Introduction

Rice is the most important food crop grown in Assam. The state has its climatic and physiographic features favorable for rice cultivation and the crop is grown in a wide range of agro-ecological situations. This region is endowed with large varieties of rice germplasm with extreme physicochemical properties. The release of high yielding varieties replaces the traditional landraces, which leads to gradual erosion of the rice genetic diversity. The rice varieties commonly have whitish kernels. 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). There are also rice varieties with a colored testa (black, purple, or red), that give slightly colored kernels on milling. It was observed that, colored rice varieties are more nutritious and rich in minerals and possess antioxidant properties (Itani et al., 2002 and Yawadio et al., 2007).

Attention is currently being given to the anti-oxidative 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.

We have already reported about the nutritional composition of twenty one traditional colored rice cultivars of Assam, India (Mudoi and Das, 2018) and phytochemicals and mineral content of sixteen indigenous red rice varieties of Assam, India (Mudoi and Das, 2019).

There is no literature available regarding the chemical composition and antioxidant potential of the colored rice varieties grown in Assam after cooking. Therefore, the present study was conducted to explore the colored rice varieties native to Assam with respect to the phytochemicals and antioxidant potentials as affected by cooking.

Materials and Methods

The varieties, selected based on our earlier study on phytochemical content (Mudoi and Das, 2019), were collected from different regions of Assam during the harvesting periods (Table 1). According to the season and ecology, the diverse varieties are grown such as Baon (deep water rice), Ahu (autumn), and Sali (winter).

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). Bran was removed and was collected separately.

Proximate composition analysis

Moisture content, crude protein, crude fat and ash content were estimated as per AOAC method, 1995. The total carbohydrate content (including crude fiber content) on dry basis was determined by subtracting the per cent (dry basis) content of crude protein, ash and crude fat from 100. The amylose content was estimated according to Sowbhagya and Bhattacharya, 1979.

Extraction of rice samples for analysis of phytochemicals

The rice flour (1.5 g) was weighed accurately and extracted at room temperature with 85% aqueous methanol (1:20 w/v) under agitation using a magnetic stirrer for 30 min. The mixtures were centrifuged at 2500g 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). Catechol was used as standard and TPC was expressed as mg catechol equivalent per 100 g flour.

Determination of total flavonoid content

The total flavonoid content was measured by colorimetric method as described previously
(Wu and Ng, 2008). The total flavonoid content was expressed as grams quercetin equivalent (QE) per kg dry wt of sample.

**Determination of DPPH radical scavenging activity**

The free radical scavenging activity of extract was measured following a previously reported procedure using the stable 2,2′-diphenyl-1-picrylhydrazyl radical (DPPH•) (Brand-Williams et al., 1995). An aliquot of 0.3 mL of a diluted extract (2 times) was vigorously mixed with 1.5 mL of freshly prepared 0.004% DPPH in methanol and held in the dark for 30 min at room temperature. The absorbance was then read at 517 nm against blanks. DPPH free radical-scavenging ability was calculated by using the following formula:

\[
\text{Scavenging activity (\%)} = \frac{(\text{Absorbance of control} - \text{Absorbance of sample})}{\text{Absorbance of control}} \times 100
\]

**Determination of Zn content**

The ash obtained 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 Zn in colored rice samples by atomic absorption spectrometer.

**Cooking of colored rice**

Thirty gram rice grain of each variety (both brown and polished) was taken in beakers and 54 mL distilled water (1:1.8 w/v) was added to each. After soaking for 30 min at room temperature (27±1 °C), the samples were cooked at water bath for 10 min by open steaming at 100 °C in the water used for initial soaking. Complete cooking was indicated by loss of opaque uncooked portions when cooked kernel was pressed between glass slides. After cooking, samples were dried at 50°C in a hot air oven till constant weight, cooled and powdered in grinder and stored air tight till further analysis.

**Morphological and physical properties of milled rice grain**

Each sample (10 kernels) was cooked in a water bath at 98°C for 10 min. The cooked rice was then transferred to a petri dish lined with filter paper. Length and breadth of raw and cooked rice kernels of cultivars were measured by using Vernier caliper. The measurements were repeated 6 times in each sample and thus an average of 6 grains was recorded. Ratio of length and breadth gave L/B ratio. The elongation ratio (ER) was calculated using the following formula:

\[
\text{ER} = \frac{\text{Average length of cooked rice grains (mm)}}{\text{Average length of raw rice grains (mm)}}
\]

**Statistical analysis**

All assays were carried out in triplicate and the results expressed as mean ± SEM.

**Results and Discussion**

**The amylose content**

The amylose content of rice is one of the most important criteria of rice quality in terms of cooking and pasting properties. The amylase content of the varieties was found in the range of waxy to intermediate amylase containing group. There was higher amylose content in polished rice samples (4.21% in Betu to 21.18% in Rongachakua) as compared to brown rice (1.07% in Betu to 20.98% in Rongachakua). This might be due to percent increase (amylose is located at the
endosperm) for loss of bran and aleuron layer during polishing. In the present study, the amylose content (Table 2) in cooked samples ranged from 0.02-8.98%. All the brown cooked rice samples showed decrease in amylose content (maximum 98.13% in Betu, to 0.004% in Kenekuabao, except 'Negheribao' (brown rice) than their raw forms. The polished form of rice samples showed decrease in amylose content (maximum 98.81% in Rangachakua, to 31.14% in Amanabao). The decrease in amylose content on cooking might be either due to rupture of some of the glycosidic linkages during heating or formation of resistant starch (RS) (Kim et al., 2006). Kavita et al., (1998) found that the RS content of cooked rice was 1.96 g/100 g DM. When the samples were stored for either 24 or 48 h at 4°C, the RS contents increased to 3.37 g and 4.38 g/100 g DM, respectively. In our study also, the cooked rice after dying was stored at 4°C till analysis. However, the observed increase in amylose content in 'Negheribao' (brown rice) might be due to rupture of alpha 1-6 linkages of amylopectins. The rupture of glycosidic linkages during processing (prolonged heating) was reported by Svihus et al., 2005. Hydrolysis of starch as a result of heat treatments was also reported by Rehman and Shah, 2005. In addition, the decrease in amylase content might be due to increase in bound water content after cooking, which was not evaporated when the cooked rice was dried before analysis.

Total carbohydrates, crude fat, crude protein and ash content

The total carbohydrates including crude fibers, crude fat, crude protein and ash content of cooked colored rice varieties of Assam is presented in Table 3. The observed differences among the varieties might be due to genetical differences, and differences in nutrient status of soil, where these were grown. The crude protein was also detected in higher level (more than 10%, dry basis) in a few varieties (Jul bao and Negheri bao) in brown form. The variety Jul bao (brown rice) also contains higher ash content (1.85%), and the lowest value of ash (0.56%) was found for Betu (polished rice). There was a significant loss of crude fat, protein and ash in polished rice samples as compared to brown rice. This difference may be attributed to the degree of milling, as milling of rice removes the outer layer of the grain where most of the fats and minerals are concentrated (Thomas et al., 2016). Devi et al., 2015 also observed increase of carbohydrate content and decrease of crude protein, crude fat and ash content with increase of degree of polishing of rice. Our result on proximate composition of raw form of rice samples are in agreement with those already reported (Devi et al., 2015, Thomas et al., 2016, Das et al., 2018). Murdifin et al., (2015) reported the total contents of ash, fat, protein, crude fiber and carbohydrate of pigmented rice varieties of Indonesia were in the range of 1.19-2.13, 1.06-3.05, 7.24-14.02, 0.66-0.99 and 71.29-77.14%, respectively at less than or equal to 14% moisture content.

The observed reduction of crude fat, crude protein and ash content of cooked rice samples as compared to respective raw samples might be due to increase of bound moisture content of the dried cooked rice samples. However, the observed increase in some of the samples was not actual increase, only changes in percentage due to change of other parameters. The same can be justified for the increase in total carbohydrate including the crude fibre content of all the cooked rice samples as it was calculated by subtraction method. Thomas et al., (2016) reported that the cooking of raw rice samples resulted in
significant reduction in value of crude protein. However, they compared raw rice and freshly cooked rice, without removal of moisture.

A few reports can be traced on analysis of cooked rice for proximate composition on dry weight basis.

**Total phenol content (TPC)**

TPC of the investigated rice varieties are presented in Table 4. The present study shows high phenol content. TPC of brown rice samples ranged from 1136.98 mg (in Betu) to 2223.68 mg (in Amanabao) catechol equivalents per 100 g rice (dry basis). TPC of polished rice samples ranged from 240.41 mg (in Kenekuabao) to 933.89 mg (in Jul bao) catechol equivalents per 100 g rice (dry basis). There was loss of TPC in polished samples in comparison their respective brown rice samples.

Total phenol content was decreased in cooked sample as compared to raw. Total phenol content in cooked brown rice was found in the range of 132.86 mg (in Negheribao) to 368.15 mg (in Rangachakua) catechol equivalents per 100 gm dry sample.

The TPC of cooked polished rice also varies from 123.01 (in Negheribao) to 296.99 mg (in Amanabao) per 100 gm dry wt. There was loss of phenolic compounds up to 88% in cooked brown rice sample (Dal bao) and 86.68% (Negheribao) in cooked polished sample as compared to the same in raw.

**Total flavonoid content (TFC)**

TFC of brown rice samples ranged from 387 mg (in Rangachakua) to 1000.75 mg (in Dalbao) quercetin equivalents per 100 g rice (dry basis). TFC of polished rice samples ranged from 72.60 mg (in Kenekuabao) to 374.46 mg (in Negheribao) quercetin equivalents per 100 g rice (dry basis). There was loss of TFC in polished samples in comparison their respective brown rice samples.

Total flavonoid content (TFC) in cooked brown rice sample ranged from 81.00 mg (in Dalbao) to 303.82 mg (in Kenekuabao) QE per 100 gm dry wt and in cooked polished rice from 1.75 mg (in Biroi) to 112.68 mg (in Amanabao) QE per 100 gm dry wt.

It was observed that the total phenolic and flavonoid content decreased drastically on cooking when compared to the respective raw samples. The drastic decrease in TPC and TFC could be due to thermal degradation of phenol and flavonoid compounds (Chmiel et al., 2018).

**DPPH free radical scavenging activity**

DPPH free radical scavenging activity in brown rice sample ranged from 81.54% (in Betu) to 96.00% (in Negheribao). In polished rice sample, DPPH activity varied from 73.74% (in Betu) to 86.35% (in Kenekuabao). DPPH activity is also decreased in cooked samples than raw ones.

DPPH free radical scavenging activity in cooked brown rice and polished rice samples varies from 42.78% (in Dalbao)-79.23% (in Kenekuabao) and 32.06 (in Biroi) -51.86% (in Negheribao). Study on the determination of phenolic compounds in different parts of rice grain confirmed that phenolic acids in bran ensure the highest contribution to the total phenolic content in the grain compared to endosperm and embryo (Shao and Bao, 2015; Shao et al., 2014).

Hence, bran removal process during polishing of dehulled rice to obtain milled rice, the form that is generally consumed, reduces the concentration of phenolic compounds in the grain. Chmiel et al., 2018 reported that the level of total polyphenols in unpolished grains was 3.5-fold higher than in polished ones and
the brown rice showed the highest TAA (total antioxidant activity) and phenolic content (622.5 mg/kg dry weight or 62.5 mg/100 gm dry matter). Murdifin et al., (2015) reported that the anthocyanin and phenolic contents of black glutinous rice extracts from some pigmented varieties of Indonesia were in the range of 94.70-202.46 mg Cy-3-glc/100 g db and 292.74-746.25 mg GAE/100 g db, respectively, which were higher than the black rice (66.08-113.83 mg Cy-3-glc/100 g db and 119.74-230.10 mg GAE/100 g db) and the red rice (0-12.85 mg Cy-3-glc/100 g db and 12.52-64.52 mg GAE/100 g db) and they found that the antioxidant activity was positively correlated with total phenolic and anthocyanin compounds.

Massaretto et al., 2011 reported that the cooking was found to reduce the average content of total phenolics in the pigmented group by about 50% (from 409.7 to 202.6 mg FA eq./100 g). The average content of soluble phenolics in pigmented rice dropped by 83% after cooking (from 335.3 to 57.9 mg ferrulic acid eq./100 g), indicating that the soluble phenolic fraction, mainly composed of proanthocyanidins, was the most affected by the thermal treatment. Chmiel et al., 2018 reported that among three processing methods, cooking using rice cooker caused the highest reduction of phenolic content (29–31%), followed by microwaving (18–33%), and boiling (18–28%). However, as observed by Chmiel et al., 2018, the absorption of all the cooking water by the rice during thermal treatment in our study indicated that decrease of AA is most likely related to the thermal and oxidative degradation of phenolic compounds.

**Zn content after cooking**

Generally, pigmented rice has the highest mineral content compared to non-pigmented rice (Hurtada et al., 2018). Zn is highly concentrated in rice embryo and uniformly distributed in bran layer and endosperm (Liang et al., 2008). Liu et al., 2019 observed decrease in some of the minerals including zinc after cooking which involved washing and soaking prior to cooking and they suggested that decrease was mainly due to washing step. The reduced mineral content by washing was mainly related to the thermal and oxidative degradation of phenolic compounds. It was reported (Neelamraju et al., 2012) that in ‘Madhukar’ and ‘Jalmagna’, two deep-water rice varieties of India, the grain zinc concentration ranged from 0.4 to 104 ppm (or 0.04 to 10.4 mg per 100gm). Cooking generally leads to reduction in mineral content of food samples due to leaching of the minerals into the cooking water or due to increase of moisture content (Thomas et al., 2016). Although, in the present analysis, sample was not washed and cooking water was not allowed to leach out and the result was also expressed on dry weight basis, the decrease in zinc content can be justified considering increase of bound water content during cooking, which was not evaporated during drying after cooking.

**Morphological character of raw and cooked colored rice varieties of Assam**

Morphological character of raw and cooked colored rice varieties of Assam are presented at the Table 6. For the raw form of brown and polished varieties, the L/B ratio ranged from 1.82 (in Jul bao) to 2.85 (in Rongachakua) and 1.75 (in Dalbao) to 2.80 (in Biroi), respectively.
Table 1: Description of indigenous colored rice varieties collected from different regions of Assam

| Sl No | Name of varieties | Place of collection | Type of rice |
|-------|-------------------|---------------------|--------------|
| 1     | Amana bao         | North Lakhimpur, Assam | deep water   |
| 2     | Hurupi bao        | North Lakhimpur, Assam | deep water   |
| 3     | Dal bao           | North Lakhimpur, Assam | deep water   |
| 4     | Biroi             | North Lakhimpur, Assam | winter       |
| 5     | Kenkuabao         | North Lakhimpur, Assam | deep water   |
| 6     | Betu              | Majuli, Assam, Assam | autumn       |
| 7     | Negheribao        | North Lakhimpur, Assam | deep water   |
| 8     | Jul bao           | North Lakhimpur, Assam | deep water   |
| 9     | Rongachokua       | North Lakhimpur, Assam | autumn       |

Table 2: The amylose content of raw* and cooked colored rice

| Sl No | Name of variety | Form  | Amylose content (% dry basis) | % change due to cooking |
|-------|-----------------|-------|-------------------------------|-------------------------|
|       |                 |       | Brown rice                    | polished rice           |
|       |                 |       | Raw                           | Cooked                  |
| 1     | Jul Bao         | Raw   | 8.85±0.11                     | 9.55±0.15               |
|       |                 | Cooked| 3.17±0.14                     | 1.87±0.06               |
| 2     | Dal bao         | Raw   | 11.78±0.15                    | 12.98±0.10              |
|       |                 | Cooked| 0.25±0.07                     | 1.59±0.07               |
| 3     | Biroi           | Raw   | 9.92±0.03                     | 13.16±0.13              |
|       |                 | Cooked| 1.30±0.23                     | 2.38±0.15               |
| 4     | Hurupibao       | Raw   | 5.74±0.59                     | 13.36±0.41              |
|       |                 | Cooked| 2.06±0.07                     | 4.25±0.26               |
| 5     | Negheribao      | Raw   | 4.61±0.35                     | 10.17±0.59              |
|       |                 | Cooked| 8.98±0.25                     | 0.41±0.05               |
| 6     | Kenkuabao       | Raw   | 2.22±0.07                     | 16.42±0.34              |
|       |                 | Cooked| 2.21±0.08                     | 3.66±0.08               |
| 7     | Betu            | Raw   | 1.07±0.02                     | 4.21±0.07               |
|       |                 | Cooked| 0.02±0.01                     | 1.80±0.04               |
| 8     | Amana bao       | Raw   | 12.29±0.11                    | 12.36±0.06              |
|       |                 | Cooked| 0.51±0.01                     | 8.51±0.18               |
| 9     | Rongasokua      | Raw   | 20.98±0.22                    | 21.18±0.14              |
|       |                 | Cooked| 1.16±0.05                     | 0.25±0.02               |

*Mudoi and Das, 2018
Table 3: The total carbohydrates (including fibre), crude fat, crude protein and ash content (% dry basis) of raw* and cooked colored rice

| Sl No | Name of variety          | Form        | Total carbohydrates | Crude fat  | Crude protein | Ash   |
|-------|--------------------------|-------------|---------------------|------------|--------------|-------|
| 1     | Jul bao brown rice       | Raw         | 80.62± 0.28         | 3.70±0.11  | 13.83±0.35   | 1.85±0.05 |
|       |                          | Cooked     | 86.61± 0.17         | 3.10±0.08  | 8.69±0.56    | 1.60±0.07 |
| 2     | Jul bao polished rice    | Raw         | 88.15 ±0.50         | 3.25±0.02  | 7.35±0.33    | 1.25±0.09 |
|       |                          | Cooked     | 88.00 ±0.54         | 1.25±0.06  | 9.29±0.18    | 1.46±0.25 |
| 3     | Negheribao brown rice    | Raw         | 85.13±0.20          | 3.10±0.11  | 10.03±0.10   | 1.74±0.13 |
|       |                          | Cooked     | 87.58±0.40          | 2.09±0.05  | 8.4±0.27     | 1.93±0.32 |
| 4     | Negheribao polished rice | Raw         | 87.85±0.27          | 1.55±0.12  | 9.35±0.32    | 1.25±0.10 |
|       |                          | Cooked     | 88.36±0.11          | 0.73±0.05  | 9.61±0.45    | 1.30±0.07 |
| 5     | Hurupibao brown rice     | Raw         | 87.96±0.69          | 3.83±0.10  | 6.91±0.35    | 1.30±0.07 |
|       |                          | Cooked     | 92.93±0.68          | 1.99±0.09  | 3.56±0.24    | 1.52±0.21 |
| 6     | Hurupibao polished rice  | Raw         | 89.06±0.57          | 2.23±0.10  | 7.56±0.42    | 0.70±0.07 |
|       |                          | Cooked     | 91.65±0.53          | 0.74±0.09  | 7.03±0.13    | 0.58±0.07 |
| 7     | Dal bao brown rice       | Raw         | 88.09±0.20          | 3.1±0.11   | 7.54±0.24    | 1.27±0.07 |
|       |                          | Cooked     | 86.31±0.57          | 2.64±0.07  | 9.62±0.36    | 1.43±0.09 |
| 8     | Dal bao polished rice    | Raw         | 89.76±0.15          | 1.4±0.07   | 8.18±0.20    | 0.66±0.07 |
|       |                          | Cooked     | 90.7±0.57           | 0.52±0.08  | 8.05±0.12    | 0.73±0.04 |
| 9     | Biroi brown rice         | Raw         | 87.37±0.53          | 3.6±0.04   | 7.81±0.35    | 1.22±0.13 |
|       |                          | Cooked     | 85.34±0.16          | 3.08±0.07  | 9.82±0.42    | 1.76±0.12 |
| 10    | Biroi polished rice      | Raw         | 88.55±0.36          | 1.11±0.06  | 9.60±0.22    | 0.74±0.04 |
|       |                          | Cooked     | 89.05±0.03          | 0.33±0.07  | 9.73±0.11    | 0.89±0.07 |
| 11    | Rongasokua brown rice    | Raw         | 88.45±0.22          | 3.20±0.11  | 7.00±0.42    | 1.35±0.16 |
|       |                          | Cooked     | 88.31±0.24          | 2.79±0.13  | 7.62±0.35    | 1.28±0.12 |
| 12    | Rongasokua polished rice | Raw         | 91.77±0.40          | 1.70±0.14  | 5.78±0.20    | 0.75±0.06 |
|       |                          | Cooked     | 90.39±0.27          | 1.89±0.09  | 6.61±0.20    | 1.11±0.06 |
| 13    | Amana bao brown rice     | Raw         | 88.63 ±0.18         | 3.60±0.59  | 6.44±0.26    | 1.43±0.10 |
|       |                          | Cooked     | 88.88±0.71          | 2.80±0.09  | 6.71±0.13    | 1.61±0.12 |
| 14    | Amana bao polished rice  | Raw         | 89.24±0.55          | 2.20±0.19  | 7.05±0.05    | 1.51±0.06 |
|       |                          | Cooked     | 88.98±0.71          | 1.68±0.14  | 7.83±0.42    | 1.51±0.17 |
| 15    | Kenkuabao brown rice     | Raw         | 87.54±0.55          | 2.18±0.01  | 8.97±0.36    | 1.31±0.06 |
|       |                          | Cooked     | 87.51±0.27          | 2.17±0.04  | 9.03±0.10    | 1.29±0.08 |
| 16    | Kenkuabao polished rice  | Raw         | 89.65±0.62          | 1.12±0.05  | 8.65±0.47    | 0.58±0.07 |
|       |                          | Cooked     | 91.35±0.32          | 0.52±0.04  | 7.50±0.27    | 0.63±0.04 |
| 17    | Betu brown rice          | Raw         | 90.48±0.34          | 2.77±0.15  | 6.02±0.10    | 0.73±0.08 |
|       |                          | Cooked     | 90.11±0.23          | 0.89±0.07  | 8.34±0.17    | 0.66±0.09 |
| 18    | Betu polished rice       | Raw         | 92.44±0.70          | 1.40±0.18  | 5.6±0.31     | 0.56±0.08 |
|       |                          | Cooked     | 90.79±0.41          | 0.77±0.07  | 7.94±0.46    | 0.50±0.07 |

*Mudoi and Das, 2018
Table 4: Total phenol content, flavonoid content and % DPPH Inhibition of raw* and cooked colored rice varieties of Assam

| Sl No | Name of variety | Form  | Total phenol content (mg catechol equivalents per 100 g) | Total flavonoid content (mg quercetin equivalents per 100 gm dry wt) | % DPPH Inhibition |
|-------|-----------------|-------|----------------------------------------------------------|---------------------------------------------------------------------|-------------------|
|       |                 |       | Brown rice                                               | Polished rice                                                        | Brown rice        |
|       |                 |       |                                                          |                                                                     | Polished rice     |
| 1     | Jul Bao         | Raw   | 1145.06±33.59                                           | 933.89±34.12                                                        | 466.10±67.93      |
|       |                 |       |                                                          |                                                                     | 248.58±58.36      | 82.62±0.42 |
|       |                 | Cooked| 323.39±18.59                                            | 240.79±10.36                                                        | 99.48±7.70        |
|       |                 |       |                                                          |                                                                     | 67.28±6.31        | 43.02±0.53 |
| 2     | Dal Bao         | Raw   | 2215.73±67.50                                           | 263.50±7.12                                                         | 1000.75±86.93     |
|       |                 |       |                                                          |                                                                     | 73.62±18.19       | 94.63±0.05 |
|       |                 | Cooked| 264.04±8.62                                            | 220.37±3.32                                                        | 81.00±2.75        |
|       |                 |       |                                                          |                                                                     | 48.74±2.72        | 42.78±0.51 |
| 3     | Biroi           | Raw   | 1462.27±56.58                                           | 289.19±17.25                                                        | 495.14±40.74      |
|       |                 |       |                                                          |                                                                     | 137.92±12.90      | 95.57±0.14 |
|       |                 | Cooked| 245.49±5.80                                            | 246.63±5.85                                                        | 85.94±8.84        |
|       |                 |       |                                                          |                                                                     | 1.75±0.12         | 43.31±0.12 |
| 4     | Hurupibao       | Raw   | 1283.23±47.89                                           | 542.66±20.97                                                        | 443.65±25.47      |
|       |                 |       |                                                          |                                                                     | 82.59±0.89        | 84.65±3.14 |
|       |                 | Cooked| 292.81±0.0                                             | 205.16±5.01                                                         | 86.59±7.28        |
|       |                 |       |                                                          |                                                                     | 33.79±6.54        | 43.45±0.08 |
| 5     | Negheribao      | Raw   | 1740.38±87.51                                           | 924.51±93.63                                                        | 617.05±20.08      |
|       |                 |       |                                                          |                                                                     | 374.46±2.05       | 96.00±0.26 |
|       |                 | Cooked| 132.86±2.40                                            | 123.01±2.34                                                        | 140.69±0.00       |
|       |                 |       |                                                          |                                                                     | 20.31±0.51        | 58.24±0.21 |
| 6     | Kenkuabao       | Raw   | 1711.13±127.35                                          | 240.41±5.49                                                        | 517.50±15.96      |
|       |                 |       |                                                          |                                                                     | 72.60±0.00        | 94.82±0.34 |
|       |                 | Cooked| 290.67±4.93                                            | 134.28±2.53                                                        | 303.82±3.20       |
|       |                 |       |                                                          |                                                                     | 58.15±2.74        | 79.23±5.51 |
| 7     | Betu            | Raw   | 1136.98±53.68                                           | 462.37±6.56                                                        | 478.10±41.53      |
|       |                 |       |                                                          |                                                                     | 146.33±6.13       | 81.54±0.23 |
|       |                 | Cooked| 337.60±8.82                                            | 194.67±7.27                                                        | 221.46±5.74       |
|       |                 |       |                                                          |                                                                     | 41.63±25.57       | 60.06±0.20 |
| 8     | Amanaba         | Raw   | 2223.68±33.48                                           | 547.03±25.09                                                        | 766.65±11.45      |
|       |                 |       |                                                          |                                                                     | 216.84±2.07       | 92.80±2.05 |
|       |                 | Cooked| 349.25±2.27                                            | 296.99±6.36                                                        | 207.04±3.92       |
|       |                 |       |                                                          |                                                                     | 112.68±1.48       | 54.42±0.08 |
| 9     | Rongasokua      | Raw   | 1534.52±143.45                                          | 247.18±1.19                                                        | 387±23.15         |
|       |                 |       |                                                          |                                                                     | 80.97±35.37       | 83.07±0.09 |
|       |                 | Cooked| 368.15±3.18                                            | 132.71±19.09                                                       | 212.86±3.88       |
|       |                 |       |                                                          |                                                                     | 26.77±2.19        | 57.08±0.08 |

*Mudoi and Das, 2019
Table 5 Zn content of raw (brown)* and cooked colored rice varieties of Assam

| Varieties      | Form   | mg/100g dry wt |
|----------------|--------|---------------|
| Amana bao      | Raw    | 2.42±0.21     |
|                | cooked | 1.31±0.07     |
| Rongasokua     | Raw    | 9.99±0.36     |
|                | cooked | 1.32±0.07     |
| Negheribao     | Raw    | 6.01±0.09     |
|                | cooked | 2.15±0.04     |
| Biroi          | Raw    | 6.31±0.14     |
|                | cooked | 1.83±0.21     |
| Betu           | Raw    | 5.34±0.14     |
|                | cooked | 1.45±0.14     |
| Hurupibao      | Raw    | 10.63±0.18    |
|                | cooked | 1.26±0.10     |
| Dal bao        | Raw    | 6.65±0.17     |
|                | cooked | 2.00±0.18     |
| Kenkua bao     | Raw    | 5.42±0.23     |
|                | cooked | 1.35±0.16     |

*Mudoi and Das, 2019

Table 6 Morphological characters of colored rice of Assam before and after cooking

| varieties                   | Before cooking | After cooking |
|-----------------------------|----------------|---------------|
|                             | Length (L, mm)| L/B Ratio     | L (L, mm)| L/B Ratio | ER |
| Dal bao brown rice          | 6.02±0.01     | 2.74±0.18     | 2.19     | 5.5±0.19  | 2.83±0.12 | 1.94 | 0.91 |
| Dal bao polished rice       | 5.04±0.01     | 2.88±0.17     | 1.75     | 6.25±0.19 | 3.16±0.12 | 1.97 | 1.24 |
| Biroi brown rice            | 6.21±0.19     | 2.53±0.04     | 2.40     | 6.17±0.34 | 3.16±0.12 | 1.90 | 0.99 |
| Biroi polished rice         | 5.73±0.18     | 2.04±0.01     | 2.80     | 9.0±0.28  | 2.00±0.00 | 4.50 | 1.57 |
| Kenkua bora brown rice      | 6.55±0.00     | 3.01±0.004    | 2.17     | 5.67±0.23 | 3.08±0.09 | 1.84 | 0.86 |
| Kenkua bora polished rice   | 6.64±0.39     | 3.03±0.008    | 2.19     | 6.42±0.46 | 2.58±0.22 | 2.48 | 0.96 |
| Jul bao brown rice          | 5.51±0.004    | 3.02±0.01     | 1.82     | 5.58±0.22 | 3.00±0.00 | 1.86 | 1.01 |
| Jul bao polished rice       | 5.06±0.03     | 2.8±0.25      | 1.8      | 6.5±0.24  | 3.08±0.22 | 1.86 | 1.28 |
| Rongasokua brown rice       | 6.00±0.00     | 2.10±0.00     | 2.85     | 5.83±0.34 | 3.02±0.24 | 1.66 | 0.97 |
| Rongasokua polished rice    | 6.51±0.01     | 2.95±0.16     | 2.20     | 7.33±0.36 | 3.00±0.00 | 2.44 | 1.13 |
| Amana bao brown rice        | 6.54±0.016    | 3.00±0.00     | 2.18     | 6.02±0.48 | 3.83±0.18 | 1.57 | 0.92 |
| Amana bao polished rice     | 5.78±0.11     | 3.03±0.01     | 1.90     | 6.83±0.34 | 3.00±0.00 | 2.27 | 1.18 |
| Negheri brown rice          | 6.27±0.17     | 3.01±0.01     | 2.08     | 5.83±0.34 | 3.25±0.19 | 1.79 | 0.92 |
| Negheri polished rice       | 6.02±0.004    | 3.03±0.03     | 1.98     | 7.5±0.245 | 3±0.00    | 2.5  | 1.25 |
| Kenkua bao brown rice       | 6.59±0.34     | 2.86±0.25     | 2.3      | 5.83±0.34 | 3±0.00    | 1.94 | 0.88 |
| Kenkua bao polished rice    | 6.03±0.04     | 2.79±0.18     | 2.16     | 8.75±0.34 | 2.83±0.18 | 3.09 | 1.45 |
| Hurupi bao brown rice       | 7.02±0.004    | 3.01±0.01     | 2.33     | 6.25±0.18 | 3.08±0.29 | 2.02 | 0.89 |
| Hurupi bao polished rice    | 7.01±0.01     | 2.71±0.19     | 2.58     | 8.67±0.34 | 3.00±0.00 | 2.89 | 1.24 |
After cooking, the same changed to 1.57 (in Amana bao) to 2.02 (in Hurupibao) and 1.86 (in Julbao) to 4.5 (in Biroi). After cooking, there was decrease of L/B ratio for brown rice and the reverse was for polished rice. Yadav et al., 2007 reported that the length and breadth of milled raw rice varied from 5.85 to 8.25 mm and 1.65 to 2.93 mm, respectively. Murdifen et al., (2015) reported that thirteen of pigmented rice (PR) varieties had no significant differences in the length and L/B ratio.

The PR length was in the range of 5.60-6.82 mm. The L/B ratio was in the range of 2.22-2.90 indicating that all rice had medium shape (between slender and bold). The ER was found to vary from 0.86 (in Kenekua bora) to 1.01 (in Julbao) for brown rice and 1.13 (in Rongachakua) to 1.57 (in Biroi) polished rice respectively. Shahidullah et al., 2009 stated that higher ER is preferred than lower ER for quality of cooked rice.

It was observed that open cooking without allowing the loss of cooking/soaking water, caused a decrease of crude fat, amyllose and zinc content and increase in the total carbohydrate. Cooking probably caused percent changes in crude protein, ash and zinc content, not actual change, which might be due to increase of bound water after cooking. Moreover, there was decrease of total phenols, flavonoids and antioxidant activities after cooking.

The prominent varieties for cooking as indicated by the present research are Negheribao (brown) and Amanabao (polished) regarding amyllose content (8.98% and 8.51%, respectively), Julbao (polished), Negheribao ((polished), Dalbao (brown), Biroi (both brown and polished) regarding crude protein content (more than 9%), Rongachakua, Betu, kenekuabao (all brown), Amanabao, Julbao, Biroi, Dalbao, Hurupibao, (both brown and polished regarding total phenol content (more than 200mg catechol equivalent/100gm), Negheribao, Biroi and Dalbao (all brown forms) regarding higher zinc content (more than 1.5mg/100gm DM), and Biroi, Kenekuabao, Julbao, Negheribao (all polished form) regarding morphological character (ER more than 1.25).

Acknowledgement

The first author is grateful to Department of Biotechnology, Ministry of Science and Technology, Govt of India for offering her DBT Research Associate ship and funding to carry the project work.

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**How to cite this article:**

Tiluttama Mudoi and Priyanka Das. 2020. Biochemical Composition and Morphological Characters of Cooked Indigenous Colored Rice Grown in Assam, India. *Int.J.Curr.Microbiol.App.Sci*. 9(05): 402-414. doi: [https://doi.org/10.20546/ijemas.2020.905.045](https://doi.org/10.20546/ijemas.2020.905.045)