sodium carbonate solution (980 µl) was added to the mixture after 2 min reaction time. The absorbance of the resulting blue colour was measured at 760 nm against a blank after 5 min of reaction time at 50 °C. Catechol was used as standard and TPC was expressed as mg catechol equivalent per 100 g dry sample.

### **Determination of total flavonoid content**

The total flavonoid content was measured by colorimetric method as described previously (Wu and Ng, 2008). Briefly, 0.5 ml of sample extract in methanol was mixed with 2 ml of deionized water, 0.15 ml of 5% sodium nitrite and 0.15 ml of 10 % aluminium chloride, followed by reaction time of 6 min. Then, 4% NaOH (2 ml) was added to the mixture and mixed well. After 15 min at room temperature, the absorbance of the mixture was measured at 510 nm. All values were expressed as mg quercetin equivalent (QE) per 100 gm dry wt.

### **Determination of anthocyanin content**

To determine total anthocyanins, the spectrophotometric method reported by Abdel-Aal and Hucl (1999) was employed. The anthocyanins were extracted using acidified methanol (0.1 M HCl/methanol 85:15, v/v) with a solvent to sample ratio of 10:1, at room temperature for 30 min on a magnetic stirrer and then centrifuged and the supernatants were collected. The residues

were re-extracted twice under the same conditions, and the supernatants were combined and kept in the dark and at 4°C until further analyzed. The absorbance was measured at 525 nm using a UV-visible spectrophotometer against a reagent blank. Cyanidin-3-chloride was used to prepare the standard calibration curve. Total anthocyanin contents in the red rice samples were expressed as µg Cyanidin-3-chloride equivalents per 100 g dry weight of samples.

### **Determination of 2, 2-diphenyl-1-picryl hydrazyl (DPPH) radical scavenging activity**

The free radical scavenging activity of the methanol extract was measured following a previously reported procedure (Brandwilliams *et al.*, 1995), using the stable 2,2-diphenyl-1-picryl hydrazyl radical (DPPH•). An aliquot of 0.3 ml of a diluted methanolic extract (2 times) was vigorously mixed with 1.5 ml of freshly prepared 0.004% DPPH in methanol and held in the dark for 30min at room temperature. The absorbance was then read at 517 nm against blank (only methanol). An equal mixture of methanol and 0.004% DPPH in methanol was used as control. DPPH free radical scavenging ability was calculated by using the following formula:

$$\text{Scavenging activity (\%, dry basis)} \\ = (\text{absorbance of control} - \text{absorbance of sample}) / (\text{absorbance of control}) \times 100$$

### **Mineral content**

The mineral contents in the powdered rice samples were determined using the methods described in AOAC (1997). The ash obtained as per AOAC method, 1997 was dissolved in dilute HCl (1:1) on a water bath at 100°C and the mixture was evaporated to dryness. 4 ml of HCl and 2 ml of glass distilled water were added, warmed and the acid soluble portion obtained after filtration was made up to 100

ml with glass distilled water. This solution was used for estimation of Fe, Zn and Mn in colored rice samples by atomic absorption spectrometer.

## **Results and Discussion**

### **Total phenol content (TPC)**

TPC of the investigated rice germplasms is presented in Table 2. The TPC content of red rice germplasms was compared with non-pigmented rice variety, 'Ranjit' which is commercially cultivated in Assam. All the brown form of pigmented rice samples contained higher amount of phenolic compound than non-pigmented brown form of rice 'Ranjit' (232.94±11.45 mg, Table 2). TPC of brown form of rice samples (catechol equivalents per 100 g, dry wt basis) ranged from 752.89mg in 'Ranga Dariya' to 2223 mg in 'Amana Bao'. TPC of polished rice samples (catechol equivalents per 100 g, dry basis) varied from 76.51 mg in 'Ranga Dariya' to -1409 mg in 'Kolaguni'. There was loss of TPC in polished samples in comparison to their respective brown rice after polishing (4%). Reddy *et al.*, 2017 also reported reduction of 85.54% to 89.97% TPC in pigmented rice by 9% polishing treatment and 7.75-10.55 mg/g TPC in brown form of pigmented rice varieties.

For polished form of rice, the detection of lower amount of total phenols in some of the pigmented varieties than the same in non-pigmented 'Ranjit' (162.98±8.97) might indicate the presence of phenolic compound mainly on outer layer of grains which was lost on polishing. The phenolic compounds in whole rice grain were reported to be from 108.1 to 1244.9 mg gallic acid equivalent/100 g depending on color of the grain (Shen *et al.*, 2009). Chen *et al.*, 2012 also reported that the total phenolic compounds in red rice ranged from 460.32–725.69 mg/100 g.

### **Total flavonoid content (TFC)**

Total flavonoid content (mg quercetin equivalent per 100 gm rice samples, on dry wt basis) was significantly different among the red rice germplasm (Table 2). In the brown form of rice, the highest content of flavonoid was found in 'Dal bao' (1000.75±86.93mg) and the lowest in 'Ixojoy' (252.12±15.40mg). There was decrease in TFC in polished rice samples as compared to their respective brown rice samples. In the polished rice, the TFC varied from 32.09± 7.17 mg in 'Ranga Dariya' to 374.46± 2.05mg in 'Negheribao'. However, the same for the non-pigmented variety 'Ranjit' was found to be 109.81± 7.15mg and 66.93 ±10.01mg for brown and polished form, respectively.

Shen *et al.*, 2009 reported the TFC in whole rice (white, red and black) to be in the range from 88.6 to 286.3 mg rutin equivalent/100 g (Shen *et al.*, 2009). The present study also indicated that the brown form of pigmented rice varieties contained a higher value of TFC than the brown form of non-pigmented rice variety 'Ranjit' (109.81± 7.15mg). Reddy *et al.*, 2017 reported the TFC in pigmented rice varieties, which ranged from 3.25 to 3.90 mg/g. Ghasemzadeh *et al.*, 2018 reported higher flavonoid content in red rice bran (238.76- 457.00 mg QE/100 g dry matter, respectively) than brown rice bran (105.7-240.88 mg QE/100 g dry matter, respectively).

### **Anthocyanin content**

The anthocyanin content in different red rice germplasms of Assam is presented in Table 2. Anthocyanin content in brown rice sample varied from 76.05-159.42 ug cyaniding choride equivalent per 100 gm dry wt. For brown rice, the highest content of anthocyanin was found in 'Betu' (159.42±15.97ug) with the lowest in 'Kolaguni' (76.05± 0.32 ug). In

polished rice, anthocyanin content varied from 17.91±5.08 ug to 115.42±11.72 ug cyanidin chloride equivalents per 100 gm. In comparison to brown form, the loss of anthocyanin content in polished rice sample occurred up to 88 % in 'Biroi'. However, in some of the samples, the decrease in anthocyanin content in polished samples than those of brown, was not significant, which represented more uniform distribution of the pigment in the grain. Saikia *et al.*, 2012 reported higher anthocyanin content (35.87 mg per 100 gm) in black rice (polished) cultivar from Manipur, 'Poreiton Chakhao' than red rice, 'Chak-hao-amubi' (1.81 mg per 100gm). A higher level of total anthocyanin content (TAC) than the result of the present finding was reported by Sompong *et al.*, 2011, which ranged from 0.3 to 1.4 mg and 109.5–256.6 mg/100 g in red and black rice varieties, respectively.

### **DPPH free radical scavenging activity**

DPPH free radical scavenging activity (Table 3) in brown rice samples ranged from 81.54±0.23-96.00±0.26%. 'Negheribao' showed the highest antioxidant activity which might be due to presence of higher amount of total phenols, total flavonoids and anthocyanins. In polished rice sample, DPPH scavenging activity varied from 59.65±4.64 to 86.35± 3.88%. It was reported that the pigmented rice varieties showed high DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging activity (94.19% and 96.43% in polished rice sample) (Saikia *et al.*, 2012). Finocchiaro *et al.*, (2007, 2010) reported that the total antioxidant capacity of red-grained rice genotypes were three times higher than those of white-grained rice genotypes. DPPH activity in brown form of pigmented rice varieties ranged from 84.77% to 92.67% as reported by Reddy *et al.*, 2017. After polishing, the lowest DPPH activity was observed with 6.11-6.55%. Previously, it was

reported (Ghasemzadeh *et al.*, 2015 and Djeridane *et al.*, 2006) that the concentration of total phenolics and flavonoids in rice grains were positively correlated with the antioxidant activity. Oki *et al.*, (2002) reported that in red pericarp grains, a strong correlation between antioxidant activity and the content of proanthocyanidins was observed; however, in the case of black pericarp grains, the correlation was dependent on the content of anthocyanins. These results suggest that phenolic compounds were primarily responsible for the antioxidant activity of rice grains.

### Mineral content

Minerals play an important role in human health and are required to maintain a balanced diet, which is important for conserving all regular metabolic functions. In the present study, on dry weight basis, the iron content in brown form of rice samples ranged from 2.12-54.40 mg per 100 gm (Table 4). The autumn rice ‘Rongasokua’ (brown form) contained the highest (54.40 mg per 100 gm dry wt) amount of iron. Detection of higher iron

content in some varieties might be related to low soil pH of the locality where the variety was grown. Bhuyan *et al.*, (2014) reported that in Lakhimpur district of Assam, soils were strongly acidic to near neutral in reaction (pH 4.60–6.61). The wet land rice in many humid tropical regions of Asia, Africa, and South America are affected by iron toxicity, which mainly occur due to increase in Fe(II) concentration in soil solution resulting from drop of redox potential arising from anaerobic situations in submerged rice fields. The high quantity of ferrous ions in the soil solution upsets the mineral element balance in rice plants and affects its growth. A field experiment was carried<sup>32</sup> out in acidic laterite soil (pH 5.1) having 400mg kg<sup>-1</sup> diethylene tri amine penta acetic acid (DTPA) extractable Fe for developing strategies to combat Fe toxicity and to study Fe, Zn, and Mn nutrition in rice. Among the treatments, the highest Fe content (124 mg per kg or 12.4 mg per 100gm in grain) was recorded in control for all cultivars. They also reported the Zn and Mn content of grain to be 35 and 59 mg per kg (or 3.5 and 5.9mg per 100 gm).

**Table.1** Indigenous red rice germplasms collected from different regions of Assam

SI No.	Names of germplasm	Place of collection	Type of rice
1	Amana Bao	North Lakhimpur, Assam	Deep water rice
2	Betu	Majuli, Assam	Autumn rice
3	Biroi	North Lakhimpur, Assam	Winter rice
4	Bogaguni	North Lakhimpur, Assam	Autumn rice
5	Burali	North Lakhimpur, Assam	Autumn rice
6	Dal Bao	North Lakhimpur, Assam	Deep water rice
7	Hurupi Bao	North Lakhimpur, Assam	Deep water rice
8	Ixojoy	North Lakhimpur, Assam	Autumn rice
9	Jul Bao	North Lakhimpur, Assam	Deep water rice
10	Kenkua Bao	North Lakhimpur, Assam	Deep water rice
11	Kolaguni	North Lakhimpur, Assam	Autumn rice
12	Kopouguni	North Lakhimpur, Assam	Autumn rice
13	Kotia Bao	North Lakhimpur, Assam	Deep water rice
14	Negheri Bao	North Lakhimpur, Assam	Deep water rice
15	Ronga Chokua	North Lakhimpur, Assam	Autumn rice
16	Ronga Dariya	North Lakhimpur, Assam	Autumn rice

**Table.2** Total polyphenol, flavonoid content and anthocyanin content of different red rice germplasms of Assam

SI No	Name of variety	Total phenol content(mg catechol equivalents per 100 g)		Total flavonoid content (mg quercetin equivalents per 100 gm dry wt)		Anthocyanin content (ug cyaniding choride equivalent per 100 gm dry wt)	
		Brown rice	Polished rice	Brown rice	Polished rice	Brown rice	Polished rice
1	Amana bao	2223.68±33.48	547.03±25.09	766.65±11.45	216.84±2.07	96.75±9.87	79.481±1.12
2	Betu	1136.98±53.68	94.67±7.27	478.10±41.53	41.63±25.57	159.42±15.97	66.93±9.915
3	Biroi	1462.27±56.58	289.19±17.25	495.14±40.74	137.92±12.90	155.26±48.48	17.91±5.08
4	Bogaguni	1074.77±14.09	306.29±65.92	559.05±12.87	78.91±10.90	118.17±8.14	89.67±0.038
5	Burali	1986.09±31.51	298.28±5.72	778.67±39.62	115.66±5.69	107.93±19.263	40.46±24.57
6	Dal bao	2215.73±67.50	263.50±7.12	1000.75±86.9	73.62±18.19	112±11.12	48.26±19.48
7	Hurupibao	1283.23±47.89	142.66±20.97	443.65±25.47	33.79±6.54	144.73±1.24	103.63±16.87
8	Ixojoy	762.52±76.83	165.72±9.46	252.12±15.4	125.82±19.91	95.26±7.51	52.14±18.52
9	Jul bao	1145.06±33.59-	933.89±34.12	466.10±67.93	248.58±58.36	80.31±0.35	78.61±0.36
10	Kenkuabao	1711.13±127.35	240.41±5.49	517.50±15.96	72.60±0.00	130.78±12.23	88.19±8.39
11	Kolaguni	1850.92±71.73	1409.13±100.88	647.74±33.41	355.27±12.52	76.05±0.32	74.64±1.66
12	Kopouguni	1071.02±88.46	440.11±14.89	329.74±60.82	182.70±55.6	79.36±7.83	75.88±0.63
13	Kotiabao	897.53±172.52	79.45±14.63	372.07±51.95	37.28±14.39	128.13±18.26	84.73±56.83
14	Negheribao	1740.38±87.51	924.51±93.63	617.05±20.08	374.46±2.05	148.55±31.74	61.60±9.72
15	RangaDariya	752.89±18.12	76.51±1.46	394.01±21.34	32.09±7.17	85.09±7.87	39.23±24.19
16	Rongasokua	1534.52±143.45	247.18±1.19	387±23.15	80.97±35.37	77.61±1.34	46.43±22.78
17	Ranjit (Non pigmented rice)	232.94±11.45	162.98±8.97	109.81±7.15	66.93±10.01	-	-

**Table.3** DPPH free radical scavenging activity of different red rice germplasm of Assam

Sl No	Name of variety	DPPH free radical scavenging activity	
		Brown rice	Polished rice
1	Amana bao	92.80±2.05	82.05±0.36
2	Betu	81.54±0.23	73.74±2.29
3	Biroi	95.57±0.14	84.23±0.16
4	Bogaguni	94.51±0.05	85.12±2.05
5	Burali	88.61±2.69	85.30±0.04
6	Dal bao	94.63±0.05	82.33±1.77
7	Hurupibao	84.65±3.14	84.14±0.00
8	Ixojoy	83.97±0.78	82.88±1.44
9	Jul bao	82.62±0.42	82.96±0.20
10	Kenkuabao	94.82±0.34	86.35±3.88
11	Kolaguni	81.62 ±0.20	84.00±0.25
12	Kopouguni	84.51±0.47	82.22±0.05
13	Kotiabao	84.17±0.29	81.55±1.69
14	Negheribao	96.00±0.26	82.37±0.24
15	Ranga Dariya	83.32±0.32	59.65±4.64
16	Rongasokua	83.38±0.40	83.07±0.09

**Table.4** Mineral content of red rice germplasm (brown form) of Assam

Sl No	Variety	Fe content (mg/100gm)	Zn content (mg/100gm)	Mn content (mg/100gm)
1	Amana bao	2.12	2.42	ND
2	Betu	3.54	5.34	ND
3	Biroi	3.87	6.31	3.72
4	Bogaguni	5.55	12.16	0.65
5	Burali	3.43	8.92	0.04
6	Dal bao	3.79	6.65	ND
7	Hurupibao	16.67	10.63	ND
8	Ixojoy	6.09	5.22	2.81
9	Jul bao	6.20	7.49	ND
10	Kenkuabao	5.69	5.42	4.95
11	Kolaguni	16.17	24.94	25.13
12	Kopouguni	8.72	7.67	ND
13	Kotiabao	9.81	26.57	ND
14	Negheribao	5.70	6.01	5.79
15	Rangadariya	3.28	8.64	3.75
16	Rongasokua	54.40	9.99	ND

ND: Not detected

However, Yodmanee *et al.*, (2011) reported the iron content in pigmented brown rice samples to be 0.91-1.66 mg/100 g. Low mineral (iron and Zn) content reported for some of the rice germplasm of India might be due to expression in polished (up to 10%) form (Rao *et al.*, 2014). The micronutrients are lost during polishing (Sellappan *et al.*, 2009). Thus rice grain iron content will also vary with degree of milling / polishing (Reddy *et al.*, 2018).

In the present study, the manganese was not detected in some of the rice germplasm in brown form. On dry weight basis, the manganese content was found to be the highest in brown form of autumn rice 'Kolaguni' (25.13 mg per 100 gm). The zinc content in brown rice was observed to be 2.42 mg in 'Amana bao' to 26.57 mg per 100 gm in 'Kotiabao'. Anuradha *et al.*, (2012) analyzed brown rice of 126 accessions of rice genotypes for Fe and Zn concentration. Iron concentration ranged from 6.2 ppm to 71.6 ppm (or 0.62mg to 7.16mg per 100gm) and zinc from 26.2 ppm to 67.3 ppm (or 2.62 to 6.7 3mg per 100gm). It was reported that in 'Madhukar' and 'Jalmagna', two deep-water rice varieties of India, the grain iron concentration ranged from 0.2 to 224 ppm (or 0.02 to 22.4 mg per 100 gm) and zinc concentration from 0.4 to 104 ppm ( or 0.04 to 10.4 mg per 100gm) (Neelamraju *et al.*, 2012).

In conclusion, the present study reveals that the pigmented rice germplasm of Assam, India are rich source of phenolic compounds, particularly flavonoids among which the anthocyanins are not the major one. Most of the phenolic compounds can be retained at four percent polishing rate. The study also reveals that some of the indigenous pigmented rice germplasm (brown form) are rich in iron, zinc and manganese, which might be due to low pH of soil and growing

situation. These varieties can be considered by the plant breeders for bio fortification program of rice. There is scope to study the profiles of various phenolic compounds and the micronutrients present in abundantly available indigenous pigmented rice germplasm of Assam, India.

**Conflict of interest:** Authors declare that they have no conflict of interest.

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