Nutritional parameters of unique black rice in Assam, India, and its prospect of boosting rural economy

Rice is the staple food for over half of the world's population with a global production of 731.2 MT/annum from 164 m ha, which makes it the single largest user of cultivable land[1]. However, there are certain special categories of rice with unique characteristics which fetch remunerative price. Hence they can be considered as cash crops which can significantly contribute to economic upliftment of farmers in specific regions. Prominent among them in India are Basmati, which is considered as a delicacy for its unique taste and aroma. It is cultivated mostly in localized pockets of north India. Njavara black and Njavara yellow are native to and cultivated in Kerala, they are popular for health-promoting and health-protective value[2]. Joha (scented rice) rice of Assam is known for its characteristic taste and sweet aroma[3]. With market price ranging from Rs 60 to Rs 100 it is more of a delicacy than a staple food. Similar but less studied is black rice of Assam. Grown in certain pockets of lower Assam, its cultivation is relatively recent but it has been able to draw attention at national and international level (Table 1). Chakhao amubi is a type of black rice cultivated since a long time in the central valley of Manipur, it is a popular delicacy with high demand in the market. Recent reports show that black rice is rich in dietary antioxidants, anthocyanin and phenolics with strong *in vitro* antioxidant activity, this indicating its health-protective and health-promoting qualities[3,4]. Black rice is cultivated as *kharif* paddy under rainfed condition. Recently, in Assam more farmers are attracted towards black rice cultivation with resultant increase in cultivation area and production. The present study was undertaken to evaluate the basic nutritional and nutraceutical parameters of black rice. A field-based study was also conducted to assess the growth of black rice cultivation, farmer's participation and economic gains.

Black rice samples were collected from Goalpara district of lower Assam, Nagaon district of central Assam and Imphal in Manipur (Chakhao/amubi). The paddy grains were manually dehusked and ground in a mortar and pestle. The samples were dried in a hot-air oven at 50° ± 1°C till constant weight was recorded. Chemical analysis were done on dry-weight basis. Crude protein was estimated by Microkjeldahl method, as outlined in Association of Official Chemical Analytical Chemists (AOAC)[6]. Total carbohydrate was estimated by anthrone method[7]. Lipid content was estimated according to AOAC method by extracting the sample in soxhlet apparatus. Crude fibre was estimated by digestion of the sample with acid followed by digestion with alkali, as outlined in AOAC. Total mineral in the form of ash content was determined by ashing the sample in a muffle furnace at 630°C for 3 h, according to the AOAC protocol. Calorific value was computed using the equation of Sherman[8].

For anthocyanin estimation, finely ground sample was extracted with 80% methanol supplemented with 0.2% hydrochloric acid. The mixture was homogenized and centrifuged to obtain the supernatant. Quantification of anthocyanin was done by pH differential spectroscopic method[8]. *In vitro* antioxidant activity was assessed by 1,1-diphenyl-2-picryl-hydrazil (DPPH) free radical scavenging assay and results were expressed as radical scavenging activity (RSA%)[9]. For determination of IC-50 value, a series of methanolic extracts with increasing concentration was subjected to DPPH radical scavenging assay. From the absorbance values in a linear regression, IC-50 was computed.

Black rice varieties from Goalpara and Nagaon districts of Assam are similar, and both appear different from Chakhao amubi of Manipur. The differences are with respect to grain morphology and cooking characteristics. Black rice from Manipur takes comparatively less time to cook with gummy texture after cooking, and the preferred traditional use is to prepare porridge. Both the black rice varieties of Assam take longer time to cook and remain non-gummy after cooking. Apart from being a staple food, they are used to prepare traditional delicacy (pitha) and rice beer which has a characteristic red colour. Analysis shows that black rice from Assam has comparatively higher protein content with 11.44% and 13.10% for Goalpara and Nagaon samples respectively. Available information

Table 1. Commencement, expansion and performance of black rice cultivation by farmers under the cooperative society in Goalpara, western Assam, India

Year	No. of farmers	Area cultivated (acre)	Production (quintals)	Comment
2011	–	–	–	Commencement with a single surviving seedling
2012	–	–	–	Limited cultivation for seeds
2013	1	1.6	16.0	
2014	50	32	360	Formation and functioning of Farmer's Society
2015	200	160	2000	Local market
2016	500	480	5600	Exported to Dubai
2017	1000	640	7400	Local market
2018	650	320	3680	Drop in cultivation due to market link disruption
2019	700	320	3800	Export to Singapore, Malaysia, Australia
2020	900	576	6480–7200*	

*Projected value.

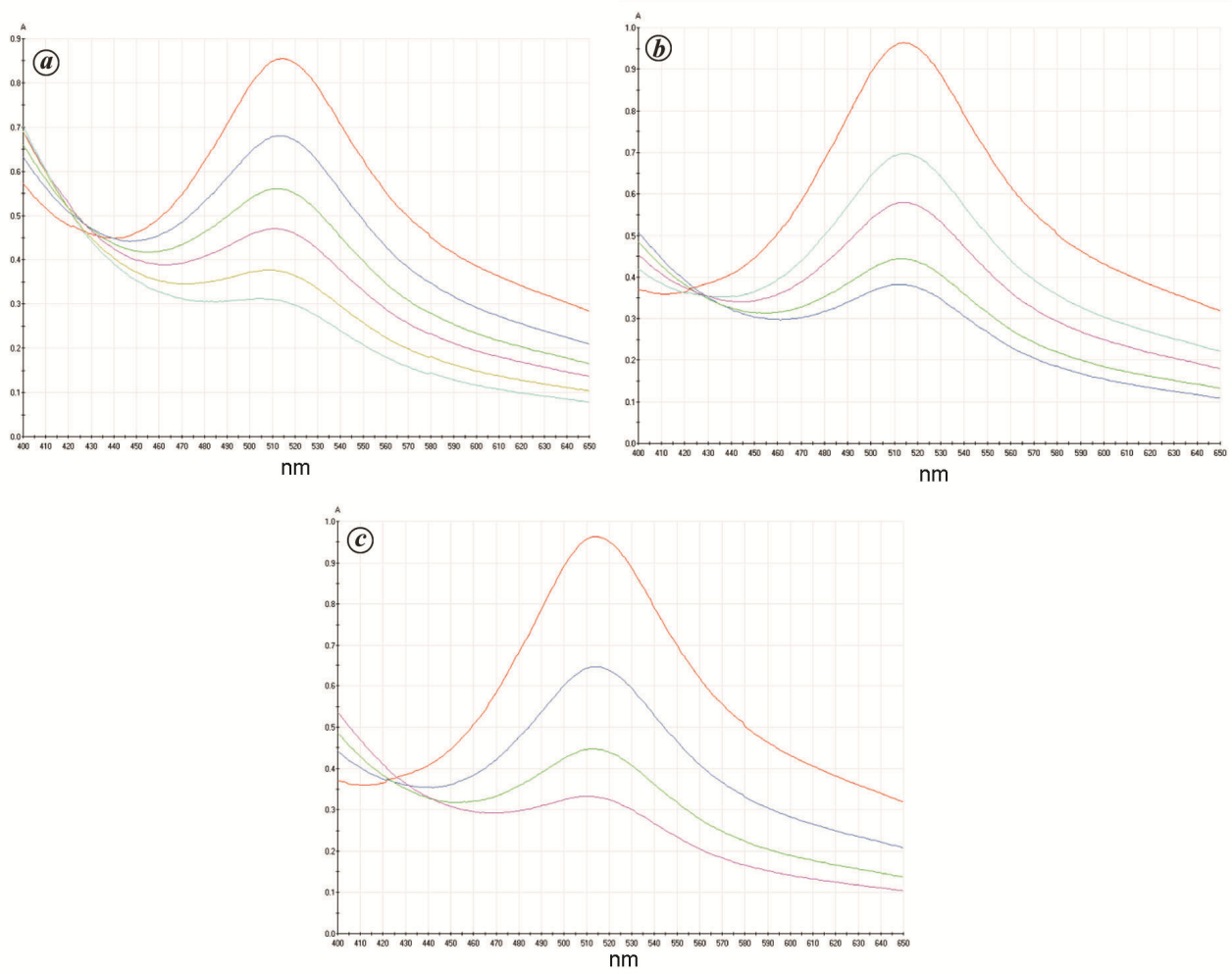

Figure 1. DPPH reduction spectra for different gradient solutions in ascending order scanned in the range 400–650 nm. (***a***) Goalpara, (***b***) Nagaon and (***c***) Chakhao amubi, Assam, India.

Table 2. Basic nutritive values among the three accessions of black rice. Values are per cent of dry matter and each value is the mean of three replications

Accession	Crude protein	Total carbohydrates	Lipid	Crude fibre	Ash content
Goalpara	11.44	80.05	2.80	1.20	1.27
Nagaon	13.10	79.00	3.44	0.95	1.42
Chakhao amubi	10.21	78.32	2.71	1.04	1.18
CD at 5%	0.452	2.965	0.198	0.101	0.117
CD at 1%	0.794	4.491	0.301	0.153	0.178

Table 3. Anthocyanin content and *in vitro* antioxidant activity among the three accessions of black rice. Values are the mean of three replications

Accession	Anthocyanin (mg/g)	Radical scavenging activity (%)	IC_{50} (mg/ml)
Goalpara	3.04	86.2	8.0
Nagaon	2.87	83.6	9.7
Chakhao amubi	3.47	90.0	6.8
CD at 5%	0.185	3.281	0.651
CD at 1%	0.280	4.971	0.987

shows that most rice cultivars have protein content in the range 7–11%, and some like deep-water paddy (red rice) have a little more than 13% protein content[10,11]. Total mineral in the form of ash content were high (Table 2). Nutritive value of a cultivar may vary depending upon the cultivation practice, local weather conditions and degree of milling[12]. The findings of the present study represent the baseline value and it appears that black rice varieties of Assam and Manipur are considerably rich in basic nutritive values. Chakhao amubi was found to be superior with respect to dietary antioxidants. In the present study anthocyanin was estimated to be the highest in Manipur black rice (3.47 mg/g). Proportionately, *in vitro* antioxidant activity was higher in Manipur black rice with RSA value 90.0% and IC-50 value 6.8 mg/ml. Among the two

black rice accessions from Assam, the one from Goalpara was superior to that from Nagaon in terms of anthocyanin content as well as *in vitro* antioxidant activity (Table 3 and Figure 1).

Black rice has been in cultivation in countries like China, Indonesia, the Philippines, Thailand, etc. on a limited scale for centuries[13]. However, it gained prominence with reports that black rice has strong antioxidant property by way of scavenging oxygen and nitrogen-derived free radicals[14,15] which was attributed to anthocyanin that imparts black colour. In Assam, a group of farmers in Goalpara district started black rice cultivation under a Farmer's Cooperative Society. Beginning with a single surviving seedling in 2011, field-production-level cultivation commenced in 2013. With market link-up, attractive pricing and increasing demand, there was remarkable growth in the number of farmers and area under cultivation subsequently (Table 3). Further success came in the form of export to countries like Singapore, UAE, Malaysia, Australia, etc. Experience shows that research, marketability and economic benefits to farmers are interlinked. In retail market, black rice is sold at Rs 150 to 200. However, the commonly consumed white rice costs Rs 30 to 45 depending upon quality. Thereby farmers get 5–7 times more profit from black rice than average white rice per unit area. In retail market high-value rice varieties like black rice, scented rice, etc. are usually sold in packets of 1–5 kg. Food law clearly stipulates that packets of food material must contain nutritional information, including calorific value. The findings of this preliminary study may help farmers and food entrepreneurs.

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