



Indigenous Flood-Resilient Rice Varieties Of Dhemaji District With Enriched Nutriment As Bioresources For Enhanced Production And Lively-Hood

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Abstract: Changing climate is an utmost challenging factor, especially in Dhemaji district of North East India, as, a significant portion of smallholder farmers reliant on rice production in rain fed conditions. Prolonged flooding and droughts, along with varied weather patterns, have significantly elevated the risk of food security. Especially flood have been responsible for severe crop loss which is a raising concern in this area. Developing flood-resilient varieties is a promising strategy to address this challenge. Although a number of such flood resilient varieties are found in this area, cultivation of such varieties is gradually decreasing due to different factors. A rebellion should persuade regarding this issue. To motivate the smallholder farmers, a study has been conducted with ten widely cultivated indigenous flood tolerant rice varieties (viz. Panikakuwa, Kakuwa, Miabao, Dalbao, Maguribao, Negheribao, Panidhan, Bhubao, Amana and Happybao), collected from different paddy growing fields of Dhemaji district, Assam to assess the enriched nutriment as foods high in Resistant Starch (RS) have the potentiality to improve human health. The proportion of RS in the diet can be increased by consuming starches with high amylose content. RS increases along with the increase of amylose content. Thus, high amylose assists in the management of diabetes, improves bowel health and function. Breeding for rice high in RS is of particular interest, as it will be easy to incorporate into the dietary-prevention strategy. Six cultivars have been identified as high protein cultivars (>10%). Dalbao has shown the highest total carbohydrate (88.4%), starch (83.25%) and protein (13.37%) content, whereas cultivar Bhubao shows highest amylose content (34.51%). Dalbao and Negheribao having superior nutritional quality may be considered for inclusion in deep-water rice breeding programmes.

Index Terms: Resistant starch, amylose, indigenous, flood prone, nutriment.

I INTRODUCTION:

One of the most serious problem adversely affects the agricultural fields of the North-Eastern region is the recurrence of devastating floods almost every year. Getting a little yield to maintain the livelihood of farm family at period of stress in such highly fragile ecosystem of deep-water areas, the people of these flood prone areas still cultivate varieties of deep water rice's, locally known as 'bao'. These rice varieties have some special adaptations i) ability to elongate with the rise of water levels. ii) development of internal air channels (aerenchyma) that facilitate aeration of submerged organs iii) develop nodal tillers and roots from the upper nodes in the water and iv) the upward bending of the terminal part of the plant called 'kneeing' that keeps the reproductive parts above the water as the flood subsides. Submergence-induced growth enables these semi aquatic plants to keep part of their foliage above the rising water and to avoid

drowning (Kende 1998). Thus these cultivars constitute an important source of genetic variation for utilization in breeding programme of rice varieties with tolerance to flooding.

Besides these morphological peculiarities, most deep water rice shows anthocyanin content which gives pigmentation to the grains (Pojul L., *et al*, 2008). Its colour ranges from various shades of red, purple, and black. Pigmented rice is high in dietary fiber and the minerals viz. iron and zinc. The zinc and iron content of pigmented rice is 2-3 times higher than that of white rice's. (Ramaiah and Rao, 1953) It is also rich in B vitamins and the trace elements viz. manganese and calcium. It has antioxidant properties also. Pigmented rice provides a host of benefits as follows, (Lila; 2004)

- It helps prevent oxidative stress
- It inhibits the initiation and promotion of cancer
- It maintain & urinary tract health through its antibacterial property
- It improves eyesight
- It may prevent atherosclerosis and cardiovascular disease
- It is recommended for diabetics

Little is known about the nutrient composition of many of the world's rice varieties. Taken in the right amount and right way, rice provides the human body with 'macronutrients' and 'micronutrients' that keep us healthy to lead a socially and economically productive life, as well as to respond to challenges and stresses without diseases. Carbohydrates serve as fuel for humans as it provides energy. On the other hand, protein provides amino acids that build and maintain body tissues. Composed of enzymes, hormones, and antibodies, protein is also a source of energy.

It is known that many indigenous land races are very rich in nutritive values (Baruah *et al* 2006, Loying *et al*. 2010) and nutraceutical values (Loying *et al*, 2008, Moko *et al* 2014, Noppawtpengkumsri, *et al* ,2015).

As deepwater rice shows promises for flood prone areas, these indigenous cultivars of rice have been subjected to quality analysis. Quality evaluation especially on nutritional aspects of these cultivars is not enough except for a few. Rice grains contain starch as the principal component and protein as the second highest component (Ahmed *et al*. 1998). On comparative basis red rice are superior in nutritive values than white rice. Earlier studies also reported that red rice are very rich in nutritive values (Baruah, *et al.*, 2006, Loying, *et al.*, 2010) as well as nutraceutical value due to presence of significant amount of anthocyanin and phenolics (Loying *et al.*, 2008 , Moko *et al.*, 2014 ; Pengkumsri *et al.*, 2015) . In view of alarming loss of agro- biodiversity there is a growing concern for conservation of traditional landraces of paddy

Starch is composed of two components, namely amylose and amylopectin. Amylose is a linear or non-branched polymer of glucose. Amylose content is considered to be the single most important characteristics for predicting rice cooking and processing behaviors (Juliano, 1979a, 1979b; Webb, 1985). It provides health benefits also.

Different types of starchy foods are digested at different rates and have different effects on blood glucose and insulin levels. Starches that are digested quickly cause a rapid increase in the amount of sugar in the blood, while those that are digested more slowly do not cause such rapid changes in blood sugar levels. The measurement of how fast foods metabolized into glucose in the blood stream is called glycemic index. Food having low glycemic index is important for people with diabetes, because they have trouble controlling the amount of sugar in their blood. Starch contains amylose, which is structurally a long string of glucose molecules bound together. It has been reported that as the amount of amylose in the starch increases, the starch will swell less (gelatinize) during cooking and will be digested more slowly. Therefore, people with diabetes have been told to eat foods that are rich in amylose. A number of studies have tried to innumerate the associations between grain composition and GI of rice [Uma *et al* 2007, Frei *et al* 2003, Hu *et al* 2004). Specifically, amylose and amylopectin ratio have been proved to be the major contributor in GI score where amylose being slowly digested would correlate negatively with high GI value (R. John *et al* 2023). Thus the determination of the amylose content of the cultivars is very much important.

Amylose has some pharmaceutical use also. In the present era of diverging pharmaceuticals upcoming in the market, those from that of natural origin are gaining increasing importance. In this context, starch when obtained from natural source has high orientation to be used as pharmaceutical excipient. Aerated starch products are a staple of the food industry, with particular relevance in the snack market. Water plays a crucial role in the formation of such products due to its utility both as a blowing agent and as a starch plasticiser. Amylose/amylopectin ratio and shear are traditionally also important factors in starch expansion (Beech *et al* 2022). Amylose is one of the two major components of starch, the other being amylopectin. In comparison with other polysaccharides, amylose and amylopectin are degraded by a broader range of colonic bacteria. While amylopectin is metabolized by pancreatic enzymes in the small intestine, amylose, in its glassy amorphous state, is resistant, but, at the same time, susceptible to digestion by amylase producing bacteria residing within the colon. Thus this material can be used as film coating in colonic drug delivery. However, the variation of amylose content in different strains of rice and the general differences between rice starch and other starches suggest that rice starch might possess some unique characteristics that makes it more suitable than other starches as some types of pharmaceutical excipients (Ornanong S. *et al.*, 2006). Thus determination of the amylose content of the cultivars is very much important. Quality evaluation done in the present study provided useful information on commercial and pharmaceutical exploitation of the rice cultivars of Dhemaji district.

North Eastern States of India are home to thousands of rice landraces which are highly diverse and good sources of nutritional traits, but most of them remain nutritionally uncharacterized. (John R. *et al.*, 2023) The fact that international Rice research Institute, Manila has a separate rice collection as "Assam rice collection" is a testimony to the unique agro-biodiversity of the indigenous land races of Assam. As per record, before the large scale cultivation of high yielding varieties (HYV'S) there were over 7000 indigenous cultivars in Assam (Borthakur, 1992).

The district Dhemaji situated in the easternmost part of the state Assam is considered as the most flood affected area. Along with a few people of other ethnic groups, most Mising people of riparian belt cultivate some deep-water rice cultivars. Quality evaluation done in the present study will provide useful information on these cultivars and their commercial exploitation and utilization in breeding programs of nutritional enhancement of rice to fight malnutrition among rice consuming population.

II. MATERIALS AND METHODS:

Materials taken for present study include 10 indigenous deep water rice cultivars viz *Panikakuwa*, *Amana*, *Kakuwa*, *Dalbao*, *Maguri*, *Panidhan*, *Bhubao*, *Negheri*, *Happybao* and *Miabao* collected from different pockets of Dhemaji District. Kernel colour has been studied by visual perception.

The total carbohydrate content has been analyzed by 'Anthrone method'. (Sadasivam *et al*; 1996a).

The starch content has also been analyzed with 'Anthrone reagent'. (Sadasivam S. *et al*; 1996b).

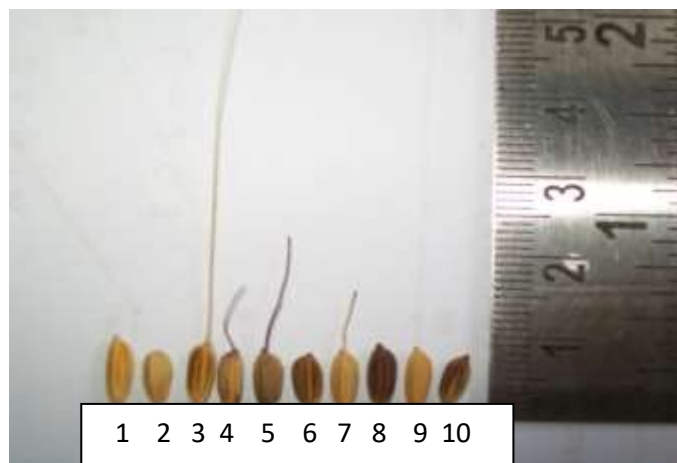
Amylose content has been determined by 'Iodine adsorption method' (Sadasivam S. *et al*; 1996c). The blue colour produced by the helical coils of amylose after adsorbing iodine is measured spectrophotometrically.

Protein content is estimated by 'Lowry's method' (1951). The spectrophotometer used in all the above mention experiments is Systronic UV-VIS spectrophotometer 118

III. RESULTS:

The kernel colour of the cultivars varies from white to dark-red (Plate 2 to 11). Besides cultivar *Panikakuwa* and *Maguri*, all other cultivars have been found with red or dark-red kernel.

The cultivar *Dalbao* shows highest total carbohydrate content ($88.4\% \pm 2.44$), starch content ($83.25\% \pm 1.5$) and protein content ($13.37\% \pm 1.7$), whereas cultivar *Bhubao* shows highest amylose content ($34.73\% \pm 1.9$) but lowest protein content ($1.72\% \pm 0.69$). *Maguri* shows lowest total carbohydrate (71.4 ± 0.97), starch (43.65 ± 4.3), and amylose ($19.17\% \pm 1.41$) content. (Table-1, Fig-1)



1- Panikakuwa, 2-Amana, 3-Kakuwa, 4- Negheri, 5- Dalbao, 6-Maguri, 7- Panidhan, 8-Miabao, 9-Bhubao and 10- Happybao

Plate 1: Comparative grain size and shape of selected cultivars

Table-1. Nutritional aspects of the selected cultivars

Sl.no	Name of the cultivar	Total carbohydrate content(%)	Starch content(%)	Amylose content (%)	Protein content(%)
1	<i>Panikakuwa</i>	80 ±1.88	54 ±0.95	21.99 ±0.28	6.1 ±0.16
2	<i>Amana</i>	79 ±3.73	69.75 ±0.99	25.47 ±0.69	10.85 ±0.27
3	<i>Kakuwa</i>	72 ± 0.51	54 ± 3.1	27.04 ±1.56	7.57 ± 1.19
4	<i>Negheri</i>	86 ± 1.47	74.26 ±1.05	22.06 ± 0.37	12.306 ±2.4
5	<i>Dalbao</i>	88.4 ± 2.44	83.25 ±1.5	28.56 ±1.5	13.37 ±1.7
6	<i>Maguri</i>	71.4 ±0.97	43.65 ±4.3	19.17 ±1.41	12.82 ±0.81
7	<i>Panidhan</i>	78 ±1.47	70.2 ±0.78	27.57 ±1.28	10.98 ±0.77
8	<i>Miabao</i>	72.75 ±0.50	68.4 ±2.3	23.31 ±3.32	10.83 ±0.49
9	<i>Bhubao</i>	81.6 ±1.27	65.88 ±1.3	34.73 ± 1.9	1.72 ±0.69
10	<i>Happybao</i>	86 ±1.48	70.5 ±0.68	24.82 ±0.87	4.21 ±0.95
	Correlation Coefficient		0.7463		-.899

Total carbohydrate content shows high positive correlation with starch content (0.7463) whereas amylose content shows moderately negative correlation (-0.899) with protein content



Plate 2. Grains of *Dalbao*



Plate 3: Grains of *Panikakuwa*



Plate 4: Grains of *Panidhan*



Plate 5: Grains of *Bhubao*



Plate 6: Grains of *Amana*



Plate 7: Grains of *Miabao*



Plate 8: Grains of *Maguri*



Plate 9: Grains of *Happybao*



Plate 10: Grains of *Negheri*

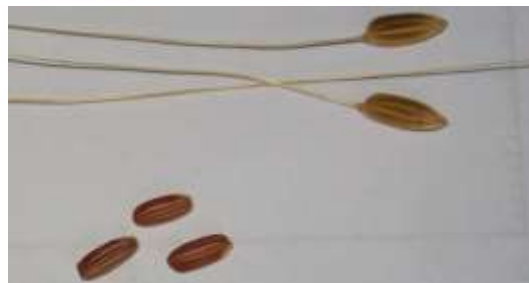
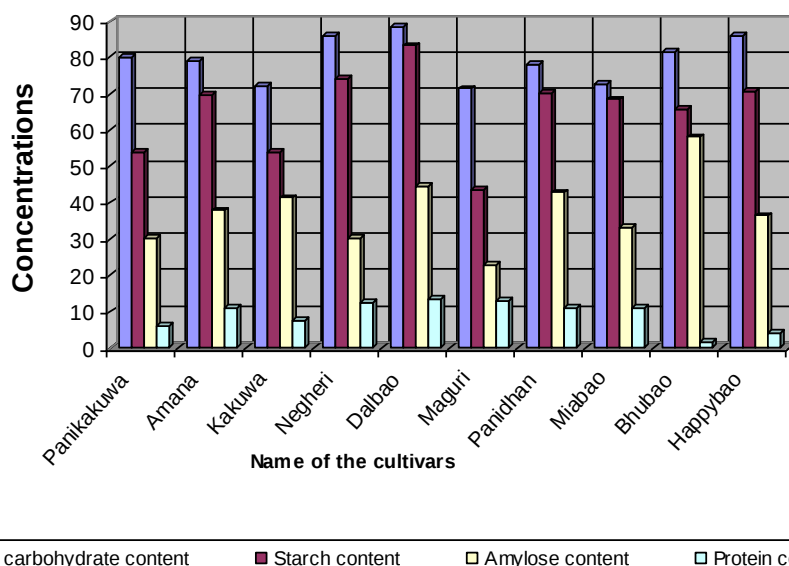


Plate 11: Grains of *Kakuwa*

Fig 1 Graphical representation of different macronutrients of the cultivars



IV. DISCUSSION:

Most of the starch in the diets of humans is ingested in cooked foods and digested rapidly in the small intestine. However, a variable proportion is not assimilated in the upper gastrointestinal tract. Instead, this fraction, known as resistant starch (RS), reaches the large intestine where it acts as a substrate for fermentation by the micro-flora that inhabit that region of the gut (Englyst, H.; *et al* 1992). Short chain fatty acids (SCFA) are end products of this fermentation, and these acids are thought to promote the optimal function of the viscera (Topping, D. L. *et al*. 2001). Foods high in RS have the potential to improve human health, prevent pathogen infections or diarrhea, and be of benefit in a variety of pathologic processes, such as inflammatory bowel disease (Jacobasch, G., 1999); colon cancer risk (Govers, M. J *et al* 1999.), insulin resistance and diabetes (Higgins, J. A. *et al* 1996) and chronic renal or hepatic disease (Younes, H. *et al* 1997). The proportion of RS in the diet can be increased by consuming starch that retains granular structures that are naturally more resistant to digestion. This resistance to digestion by raw granules is further increased if the granules have high amylose content. Resistant starch occurs in high amylose during food processing such as gelatinized starch, the granules have crystalline regions that are less susceptible to digestion by acid or α -amylase enzyme (Magdy A.S. *et al* 2010). Cristiane *et al*. (2007) reported that serum triglyceride level and cholesterol level significantly decreases after consumption of a diet rich in amylose compared to diet rich in amylopectin (low amylose). Resistant starch is a major source of nourishment for humans and many animals.

Thus high amylose assists in the management of diabetes, improves bowel health and functions, and increases the feeling of satiety, thereby reducing weight gain. It also aids in magnesium and calcium absorption in the colon, and may reduce the risk of developing colorectal cancer, cardiovascular diseases, and osteoporosis. Feeding with cooked rice high amylose instead of cooked rice low amylose may be effective to control serum blood glucose and lipids. Starchy foods with high amylose level are associated with lower blood glucose level and slower emptying of the human gastrointestinal compared to those with low levels of this macromolecule (Frei *et al.*, 2003). In view of the current concept of nutrition, rice with a higher content of digested starch and a lower content of RS is not the fittest food for health. Breeding for rice high in RS is of particular interest, as it will be easy to incorporate into the dietary-prevention strategy. Based on amylose content (AC), rice can be categorized as waxy (1–2 g/100g), very low AC (2–9 g/100g), low AC (9–20 g/100g), intermediate AC (20–25 g/100g) and high AC (25–33 g/100g) (Liu *et al* 2019).

Available reports indicate that amylose content in rice varied from 0 to about 37% (Nakagahara *et al*, 1986). However, all the deep water rice cultivars taken in the present study show high amylose content ranging from 19.17% to 34.7%. Highest amylose content has been shown by *Bhubao* (34.7 ± 1.9) and lowest by *Maguri* (19.17 ± 1.41). These cultivars might be used in further breeding programmes. The range was in accordance with the study of Dasgupta *et al*. 2018. They found the range as 24.03% to 34.45%

Protein content and other constituents such as amylose, starch, crude fibre, ash and total fat can be present in different amounts in different rice varieties (Coffman and Juliano 1987; Juliano 1993). Many reports on variability in protein content in rice are available. A range of 6.7 to 11.0% protein in brown rice was observed in 74 varieties from the Indian mainland (Guha and Mitra, 1963). Ahmed *et al*, (1998) reported 9.17 to 11.77% of protein in rice collected from Assam. However Saikia and Bains (1990) and Singh *et al*.(1998) reported low protein content (around 6-7% in both brown and milled rice of Assam). Devi P. *et al* (2008a) reported 6.14 to 12.07% protein content in 15 rice cultivars collected from north-eastern hill region of India. Govindaswami *et al* (1969) reported 6 to 12.6% protein content in 300 improved rice varieties of India. Even a range of 6.56 to 12.86% protein content was reported in 40 rice varieties grown in Kashmir (Baba 1971). In another study on protein content of indigenous and exotic varieties, a range of 5.5 to 14% was obtained (Govindaswami and Ghosh 1973). A culture from the Institute of Radiation Breeding, Japan, had shown to contain 16.3% protein (Mahadevappa and Shankare Gowda 1973). A range of 1.27% to 13.37% protein content has been found in the selected deep water rice cultivars of the present study. Highest protein content has been shown by *Dalbao* (13.37 ± 1.7). Six cultivars viz., *Amana*, *Negheri*, *Dalbao*, *Miaguri*, *Panidhan* and *Miabao* could be identified as high protein cultivars of rice with 10% or more total protein following the classification of Resurrection *et al*. (1979).

The grain protein content has shows moderate negative correlation (-0.899) with amylose content in the present study. Similar result was also found by Sampath *et al* (1968) However Devi *et al* (2008) reported that association of protein content with amylose content, though negative, was not significant(-0.29). It has been reported earlier that the grain protein content and quality of deep water rice is superior to non-floating rice (Islam, 1990& 1996). This suggests that deep water rice production can directly enhance protein supplies to low-income people in wetland areas.

Many reports on variability of carbohydrate content in rice are available. A range of 73-87% (Juliano *et al*, 1985a; Juliano *et al*, 1982) in brown rice has been observed. 79% carbohydrate content is recommended by USDA Nutritional database, U.S. A range of 75-85% for brown rice and 90% for milled rice (Michael *et al*, web book) 80% in white rice and 77.7% in brown rice (TFTC, 1999), 73.77-85.59% in some important indigenous cultivars of northern hill regions of India (Devi *et al*, 2008) are recorded. According to Dasgupta and Handique (2018) carbohydrate content in red rice ranges from 64-80%.

In our present study, in respect of total carbohydrate content *Dalbao* has shows the highest ($88.4\% \pm 2.11$) content of total carbohydrate whereas *Kakuwa bao* has shows lowest ($72\% \pm 0.45$).

From the present preliminary study we can concluded that cultivars *Amana*, *Negheri*, *Dalbao*, *Maguri*, *Panidhan* and *Miabao* could be useful as the source of high protein trait for breeding programmes intended for nutritional quality enhancement. These cultivars also can be given to protein malnourished children of this undeveloped corner of the world, where protein malnutrition is a main cause of infant mortality. Cultivars with coloured kernel also have great potential in this region. Anthocyanin content has a strong positive correlation with lipid content (Pojul *et al*, 2008). Thus the red kernel may be used as marker in breeding programme of lipid content and should be exposed to international and national consumers.

The cultivar *Dalbao* shows highest content of all the evaluated nutritional aspects, except amylose. Thus this cultivar shows extreme promises and hence should be considered for inclusion for deep water rice breeding programmes and also for consumption. Moreover, those cultivars having quality traits that are at the verge of extinction should be conserved.

REFERENCES:

- [1] Ahmed, S. A., Barua, I. and Das, D. 1998 Chemical Composition Of Sented Rice. *Oryza* (2) 167-169.
- [2] Baba, G.H. 1971 Note On Protein Content of Rice (*Oryza sativa* L.) Varieties of Kashmir. *wian J. Agric. Sci.*, 41(10), 893-894
- [3] Baruah K.K, Rajkhowa, S.C and Das, K . “Physiological analysis of growth, yield development and grain quality of some deep water rice (*oryza sativa* L.) cultivars” *J .Agronomy and Crop Science* vol. 192: p.p.228-232 , 2006
- [4] Beech D.,Beech J.,Gould J., Hill s. 2022 Effect of popping water content and amylose/amylopectin ratio on the physical properties of expanded starch products with different shear histories. *International Journal of Food Science and Technology* 2022, 57, 7368–7378
- [5] Borthakur D.N .Agriculture of the North Eastern region: with special reference to hill agriculture.p. Guwahati , India : BEECEE prakashan,1992.
- [6] Coffman, W. R., and Juliano, B.O., 1987 In Nutritional Quality of Cereal Grains, Genetics and Agronomic Improvement (R.A. Olsen and K.J. Frey, eds), 101-131
- [7] Cristiane, C.D., W. Melissa, P.S. Leila, D.S. Gabriele, A.F. Carlos, 2007. Effect of Amylose content of rice varieties on glycemic metabolism and biological responses in rats. *Food Chemistry*, 105: 1474-1479.
- [8] Devi, P., Durai, A. A., Singh, A., Gupta, S., Mitra, J., Pattanayak, A., Sarma, B. K., and Das, A.. 2008a, 2008b, Preliminary Studies on Physical and Nutritional Qualities of Some Indigenous and Important Rice Cultivars of North-Eastern Hill Region of India. *J. of Food quality* 31, 686-700
- [9] Dasgupta M., Handique, A.K., 2018, Comparative Evaluation of Major Nutritional Parameters for Eleven Pigmented Red Rice (PRR) and Nine Non Pigmented Rice (NPR), landraces of Assam. India. *SSRG International Journal of Agriculture & Environmental Science (SSRG-IJAES)* – 2018(5) 3: 66-92
- [10] Englyst, H.; Kingman, S.; Cummings, J. 1992 Classification and measurement of Nutritionally important starch fractions. *Eur. J. Clin. Nutr.* 1992, 46, 533–550).
- [11] Frei, M., P. Siddhuraju and K. becker, 2003. Studies on *in vitro* Starch Digestibility and the Glycemic Index of Six Different Indigenous Rice Cultivars from the Philippines. *Food Chemistry*, 83: 395-402
- [12] Govers, M. J.; Gannon, N. J.; Dunshea, F. R.; Gibson, P. R.; Muir, J. G. 1999 Wheat Bran Affects the Site of Fermentation of Resistant Starch and Luminal Indexes Related to Colon Cancer Risk: A Study in Pigs. *Gut* 1999, 45, 840–847.
- [13] Govindaswami, S. and Ghosh, A.K. 1973 Breeding for High Protein Content In Rice. *Indian J. Gent.* (special issue of SABRAO, Second General Congress 1972)
- [14] Govindaswami, S., Ghosh, A.K. And Nanda, B.B. 1969 Varietal Differences in Hulling And Cooking Qualities. Annual Report CRRI, Cuttack, India.
- [15] Guha, B.C. and Mitra, N.R.,1963 Studies on the Consistency of Thiamine and Protein Contents of Pure-bred Strains of Rice. *Ann. Biochem. Exp. Med.* 23(2), 69-72
- [16] Higgins, J. A.; Brand Miller, J. C.; Denyer, G. S. 1996 Development of Insulin Resistance in The Rat is Dependent on the Rate of Glucose Absorption From the Diet. *J. Nutr.* 1996, 126, 596–602.
- [17] Islam, Q. R., 1996 Ecology, Morphology and Nutritional Value of *Aponogaton undulates* Roxb. Grows in Deeply Flooded Areas in Bangladesh. *Hydrobiologia*. Kluwer Academic Publishers, Amsterdam, 340; 317-321.
- [18] Islam, Q. R., 1990 Ecological and Physiological Studies on Bangladesh Deep Water Rice. *Bulletin of the Institute of Tropical Agriculture, Kyushu University* 13; 1-93.

- [19] Jacobasch, G.; Schmiedl, D.; Kruschewski, M.; Schmehl, K. 1999 Dietary Resistant Starch and Chronic Inflammatory Bowel Diseases. *Int. J. Colorectal Dis.* 14, 201–211.
- [20] Loying ,Pojul ; Dutta Roy ,Jayanti , Handique Gautam K and Handique A.K “Anthocyanin and its co-relation with grain lipid in red grain deep water rice and scented rice and races of Assam .Indian” J . Plant physiology. 13 (1) .p 73-75,2008
- [21] Loying P, Handique G.K and Handique A.K “Nutritive value and seed protein profile of deep –water rice cultivars of Assam. ”*Oryza*. vol .47, p.p 243-247,2010
- [22] Juliano B.O. 1979a The Chemical Basis of Rice Grain Quality. In: Chemical Aspects of Rice Grain Quality, IRRI, Los banos, Philippines.
- [23] Juliano B.O. 1979b Amylose Analysis: A Review, In: Chemical aspects of rice grain quality, IRRI, Los banos, Philippines.
- [24] Juliano, 1985 Eggum, Juliano & Maningat 1982, Redersen and Eggum 1983, Rice in Human Nutrition, Nutritional value of rice and rice diets., Published with The collaboration of IRRI, Food and Agricultural Organization United Nations,. Rome 1993
- [25] Kende H, van der Knaap E and Cho HT (1998) Deepwater rice: a model plant to study stem elongation. *Plant Physiol* 118: 1105–1110
- [26] Lila M.A 2004 Anthocyanins and Human Health: An In Vitro Investigative Approach *J Biomed Biotechnol.* 2004 December 1; 2004(5): 306–31
- [27] Loying P., Roy J. D., Handique G. K, Handique A.K 2008 Anthocyanin and Its Co-relation With Grain Lipid in Red Grain Deep Water Rice and Scented Rice land Races of Assam *In. J. of Plant Physiol*, 2008, 13, 1
- [28] M. Frei, P. Siddhuraju, K. Becker, Studies on the in vitro starch digestibility and the glycemic index of six different indigenous rice cultivars from the Philippines, *Food Chem.* 83 (2003) 395–402.
- [29] Magdy A. Shallan, Hossam S. El-Beltagi 2010 Effect of Amylose Content and Pre-germinated Brown Rice on Serum Blood Glucose and Lipids in Experimental Animal; *Australian Journal of Basic and Applied Sciences*, 4(2): 114-121
- [30] Mahadevappa, M. and Shankare G. 1973. Some Important Technical Consideration in Rice Breeding. *Madras Agric. J.* 60(6) 408-411
- [31] Moko ,E.M , Purnomo H , Kusnadi ,J , and I jong , F.G . “Phytochemical content and antioxidant properties of colored and non colored varieties of rice bran from Minahasa, North Sulawesi Indonesia.” *International food research journal*. vol 21 (3); p.p 1053 -1059,2014
- [32] Noppawatpengkumsri, Chaivavat Chaiyasut, Chalernpung Swnjum, SasithornSirilun , Sartjinpeerajan , Prasitsuwannalert , sophonSirisattha , Bhagnvati , SundarumSivamaruth. “Physicochemical and antioxidative properties of black, brown and red varieties of northern Thailand ”.*Food science and technology .Campinas* ,vol 35 (2) p.p 331-338., 2015
- [33] P.S. Hu, H.J. Zhao, Z.Y. Duan, L.L. Zhang, Dian-xing Wu, Starch digestibility and the estimated glycemic score of different types of rice differing in amylose contents, *J. Cereal. Sci.* 40 (2004) 231–237.
- [34] R. Liu, R. Liu, L. Shi, Z. Zhang, T. Zhang, M. Lu, X. Wang, Effect of refining process on physicochemical parameters, chemical compositions and in vitro antioxidant activities of rice bran oil, *LWT* 109 (2019) 26–3
- [35] Ramaiah, K. and Rao, M.V.B.N. 1953. Rice Breeding and Genetics. ICAR Science Monograph 19. Indian Council of Agricultural Research, New Delhi, India.

- [36] Racheal John, Haritha Bollined, Christine Jeyaseelana, Siddhant Ranjan Padhi, Neha Sajwan, Dhruvjyoti Nath, Rakesh Singh, Sudhir Pal Ahlawat, Rakesh Bhardwaj, Jai Chand Rana. 2023 Mining nutri-dense accessions from rice landraces of Assam, India *Heliyon*9(2023)e17524
- [37] Resurrection, A.P., Juliano, B.O. and Tanaka, Y. 1979 Nutritional Content and Distribution in Milling Fractions of Rice Grains. *J. Sci. Food Agric.* 30, 475-481
- [38] Saikia, L. and Bains, G.S. 1990 Studies of Some Assam Rice Varieties for Processing and Nutritional Qualities. *J. Food. Sci. Technol.* 27(5), 345-346.
- [39] Sampath, S., Patnaik, S. and Mitra, G.N., 1968. The Breeding of High Protein Rices. *Curr. Sci.* 37, 248-249
- [40] TFCT 1999 Thai Food Composition Table (1999) Institute of Nutrition, Mahidal University
- [41] Topping, D. L.; Clifton, P. M. 2001 Short-chain Fatty Acids and Human Colonic Function: Roles of Resistant Starch and Non Starch Polysaccharides. *Physiol. Rev.* 2001, 81, 1031–1064
- [42] Uma S. Babu, Paddy L. Wiesenfeld, Rice, global food source and rice controversy related to obesity and glycemic index, in: Interactions of Rice Components and Obesity-Lipid Biomarkers and Immune Function, vols. 11–18, Transworld Research Network, Kerala, 2007.
- [43] Webb B.D., Bolich C.N., Carnahan H.L., Kuenzel K.A. and Mckenzie K.S. 1985 Utilization characteristics and qualities of U.S. rice In: Rice Grain Quality and Marketing, IRRI, Los Banos, Philippines
- [44] Younes, H.; Remesy, C.; Behr, S.; Demigne, C. 1997 Fermentable Carbohydrate Exerts A Urea-lowering Effect in Normal and Nephrectomized Rats. *Am. J. Physiol.* 1997, 272, 515–521