

Evaluation of morphology, nutrition, and phytochemicals in bamboo rice from Bangladesh

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Abstract

Bamboo rice, the grains produced from bamboo seeds, is a unique and underexplored food traditionally consumed by indigenous and economically disadvantaged communities for its nutritional and medicinal value. The present study evaluated the morphological parameters, proximate composition, mineral content, and phytochemical profile of bamboo rice grains collected from the Fulbari Upazila of Dinajpur District. As evident from the investigation, bamboo rice grains are metallic bronze in color, the average grain length was 6.87 ± 0.54 mm and average weight of the grain was 13.54 ± 3.01 mg. Proximate analysis revealed that the bamboo rice has moisture content of 10.15%, dry matter of 89.9%, crude protein of 10.1%, crude fiber of 5.65%, ash content of 4.45%, and metabolizable energy of 2943.51 kcal/kg (animal) and 3295 kcal/kg (human). Nutritional profiling revealed a total protein content of 7.81%, amylose content of 22.10%, essential minerals such as zinc (13.21 ppm), iron (4.36 ppm), calcium (53.12 ppm), and phosphorus (2.44 g/kg). Qualitative phytochemical screening confirmed the availability of several bioactive phytochemicals including carbohydrates, coumarins, flavonoids, glycosides, phenols, resins, saponins, tannins, and terpenoids. The findings indicated that bamboo rice has substantial nutritional and medicinal contents, which supports the claim of its utility in food and medicine. It also validates bamboo rice's potential applications in dietary diversification, food security, and sustainable nutrition in Bangladesh.

Keywords: Bamboo rice, health, nutrition, phytochemical, proximate

INTRODUCTION

Bamboo (*Bambusa bambos*) is a unique non-timber forest plant that is known for its rapid growth and unusual flowering behavior. They are considered as evergreen perennial flowering plants, but they differ from most plants because they usually flower once after long vegetative stages. The plants usually die after flowering. Bamboo belongs to the grass family Poaceae, and they have similar characteristics to the other major cereal crops of the family such as rice, maize and wheat. There are more than 1,250 species of bamboo growing in tropical, subtropical and mild temperate regions around the world. Their range also extends to cool mountainous regions and highland cloud forests (Ahmad *et al.*, 2021). Bamboo plants are an essential component of the ecosystem as they maintain forest stability, prevent soil loss, provide food for wildlife, and store carbon. In addition, bamboo has significant socio-economic importance as a source of raw materials

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for construction, furniture, handicrafts, paper, and household products. Moreover, various parts of bamboo plant are used as a valuable food source for humans (Sebastian *et al.*, 2023).

The grains obtained from the seeds of bamboo are called bamboo rice. They can be considered as one of the most interesting and least studied parts of bamboo. Bamboo rice has been traditionally used by indigenous and economically disadvantaged groups for food and medicinal purposes. The Bamboo rice grains are generally short to medium in size and possess a distinct aroma and taste. Also, the grains appeared brown in color and are similar to regular rice (*Oryza sativa*) grains in terms of size, shape, and physicochemical characteristics (Vasudeva *et al.*, 2011). However, the production method differs significantly for traditional cultivated rice, and the bamboo rice. Bamboo rice is only available during flowering events, which occur infrequently. Therefore, bamboo rice is not always available and cannot be obtainable every year like regular rice crops. According to previous reports, bamboo rice is a nutrition rich valuable food source because it is high in protein, dietary fiber, and essential minerals (Haldipur & Srividya, 2021; Sebastian *et al.*, 2023; Yang *et al.*, 2021).

Indigenous communities value the bamboo rice as it serves as a significant cultural, nutritional, and economic resource to them. It often plays role as an emergency staple food during the time of food scarcity. In addition to its use as food, it is believed to exert health-promoting properties and therefore utilized in folk medicine. Also, previous study found their antihyperglycemic potential, suggesting its utility to regulate blood glucose levels (Haldipur & Srividya, 2021). However, the findings are geographically constrained and not sufficient, which emphasizes the need for additional scientific research and validation.

In April 2024, social and electronic media widely reported the discovery of rice-like seeds from bamboo plants by a local individual in Fulbari Upazila of Dinajpur District. Through this, bamboo rice gained national attention in Bangladesh. This also created extensive public interest and curiosity, which persuaded numerous claims about the nutritional and medicinal benefits of bamboo rice. Although several scientific studies on bamboo rice have been carried out in neighboring countries, no systematic investigation has yet been reported from Bangladesh.

Therefore, it is apparent that there is limited information on nutritional value, morphological parameters and phytochemical constituents, so, a detailed investigation may provide useful insights. Moreover, to facilitate utilization of bamboo rice, scientific evidence is necessary in a country like Bangladesh. In this backdrop, we designed the present research to investigate the morphological, nutritional and phytochemical constituents of bamboo rice. The findings are expected to provide valid evidence against the claim of bamboo rice's utility in food and medicine. The results will also aid in the validation of using traditional resources for potential applications in food systems and in ensuring nutrition security.

MATERIALS AND METHODS

Sample Collection: Bamboo rice seeds were collected from local sources at the Fulbari Upazila of Dinajpur district in Bangladesh in May 2024. A quantity of 1 kg seeds was collected. Seeds were thoroughly cleaned to remove dirt and dust particles. The seeds were used for some of the morphological analyses. Where grains were required, manual dehusking of seed cover was performed to carefully obtain the grains. The grains were cleaned properly. The seeds and grains were stored in appropriate airtight containers for further use.

Morphology Trait Analysis: Morphology traits were evaluated based on physical measurements to obtain dimensional data and through visual inspections to obtain observable traits. All measurements were conducted using an analogue slide caliper. Color and texture were assessed visually. The weight of the seeds and grains were measured using a digital analytical weighing balance (Sartorius, Germany). Photographs were taken with mobile phone camera to keep permanent visual records.

Proximate Analysis: Proximate analysis was performed following the standard AOAC (2019) procedures with minor modifications as described previously (Baur & Ensminger, 1977). The parameters analyzed were ash, moisture, crude fiber, crude protein, dry matter, and metabolizable energy. The results were presented on a dry weight basis. Bamboo rice grains were ground using a mechanical grinder (Philips, Netherlands) to obtain powder and stored in airtight containers until analysis.

Moisture content: Oven drying process was utilized to measure the moisture content. Approximately 5 g of ground grain of bamboo rice was taken in a pre-weighed, clean crucible and dried in a hot air oven (JSR, Korea) at 105°C until a constant weight was achieved. The crucible was cooled in a desiccator and then the weight was measured again. The formula was as follows-

$$\text{Moisture (\%)} = (W_1 - W_2) / W_1 \times 100$$

Where, W_1 represents weight of the sample before drying (g), and W_2 represents the weight of the sample after drying (g).

Ash Content: Ash content was measured by incinerating the dried sample. About 5 g of the oven-dried sample was placed in a pre-weighed crucible and ignited in a muffle furnace at 550°C until a white ash was obtained. The crucibles were cooled in a desiccator and weighed again. The formula was as follows-

$$\text{Ash (\%)} = W_{\text{ash}} / W_{\text{sample}} \times 100$$

Where W_{ash} represents the weight of ash after incineration (g), and W_{sample} represents the initial weight of the sample (g).

Crude Protein Content: Crude protein was determined by following the Kjeldahl method (Kirk, 1950). One gram of the sample was digested with concentrated H_2SO_4 . After digestion, the solution was neutralized with NaOH. The released NH_3 was trapped in a H_3BO_3 solution and titrated with standard HCl to estimate the nitrogen content. A

conversion factor of 6.25 was used to calculate crude protein from nitrogen by using the following formula.

$$\text{Crude Protein (\%)} = \%N \times 6.25$$

Where, % N is the percentage nitrogen obtained after titration.

Crude Fiber Content: Crude fiber was measured by acid and alkali digestion (Horwitz & Latimer, 2005). About 2 g of the sample was boiled with 1.25% H₂SO₄ for 30 minutes followed by filtration and washing. The residue was then boiled with 1.25% NaOH for another 30 minutes followed by filtration, drying and weight measurement. The obtained residue was incinerated using a muffle furnace. Crude fiber was calculated as per the following formula-

$$\text{Crude Fiber (\%)} = (\text{Residue} - \text{Ash}) / \text{Sample weight} \times 100$$

Where, W_{residue} is the weight after digestion and drying (g); W_{ash} is the weight after incineration (g), and W_{sample} is the initial weight of the sample (g).

Dry Matter Content: Dry matter content was measured by oven drying according to standard procedures (AOAC, 2019). Around 5 g of bamboo rice powder was weighed and placed into a clean, dry, pre-weighed crucible. Then it was placed in a hot air oven and dried at 105°C for 3 hrs to achieve a constant weight. After that, the crucible was cooled in a desiccator to room temperature, and the weight was measured again. The dry matter was determined using the following formula-

$$\text{Dry Matter (\%)} = W_{\text{wet}} / W_{\text{dry}} \times 100$$

Where, W_{wet} represents the initial weight of the sample (g), and W_{dry} represents the weight after drying to constant weight (g).

Metabolizable Energy Determination: The metabolizable energy (ME) content of the samples was estimated from the proximate composition values following standard procedures used in both animal feed and human nutritional evaluation. Nitrogen-free extract (NFE), representing the available carbohydrate fraction, was calculated by difference using the following equation:

$$\text{NFE (\%)} = 100 - (\text{Moisture} + \text{CP} + \text{EE} + \text{CF} + \text{Ash})$$

where CP = crude protein, EE = ether extract, CF = crude fiber, and Ash = total ash content.

For animal feed evaluation, metabolizable energy was estimated according to the predictive equation described previously (Pauzenga, 1985).

$$\text{ME (kcal/kg)} = 37 \times \text{CP} + 81.8 \times \text{EE} + 35.5 \times \text{NFE}$$

where CP = crude protein, EE = ether extract, NFE = Nitrogen-free extract.

For human nutritional evaluation, metabolizable energy was calculated using the Atwater general conversion factors recommended by the Food and Agriculture Organization (FAO, 2003).

$$\text{ME (kcal/100g)} = 4 \times \text{Protein} + 9 \times \text{Fat} + 4 \times \text{Carbohydrate}$$

Nutritional Analysis

Protein content: Total protein content was measured according to the method described by Bradford (Bradford, 1976). 0.1 mL of bamboo rice extract was transferred into test

tube; then, 0.9 mL Bradford reagent was added to the tube. The mixture was incubated for 2 min. The absorbance was measured at 595 nm in a UV-vis spectrophotometer (PG Instruments, UK). Protein content was determined from a standard curve.

Amylose content: Amylose content was measured using a previously described method (Karve & Kale, 1992). The sample was gelatinized in an alkaline solution. The reaction was done with iodine-potassium iodide solution. The absorbance was taken at 620 nm in a UV-vis spectrophotometer, and the amylose content was determined using a standard curve.

Mineral analysis: Mineral contents such as zinc, iron, calcium, and phosphorus were determined by atomic absorption spectrophotometry (AAS) (Hooker, 2005). Bamboo rice grain powder was digested using HNO₃ and HClO₄. A clear solution was obtained after the digestion. The digested solution was filtered, diluted, and analyzed by AAS (Shimadzu, Japan). Calibration was performed with standard solutions.

Phytochemical analysis

Preparation of Extract: The bamboo rice grains were powdered in a mechanical grinder (Philips, Netherlands). 10 g powder was taken in conical flasks with methanol and water as solvents. The flasks were placed in an orbital shaker (Vision Scientific, USA) at 120 RPM for 72 hrs at 25°C. The obtained extracts were filtered through Whatman no. 1 filter paper; the filtrates were concentrated using a rectangular water bath (HH-S6, China). Finally, stock solutions of the extracts (10 mg/mL) were prepared and stored. The extracts were subjected to qualitative testing for secondary metabolites, including alkaloids, carbohydrates, coumarins, flavonoids, glycosides, phenols, resins, saponins, tannins, and terpenoids, using the following methods.

Alkaloids: 4-6 drops of Wagner's reagents [1.27 g of Iodine and 2 g of potassium iodide in 100 mL of water] were added to 1 mL of extract. Mixing resulted radish brown precipitate at the bottom of the tube which indicated the presence of alkaloid (Rizk, 1982).

Carbohydrates: 1 mL of extract was taken into test tubes to which 1 mL of Fehling's A and Fehling's B was added. The tubes were kept in a water bath at 65 °C for 10-15 min. Appearance of red brick precipitate at the bottom of the tube indicated the presence of carbohydrates (Fehling, 1849).

Coumarins: 1 mL of extract was mixed with 1.5 mL of 10% NaOH. The presence of coumarin was validated by the appearance of yellow color (Ahmed *et al.*, 2018).

Flavonoids: 2 mL of extract was taken in a test tube and 3-4 drops of 20% NaOH solution were added. The mixture produced an intense yellow color. After that, 4-5 drops of diluted HCl were added to the tube. The presence of flavonoids was confirmed by colorless appearance of the solution (Ahmed *et al.*, 2020).

Glycosides: 1 mL of the extract was taken and mixed with 1 mL of glacial acetic acid. To this mixture, 5-6 drops of 1% FeCl_3 were added. A brown color ring appeared at the top of the solution which validated the presence of glycosides (Peash *et al.*, 2017).

Phenols: 1 mL of ethanol was added to 1 mL of extract, followed by addition of 6-7 drops of 1% FeCl_3 . The appearance of green, blue, or purple colors suggested the presence of phenols (Rahman *et al.*, 2020).

Resins: 1 mL of extract was taken, and few drops of acetic anhydride were added. After that, 1 mL of concentrated H_2SO_4 was added. The color of the reaction mixture changed to yellow or orange, which verified the presence of resins (Iqbal *et al.*, 2015).

Saponins: 2 mL of distilled water was added to 1 mL of the extract and shaken for 5 min. The vigorous shaking resulted in thick foam at the top of the solution. The occurrence of 1 cm foam for at least 10 min indicated the presence of saponin (Kumar *et al.*, 2009).

Tannins: 0.5 mL of extract was mixed with 1 mL of distilled water, followed by addition of 4-5 drops of 1% FeCl_3 . Blue color in solution indicated the presence of gallic tannin and greenish black color indicated the presence of catecholic tannin (Peash *et al.*, 2017).

Terpenoids: 5 mL of the extract was taken in a test tube. 2 mL of chloroform and few drops of concentrated H_2SO_4 were added to the tube. The presence of terpenoids was confirmed by the appearance of reddish-brown color at the boundary of the mixture (Ahmed *et al.*, 2018).

RESULTS AND DISCUSSION

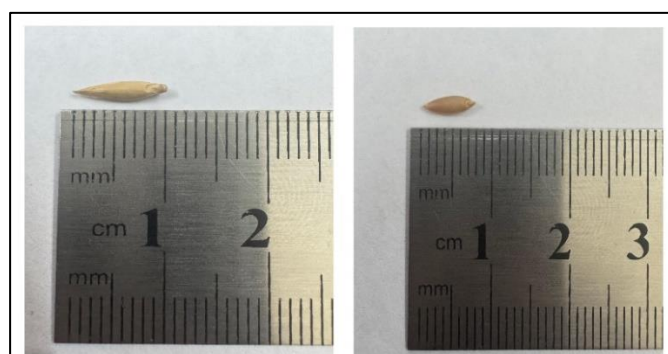
Morphology Trait Analysis

Measurement: The size measurements, weight analysis, and observable physical traits such as shape, color and texture have been summarized in Table 1. The average length of the seeds was 9.53 ± 0.45 mm, and the average width of the seeds was 2.46 ± 0.15 mm. The average length of the grains was 6.87 ± 0.54 mm, and the average width of the grain was 2.26 ± 0.18 mm. Generally, the seeds were long and elongated at one end, while the grains were less elongated and round at one end. The grain size of bamboo rice has been found shorter than the maximum rice cultivars of Bangladesh while compared to a previously conducted study (Akter *et al.*, 2022). The color of the seeds was light yellow to yellowish-brown, and the texture of the seed surface was smooth. In contrast, grains were found to be deep or metallic bronze in appearance, with a lustrous surface. The average weight of the seeds was 15.36 ± 3.18 mg, while the average weight of the grains was 13.54 ± 3.01 mg. The photographic images highlight observable traits such as shape, size, and surface color of seeds and grains (Figure 1 and 2).

Table 1. Morphology traits of bamboo rice

Measurements			
Seed		Grain	
Length (mm)	Width (mm)	Length (mm)	Width (mm)
9.53 ± 0.45	2.46 ± 0.15	6.87 ± 0.54	2.26 ± 0.18
Weight Analysis (mg)			
Seed		Grain	
15.36 ± 3.18		13.54 ± 3.01	
Other Parameters			
Parameters	Seed	Grain	
Shape	Long, elongated at one end	Medium	
Color and Texture	Light Yellow/ Yellowish Brown	Deep/Metallic Bronze	

Data presented as mean ± standard deviation (SD)

**Fig. 1. Pictorial view of bamboo seeds and grain****Fig. 2. Size determination of seeds and grains of bamboo rice**

Proximate Analysis of Bamboo Rice

Moisture Content: The moisture content of the bamboo rice was as 10.15% (Table 2). This content was lower when compared to the moisture content found in some Bangladeshi aromatic rice varieties in a previous study (Asaduzzaman *et al.*, 2013). This

relatively low moisture level indicates that bamboo rice will sustain long storage and will not be impacted by microbial growth or spoilage.

Dry Matter Content: The dry matter content was recorded as 89.9% (Table 2). The dry matter of a grain is the portion composed of nutrients and other solid components, excluding water. High dry matter percentage indicates that the overall nutrient density of bamboo rice is high, and the high dry matter content makes bamboo rice a dietary substantial element.

Crude Protein Content: The crude protein content of bamboo rice was found to be 10.1% (Table 2), indicating its potential as a moderate source of dietary protein. While compared to a previous study, the protein level was comparable to red Aman rice and maize, higher than the black rice and slightly lower than the wheat (Rupa *et al.*, 2025).

Ash Content: The ash content was measured as 4.45% (Table 2). Ash content represented the total mineral content of the bamboo rice. The content was higher than the common major, minor and pseudo-grains while compared to a previously conducted study (Rupa *et al.*, 2025).

Crude Fiber Content: The crude fiber content of bamboo rice was found as 5.65% (Table 2), indicating a substantial amount of dietary fiber. Fiber plays an essential role in maintaining digestive health and controlling blood sugar levels. However, the fiber content was lower than the common major, minor and pseudo-grains while compared to a previously conducted study (Rupa *et al.*, 2025).

Metabolizable Energy: The metabolizable energy of bamboo rice for animal nutrition was calculated as 2943.51 kcal/kg and for human nutrition was 329.5 kcal/100g or 3295 kcal/kg (Table 2). This energy value indicates the amount of usable energy available after digestion and metabolism after consumption of bamboo rice. The metabolizable energy content for human nutrition was very similar to the common major, minor and pseudo-grains while compared to a previously conducted study (Rupa *et al.*, 2025).

Table 2. Proximate Analysis of bamboo rice

Parameters	Value
Moisture (%)	10.15
Dry matter (%)	89.9
Crude protein (%)	10.1
Ash (%)	4.45
Crude fiber (%)	5.65
Fat (%)	2.1
Metabolizable Energy (kcal/kg) for animal nutrition	2943.51
Metabolizable Energy (kcal/kg) for human nutrition	3295

Nutritional Analysis of Bamboo Rice

Total Protein Content: Bamboo rice was found to contain 7.81% protein (Table 3), suggesting that it can act as a moderate dietary protein source. The protein content was found to be similar with most of the BRRI high-yielding varieties (HYV) in Bangladesh as evident from a previous study (Shozib *et al.*, 2018). This level of protein intake may help support key physiological functions such as tissue growth and repair, enzyme and hormone production, and the maintenance of a healthy immune system (Ajomiwe *et al.*, 2024).

Amylose Content: The amylose content of bamboo rice was 22.10%, indicating a medium amylose category (Table 3). The content was found to be higher than some aromatic rice varieties (Kalizira, BRRI dhan-34, BRRI dhan-50) and slightly lower than BRRI dhan-37 as evident from previous research (Asaduzzaman *et al.*, 2013). This level is typically linked to a firmer texture after cooking and slower starch digestion, which may help moderate post-meal blood glucose responses and make bamboo rice a suitable option for individuals looking for foods with a lower glycemic index.

Mineral Analysis: Presence of several essential micronutrients has been confirmed (Table 3). The zinc and iron content was found to be lower than most of the BRRI HYV rice varieties in Bangladesh as evident from a previous study (Shozib *et al.*, 2017). Zinc aids in immune function, wound healing, and enzyme activity (Bonaventura *et al.*, 2015). Iron is essential for oxygen transport in the blood and energy metabolism (Malik *et al.*, 2025). Calcium helps in better bone health, nerve function, and muscle contraction (Pravina *et al.*, 2013). Phosphorus helps in energy production and gives structural integrity of bones and teeth (Serna & Bergwitz, 2020). The presence of these minerals indicates that bamboo rice can play an essential role as a mineral rich food source.

Table 3. Mineral analysis of bamboo rice

Parameters	Value
Total Protein (%)	7.81
Amylose (%)	22.10
Zinc (PPM)	13.21
Iron (PPM)	4.36
Calcium (PPM)	53.12
Phosphorus (gm/Kg)	2.44

Phytochemical analysis: The qualitative phytochemical screening of bamboo rice revealed the presence of several bioactive secondary metabolites (Table 4). The water extract showed a high presence of carbohydrates, along with low to moderate levels of alkaloids, flavonoids, glycosides, phenols, tannins, and terpenoids. On the other hand, in the methanol extract a richer profile of secondary metabolites such as terpenoids was abundant, moderate levels of flavonoids, glycosides, phenols and tannins were present. While, alkaloids, carbohydrates, and saponins were not detected. The high concentration of carbohydrates was found in the water extract because they are polar in nature and have

a high tendency to solubilize in aqueous media (Xu & Queneau, 2014). Bamboo rice is primarily composed of starch and other water-soluble polysaccharides, which are swiftly extracted using water. Water is a commonly used solvent for extraction as it is non-toxic in nature and available at low cost. On the contrary, methanol is a moderately polar organic solvent and is preferred for its effectiveness in extracting a broader range of secondary metabolites (Lee *et al.*, 2024).

Overall, the phytochemical composition of bamboo rice indicates that its reported health benefits are due to the presence of these chemical classes. The dominance of carbohydrates supports their utility as an energy-rich food source (Jequier, 1994). Moreover, the presence of flavonoids, phenols, terpenoids, and saponins provides a biochemical basis for its traditional medicinal use and potential antioxidant and antihyperglycemic properties (Sharma *et al.*, 2025).

Table 4. Phytochemical composition of bamboo rice

Compounds	Water extract	Methanol extract
Alkaloids	+	-
Carbohydrates	+++	-
Coumarins	-	-
Flavonoids	+	+
Glycosides	++	++
Phenols	+	++
Resins	-	-
Saponin	++	-
Tannins	+	++
Terpenoids	++	+++

Indication: +++ = high; ++ = moderate; + = low; - = not detected

Conclusion and Future Directions: This study highlights bamboo rice as a nutritionally and mineral-rich yet largely overlooked food resource with strong potential as a functional food. The grain was found to contain acceptable levels of protein, dietary fiber, essential minerals, and bioactive phytochemicals, all of which may contribute to improved physical health and cognitive well-being. These findings provide scientific support for the traditional medicinal uses of bamboo rice reported in local communities. In Bangladesh, where interest in natural and underutilized food resources is steadily increasing, bamboo rice may serve as an important alternative source of nutrition as well as therapeutic value. However, further research is needed to explore its sustainable production, processing, and wider utilization.

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