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Biochemical Composition and Morphological Characters of Cooked Indigenous Colored Rice Grown in Assam, India

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A B S T R A C T

A few colored rice varieties of Assam (both brown and 4% polished) as influenced by cooking were analysed for proximate composition, total phenolic compounds, total flavonoids, antioxidant activities, zinc content and morphological character. The amylose content in cooked rice ranged from 0.02-8.98%. All the brown cooked rice varieties showed decrease in amylose content (0.004% in *Kenekuabao* to 98. 13% in *Betu*) except *'Negheribao'* (brown rice) than their raw forms. Decrease in amylose content for the polished form of cooked rice varieties was also recorded (31.14% in *Amanabao* to 98. 81% in *Rangachakua*). Total phenol content (TPC) in cooked brown rice was found in the range of 132.86mg (in *Negheribao)* to 368.15mg (in *Rangachakua*) catechol equivalents per 100 gm dry sample. The TPC of cooked polished rice also varied from 123.01mg (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 (*Dal bao*) and up to 86.68% in cooked polished rice (*Negheribao*) as compared to the same in raw. The elongation ratio (ER) was found to vary from 0.86 (in *Kenekua bora*) to 1.01 (in *Julbao*) and 1.13 (in *Rongachakua*) to 1.57 (in *Biroi*) for brown rice and polished rice, respectively.

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 30min 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:

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

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 ER =Average length of cooked rice grains (mm)/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 4^0C, 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 4^0C 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 2223.68mg (in *Amanabao*) catechol equivalents per 100 g rice (dry basis). TPC of polished rice samples ranged from 240.41mg (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 132.86mg (in *Negheribao)* to 368.15mg 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 387mg (in *Rangachakua*) to 1000.75mg (in *Dalbao*) quercetin equivalents per 100 g rice (dry basis). TFC of polished rice samples ranged from 72.60mg (in *Kenekuabao*) to 374.46mg (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 81.00mg (in *Dalbao*) to 303.82 mg (in *Kenekuabao*) QE per 100 gm dry wt and in cooked polished rice from 1.75mg (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 62.5mg/100gm 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 mineral distribution in rice grains and rice morphology (large length-to-width ratio). In our study, Zn content decreased in cooked samples as compared to their respective raw samples. In cooked brown rice, Zn content varied from 1.31mg (in *Amanabao*) to 2.15 mg (*Negheribao*)per 100 gm dry wt whereas, it varied in raw brown rice samples from 2.42mg (in *Amanabao*) to 10.63mg (in *Hurupibao*) per 100 gm.

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	Brown rice	Polished rice
1	Jul Bao	Raw	8.85±0.11	9.55±0.15	-64.18	-80.41
		Cooked	3.17±0.14	1.87±0.06		
2	Dal bao	Raw	11.78±0.15	12.98 ±0.10	-97.87	-87.75
		Cooked	0.25 ± 0.07	1.59 ± 0.07		
3	Biroi	Raw	9.92 ± 0.03	13.15± 0.13	-86.89	-81.90
		Cooked	1.30 ± 0.23	2.38 ± 0.15		
4	Hurupibao	Raw	5.74±0.59	13.36± 0.41	-64.11	-68.70
		Cooked	2.06±0.07	4.25±0.26		
5	Negheribao	Raw	4.61±0.35	10.17±0.59	+48.66	-95.96
		Cooked	8.98±0.25	0.41±0.05		
6	Kenkuabao	Raw	2.22±0.07	16.42±0.34	-0.004	-77.71
		Cooked	2.21±0.08	3.66±0.08		
7	Betu	Raw	1.07±0.02	4.21±0.07	-98.13	-57.24
		Cooked	0.02±0.01	1.80±0.04		
8	Amana bao	Raw	12.29±0.11	12.36±0.06	-95.85	-31.14
		Cooked	0.51±0.01	8.51±0.18		
9	Rongasokua	Raw	20.98±0.22	21.18± 0.14	-94.47	-98.81
		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 cooked	89.06± 0.57 91.65± 0.53	2.23±0.10 0.74±0.09	7.56±0.42 7.03±0.13	0.70±0.07 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	88.53 ± 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	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	82.96±0.20
		Cooked	323.39±18.59	240.79±10.36	99.48±7.70	67.28±6.31	43.02±0.53	40.93±0.16
2	Dal bao	Raw	2215.73±67.50	263.50±7.12	1000.75±86.93	73.62±18.19	94.63±0.05	82.33±1.77
		Cooked	264.04±8.62	220.37±3.32	81.00±2.75	48.74±2.72	42.78±0.51	37.70±0.20
3	Biroi	Raw	1462.27±56.58	289.19±17.25	495.14±40.74	137.92±12.90	95.57±0.14	84.23±0.16
		Cooked	245.49±5.80	246.63±5.85	85.94±8.84	1.75±0.12	43.31±0.12	32.06±0.23
4	Hurupibao	Raw	1283.23±47.89	542.66±20.97	443.65±25.47	82.59±0.89	84.65±3.14	84.14±0.00
		Cooked	292.81±0.0	205.16±5.01	86.59±7.28	33.79±6.54	43.45±0.08	38.45±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	82.37±0.24
		Cooked	132.86±2.40	123.01±2.34	140.69±0.00	20.31±0.51	58.24±0.21	51.86±0.08
6	Kenkuabao	Raw	1711.13±127.35	240.41±5.49	517.50±15.96	72.60±0.00	94.82±0.34	86.35±3.88
		Cooked	290.67±4.93	134.28±2.53	303.82±3.20	58.15±2.74	79.23±5.51	51.65±0.67
7	Betu	Raw	1136.98±53.68	462.37±6.56	478.10±41.53	146.33±6.13	81.54±0.23	73.74±2.29
		Cooked	337.60±8.82	194.67±7.27	221.46±5.74	41.63±25.57	60.06±0.20	44.20±0.08
8	Amana bao	Raw	2223.68±33.48	547.03±25.09	766.65±11.45	216.84±2.07	92.80±2.05	82.05±0.36
		Cooked	349.25±2.27	296.99±6.36	207.04±3.92	112.68±1.48	54.42±0.08	50.41±0.16
9	Rongasokua	Raw	1534.52±143.45	247.18±1.19	387±23.15	80.97±35.37	83.07±0.09	83.38±0.40
		Cooked	368.15±3.18	132.71±19.09	212.86±3.88	26.77±2.19	57.08±0.08	41.46±0.49

*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±0.16
	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
Jul bao	Raw	7.49±0.27
	cooked	1.40±0.08

*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)	(B, mm)	L/B Ratio	(L, mm)	(B, 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	3.013±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	3.50±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 bao 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 bao polished rice	6.02±0.004	3.03±3.03	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. Murdifin *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, amylose 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 amylose 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), *Negheri bao, 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).

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