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Evaluation of Proximate Composition, Vitamins, Amino Acids, Antioxidant activities with Minerals and Bioactive Compounds of Young Edible Bamboo (Phyllostachys mannii Gamble)

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Abstract

Bamboo is a plant which is lesser known as a source of food though awareness of the edible young shoots as food is increasing worldwide. Of the many known edible bamboos, shoots of *Phyllostachys* are popular vegetable in many South East-Asian countries. *Phyllostachys mannii* is one of the dominant species distributed extensively in regions of North-East India which is lesser known as compared to other species of *Phyllostachys*. The current study was undertaken to evaluate the proximate composition, vitamins, amino acids, minerals, bioactive components and antinutrient content of edible shoots of *P. mannii* Gamble. Results revealed that shoots contain adequate amount of protein (3.24 ± 0.03 g/100g FW), carbohydrate (2.73 ± 0.02 g/100g FW), vitamin C (3.23 ± 0.05 mg/100g FW) and are low in fat (0.44 ± 0.01 g/100g FW). Nineteen amino acids were detected in the shoots which includes eight essential, five conditionally essential and six non essential. Of all amino acids, the content was recorded minimum (1.05 ± 0.19 µg/mg DW) in ornithine and maximum (111.04 ± 9.59 µg/mg DW) in asparagine. WDXRF analysis detected 13 minerals in the shoots which includes eight macro and five microminerals with K (6660 ± 40 mg/kg DW) and P (930 ± 20 mg/kg DW) as dominant macromineral and Fe (9.1 ± 0.4 mg/kg DW) and Zn (10 ± 0.0 mg/kg DW) as dominant micromineral. Shoots are rich in phytosterols (265.49 ± 3.16 mg/100 g DW), phenols (382.23 ± 2.08 mg/100 g FW) and neutral detergent fiber (5.72 ± 0.03 g/100 g FW). Present results showed low cyanogen (36.22 ± 0.11 mg/kg FW) content in *P. mannii* compared to other bamboos and thus considered to be safe for consumption. Overall results indicate the richness of nutritional and bioactive compounds in *Phyllostachys mannii* which has thus potential to be used nutritious vegetable and as an ideal ingredient in functional food formulations and pharmaceuticals.

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Introduction

With the steady growth in global populace together with declining food production, the world especially the developing countries are facing the problems of food security and malnutrition.[1,2] To combat these challenges, it is necessary to explore the possibilities of new food resources exclusively of plant origin which are nutritionally rich but remain neglected and underutilized. Foods of plant origin not only provide essential nutrients but are also the reservoirs of many invaluable bioactive compounds.[3] Wild edible neglected plants are recently documented as the significant source of nutrients and reservoirs of many invaluable bioactive compounds beneficial for human health. Bamboo is one such plant which is underutilized and neglected as food in India. The genus *Phyllostachys* is a caespitose shrub of temperate monopodial bamboos which belongs to tribe Arundinarieae of sub-family Bambusoideae and family Poaceae. This genus includes about 55 species, all of them native to China except two species (*P. mannii* and *P. bambusoides*) which are distributed to India, Vietnam and Burma.[4,5] The genus is of very high economic value and used for various purposes like paper, construction, handicrafts, woven bamboo articles and edible shoots.[6] In China, more than 60% of the total bamboo area is covered with *Phyllostachys* and the whole bamboo industry including paper, panels and shoots, mainly depend on five species of genus *Phyllostachys* (*P. pubescens, P. praecox, P. glauca, P. bambusoides* and *P. virdis*).[4,6,7]

Among all the bamboos, the shoots of *Phyllostachys* are considered of high quality and sweet in taste. Its shoots are used for vegetables, soups and for various other Purposes and not only in high demand in China but now throughout the world, particularly shoots of *P. praecox, P. dulcis, P. vivax* and *P. edulis.*[4,6,8]

P. mannii has a restricted distribution in India particularly in the North-Eastern regions i.e., Arunachal Pradesh, Meghalaya, and Nagaland where it is naturally profuse at an elevation up to 2400 m.[9] The shoots of *P. mannii* which are well-known for its crunchy palate and sweet aroma has not been exploited yet as food source even though naturally abundant. In recent years, research in several other species of *Phyllostachys* (*P. aurea, P. pubescens, P. praecox, P. spraecox* and *P. glauca*) has been carried out for their nutritive components (carbohydrate, amino acids, minerals and vitamins), phytochemicals (phenolics, organic acids, sterols and fibers) and medicinal (antioxidant, antibacterial, anti-cancerous and hypolipidemic) properties.[10,11,12,13] But no scientific studies have yet been conducted on *Phyllostachys mannii* due to which the nutrient and phytochemical composition are not known as in other species of *Phyllostachys*. With this background, the study was conducted to analyse the various nutrient components like proteins carbohydrates, vitamins, mineral elements, amino acids and various bioactive compounds and antinutrients like cyanogenic glycoside in the fresh shoots of *P. mannii*. Present study will be helpful in attaining awareness regarding nutrient and bioactive composition of this species. Besides, current work aims to encourage and utilize this vastly important underutilized produce with respect to food, for nutritional and health benefits.

Material and Methods

Sample Collection and Preparation

The apical shoots of *Phyllostachys mannii* Gamble (average weight of 0.20 ± 0.05 kg, length of 41.74 ± 11.4 cm, and basal width of 11.66 ± 2.9 cm) were collected from Shillong, Meghalaya (25.5º N, 91.89º E), India from May to September for four consecutive years i.e., 2014-2017. After harvesting, shoots were washed under running tap water with sheath still intact to remove soil debris and plant hairs. The outer culm sheaths of shoots and inedible portion of shoots were removed. The inner edible portion of shoots was cleaned, washed with distilled water, drained and stored in ziplock bags in refrigerator at 4º C until further use.

Proximate Composition and Vitamins Analysis

Proximate composition of the shoots was analysed by using different established methods.

Protein content was determined by using bovine serum albumin as standard.[14] 1g of sample was crushed in 3 mL of homogenization buffer and centrifuged at 10,000 r.p.m for 30 minutes at 4º C. To 0.1 mL of extract, 5 mL of Bradford reagent was added and kept for 10 minutes. The absorbance of final mixture was taken at 595 nm using UV-Visible spectrophotometer.

Total carbohydrate content was determined by using glucose as standard.[15] 1 g of sample was crushed in

5 mL of 80% ethanol and centrifuged at 10,000 r.p.m for 15 min. To 0.1 mL of extract, 4 mL of anthrone reagent was added and the mixture was vortexed and boiled for 10 minutes. The optical density was measured at 620 nm.

The estimation of starch was done by the anthrone method.[16] 1 g sample was crushed in 80% ethanol and treated with 5 mL of distilled water and 6.5 mL of 52% perchloric acid. The mixture was centrifuged at 2000 r.p.m for 20 min. To 0.1mL extract 2 mL of anthrone reagent was added. The absorbance was taken at 630 nm.

Ash content was estimated by using the dry-ashing method.[17] 1 g powder was ignited in the muffle furnace at 550° C for 12 hrs. Ash content was calculated by weight loss before and after ignition.

Fat extraction and estimation of crude fat in the shoot samples was done by using soxhlet method.[18]

For moisture content, 1 gram of shoot was weighed into a crucible and kept for drying in the oven at 60 °C for 24 hours. The percent of moisture was calculated by weight lost after drying.

Vitamin C was estimated by using ascorbic acid as standard.[19] 1 g sample was homogenized with 10 mL of 5% metaphosphoric acid and 10% acetic acid solution. This solution was filtered and centrifuged at 4000 r.p.m for 15 minutes. To 1 mL of sample extract, 0.115 mL of 3% bromine water was added followed by 0.065 mL of 10% thiourea and 0.5 mL of 2, 4-Dinitrophenylhydrazine. Optical density was measured at 521 nm.

Vitamin E by using α-tocopherol as standard.[20] 1 g sample was homogenized in chloroform: methanol (2:1) mixture and vortexed for 2 min. To this, 1 mL of chloroform and 1.8 mL of water was added and centrifuged at 2000 r.p.m for 10 min. After centrifugation and filtration, the lower layer was evaporated and dehydrated at 80°C. To dried extract, 2, 2- dipyridyl solution (0.2%), $FeCl_3$ (0.5%) and butanol was added. The absorbance was measured at 520 nm.

Mineral Analysis

For mineral analysis, samples were lyophilized using lyophilizer (LYOQUEST 55, Skadi, Europe) and homogenized to fine powder. Powdered samples were then made into pellets (diameter 34mm, thickness 4mm) by using hydraulic pressure approx. 15 tons. Analysis was performed by using a commercial WD-XRF (Wavelength Dispersive X-Ray Fluorescence) spectrometer S8 TIGER (Bruker, Germany) which was controlled by software (Quant Express). The Equipment was characterized with rhodium X-ray tube; six analyzer crystals (LiF200, LiF220, PET, XS55, XSN, XSC) and eight primary beam filters. The scintillation counter for heavy elements and gas proportional counter for lighter elements were implied. Maximum current and power directed were 170 mA and 4 kW respectively. Analysis of individual sample was carried out for 20 min. The calibration was carried out by using standard reference materials; apple leaves (1515), peach leaves (1547), spinach leaves (1570a) and tomato leaves (1573a).

Amino Acids Analysis

The free amino acids profile was determined by High Performance Liquid Chromatography (Agilent technologies, USA). Sample preparation was carried out by dissolving 25 mg of finely grounded dried sample in 25 mL of borate buffer (pH-8.5) followed by sonication for 2 min.[21] The extract was then centrifuged at 5000 r.p.m. for 5 min, filtered and a concentration of 1mg/mL was obtained. The final mixture was derivatized with O-Phthalaldehyde (OPA) in an auto sampler with quaternary gradient pump series 1290. Chromatographic analysis of derivatized samples was carried out by using Zorbax eclipse plus C18 Reverse Phase (1.8µm). The mobile phase was prepared by 10 mM disodium phosphate and 10 mM sodium tetraborate (pH 8.35) and mixture of methanol: acetonitrile: water (40:40:20, v/v). The flow rate was kept at 0.5 mL/min and detection were achieved by fluorescent detector with excitation at 340 nm and emission at 450 nm.

Bioactive Components Analysis

Total phenolic content was determined by Folin-Ciocalteau reagent using gallic acid as standard.[22] To 0.1 mLof extract, 5 mL of 10% Folin-Ciocalteau reagent was added. After 5-8 min, 3.5 mL (1M) of sodium carbonate was added and mixed well. The samples were incubated in water bath for 1 hour at 40° C before absorption was measured at 765 nm using double beam UV-Visible spectrophotometer.

Total phytosterol content was determined by method of Srivastava[23] using cholesterol as standard. To 1 mL extract, the Lieberman Burchard reagent of acetic anhydride and sulphuric acid (30:1) was added and kept in dark for 15-20 min. The absorbance was measured at 680 nm.

Dietary fiber components determined in the study were neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, hemicellulose and cellulose. Analysis of these components were carried out by method of Goering and Van Soest.[24] For quantification of NDF, dried powdered sample was gelatinized by boiling in distilled water and 0.01g of α-amylase was added to it. The sample was kept in oven at 60 ºC for 2 hours. Afterwards, 10 mL of neutral detergent solution (pH 7), 0.2 mL of dekalin and 0.1g of sodium sulphate were added and heated for 20 min. The precipitate formed was ignited in the muffle furnace (NSW 101, Narang Scientific, India) at 500ºC for 3 hours and the loss in weight measured as NDF.

For quantification of ADF, dried powdered sample was acid hydrolysed in 1N sulphuric acid, cetyltrimethyl ammonium bromide and dekalin for 30 min. The precipitate was then washed with hot water followed by acetone and final residue was dried in oven at 100ºC for 8 hours. The loss in weight after ignition determined the amount of ADF. For determination of lignin, the NDF and ADF residues were immersed in 72% sulphuric acid for 2 hours. The residue was repeatedly rinsed with boiling hot distilled water to remove traces of acid until pH becomes 5 and finally treated in acetone to eliminate water. The residue was then ignited at 100ºC and lignin content was determined by loss in weight before and after ignition. Hemicellulose content was calculated by difference in ADF and NDF values. Cellulose was determined by the difference in the amount of ADF and lignin.

Antinutrient Analysis

The antinutrient cyanogenic glycoside was determined by method of Haque and Bradbury.[25] 25 mg of shoot was grounded and taken in a plastic bottle with 0.5 mL of 0.1 M phosphate buffer. A yellow picrate paper (made by immersing Whatman™ filter paper no. 1 in mixture of 1.4 g of picric acid+2.5% Na_2CO_3) attached to a plastic strip was added immediately in a plastic bottle containing sample with phosphate buffer (pH-6). After 16-24 hours at room temperature (20-35°C), the picrate paper strips were separated and immersed in distilled water for 30 min. The absorbance was measured at 510 nm against a blank.

Statistical Analysis

All experimental analysis was conducted in triplicate. The mean and standard deviation of the mean were calculated using PASW statistics software version 18.0. The result is presented in the form of mean of the replicates ± standard deviation.

Results and Discussion

Proximate Composition and Vitamins

Proximate studies in the fresh edible shoots of *P. mannii* were carried out to examine its chemical composition and nutrients and the results are shown in Table 1. The content was compared with other *Phyllostachys* species reported in literature. From the table, it can be seen that on g/100g fresh weight (FW) basis, shoots of *P. mannii* contain high content of moisture (90.34), protein (3.24 ± 0.03), followed by carbohydrate (2.73 ± 0.02), starch (1.09 ± 0.02), ash (0.86 ± 0.01) and fat (0.44 ± 0.01). In our findings, the protein content was 9.25% higher than previously reported values in *P. pubescens* and *P. spraecox* while similar to *P.praecox*.[10,11,26] Protein content in our study was found to be higher than values reported earlier in other vegetables i.e. spinach and carrot.[27]

Shoots of *P. mannii* contain appreciable amount of protein and thus consumption as a part of everyday food regime can contribute to good source of vegetable protein especially for vegan consumers. Carbohydrate content was 51.65% higher than the earlier reports in *P. praecox* but found to be lesser than the prior reported values in other vegetables.[27] Starch content in present study was 37.71% and 57.42% lesser than previously reported in *P. praecox* and *P. spraecox* shoots respectively. Fat content of *P. mannii* was 24.14 % lower than *P. spraecox* and 52.27% higher than *P. praecox*.[10, 26] Ash content is representative of amount of minerals present in food. Ash content in *P. mannii* was almost similar to *P. praecox* and 18.09% lower to *P. pubescens*.[10,11]

Vitamins are a group of organic compounds which are essential for normal physiological function, they are not synthesised endogenously by the body and

Table 1: Proximate Composition (g/100 g FW) and Vitamins (mg/100 g FW) in the Edible Shoots of *Phyllostachys mannii* compared to other Species

		P. mannii	*P. pubescens*[11]	*P. praecox*[10]	*P. spraecox*[26]
Proximate Composition	Carbohydrate	2.73 ± 0.02	-	1.32	-
	Protein	3.24 ± 0.03	2.94	3.25	2.95
	Starch	1.09 ± 0.02	-	1.75	2.56
	Fat	0.44 ± 0.01	-	0.21	0.58
	Ash	0.86 ± 0.01	1.05	0.85	-
	Moisture	90.34 ± 0.12	89.70	91.25	
Vitamins	Vitamin C	3.23 ± 0.05	0.00	-	-
	Vitamin E	0.53 ± 0.03	0.40	-	-

All values are presented in mean ± Standard deviation (n=3)

therefore have to be sequestered in small quantities from the diet. Vitamin C and Vitamin E content were determined in edible shoots of *P. mannii* and compared with other *Phyllostachys* species (Table 1). *P. mannii* presented higher content of vitamin C (3.23 ± 0.05 mg/100 g FW) and vitamin E (0.53 ± 0.03 mg/100 g FW) compared to *P. pubescens*. However, vitamin C content was observed to be higher than earlier reported values in amaranth and carrot and lower than Brassica vegetables.[28, 29] Vitamin E content in present study was higher than the values reported in Brassica (0.47 mg/100g) vegetables.[28] Vitamin C is a potent antioxidant, anti-inflammatory, anticatabolic, reduces progression of cancer and accelerates the recovery from diseases.[30,31] Vitamin E has antioxidant, anti-inflammatory, immunomodulatory, neuroprotectory effects and has shown efficacy in prevention of muscular degeneration, cancer and liver toxicity.[32,33]

Minerals

Qualitative and quantitative measurement of minerals in *P. mannii* was carried out by WDXRF. X-ray fluorescence spectra in Figure 1 represented the existence of 13 minerals, of which eight are macrominerals (P, K, Ca, Mg, S, Cl, Na, Si) and five microminerals (Fe, Cu, Zn, Mn, Ni). The content of macro and micro elements determined in shoots was compared with other species of *Phyllostachys* evaluated in literature and is presented in Table 2. Among micromineral, shoots contain the highest concentration of K (6660 ± 40 mg/kg DW) followed by P (930 ± 20 mg/kg DW), Cl (850 ± 30 mg/kg DW), S (330 ± 30 mg/kg DW), Mg (230 ± 10 mg/kg DW), Ca (110 ± 10 mg/kg DW), Si (70 ± 10 mg/kg DW) and Na (60 ± 10 mg/kg DW). The content of all the macrominerals were found to be higher in *P. mannii* with respect to other species (*P. aurea* and *P. glauca*) except sodium which was similar to *P. glauca*.[34] K content in *P. mannii* was found to be higher than the prior reported range (724-4833 mg) in common beans, sweet potatoes and tomatoes.[35] However, Mg and P content was higher than previously recorded values from sweet potatoes and tomatoes and lower than common bean and soybeans.[35]

Considering recommended dietary allowances of macro minerals, Shoots of *P. mannii* are rich in K, P, Mg, Si and S. K and Mg are essential for sustaining regular fluid equilibrium of body. K has protective role against cardiac dysfunctions, kidney stones, osteoporosis. To the best of our knowledge, silicon and sulphur are first time reported in the *Phyllostachys* species. Shoots are abundant source of silicon which has advantageous role in cancer lowering, connective tissue development, bone formation and mineralisation.[36] Sulphur reported in shoots has anti-cancerous properties, controls blood cholesterol, relieves constipation, haemorrhoids and skin infirmities.[37,38]

Besides macro-minerals, five microminerals (Cu, Fe, Mn, Ni and Zn) were identified and quantified in shoots. It was reported that *P mannii* had the highest content of all microminerals compared to other reported species.[34] Among five micro-minerals assessed in present findings, concentration of Fe (9.1 ± 0.4 mg/kg DW) and Zn (10 ± 0.0 mg/kg DW) were found to be dominant in the shoots. Zn content in *P. mannii* was higher than previous

values recorded in most of the vegetables while Fe content was higher than tomatoes and sweet potatoes and lesser than common beans and soya beans.[35]

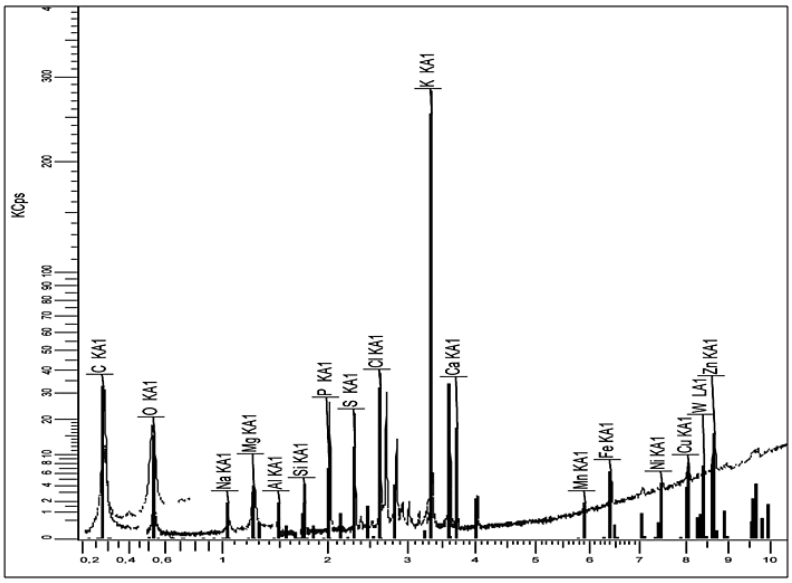

Fig. 1: X-ray fluorescence spectra of fresh shoots of *P. mannii* depicting different peaks of various macro and micromineral elements

Fe is required for haemoglobin formation, brain functioning and Zn have antioxidant properties.[39] Trace minerals such as Fe and Zn are crucial in enzyme metabolism. Micro mineral particularly Fe and Zn are the two most dominantly deficient trace mineral in the global populace therefore highly targeted micronutrients in fortification of food.[40,41] Abundance of these minerals in young shoots can specify it a noteworthy food to overcome their deficiencies and moreover for an active intervention to expand micronutrients value of usually consumed staple food. It is worth noticing that high K, Fe, Zn in shoots make them natural source of these elements for supplementation for pregnant, lactating mother as well as children and elderly people.

Table 2: Macro and Micro Minerals content (mg/100 g dry weight) of Edible shoots of *Phyllostachys mannii* in Comparison with other Species

		P. mannii **(mg/kg DW)**	***P. aurea*** [34] **(mg/kg DW)**	***P. glauca*** [34] **(mg/kg DW)**
Macro minerals	Calcium (Ca)	110 ±10	40	10
	Chlorine (Cl)	850 ± 30	-	-
	Potassium (K)	6660 ± 40	4170	3970
	Magnesium (Mg	230 ± 10	-	-
	Sodium (Na)	60 ± 10	40	60
	Phosphorous (P)	930 ± 20	-	-
	Sulphur (S)	330 ± 10	-	-
	Silicon (Si)	70 ±10	-	-
Micro minerals	Copper (Cu)	2.6 ± 0.2	0.73	0.56
	Iron (Fe)	9.1 ± 0.4	4.32	3.18
	Manganese (Mn)	5.4 ± 0.2	2.73	1.78

Nickle (Ni)	0.6 ± 0.0	-	-
Zinc (Zn)	10 ± 0.0	3.82	3.01

All values are presented in mean ± Standard deviation (n=3)

Amino Acids

Nutritional value of a plant protein based is on the amount and class of its amino acid composition.[42] Amino acids are essential macronutrients that contribute in the regulation of metabolic pathways and have significant role in deterrence and treatment of several metabolic and communicable diseases.[43] In present work, amino acids were accessed qualitatively and quantitatively in *P. mannii* by using RP-UHPLC. Figure 2 shows the HPLC chromatogram of free amino acids of juvenile edible shoots of *Phyllostachys mannii*. HPLC peaks depicted presence of 19 amino acids in *P. mannii* including 8 essential amino acids. Previously, tweleve amino acids in shoots of *P. praecox* and nineteen amino acids in the shoots of *P. pubescens* were reported by few authors[10,11]

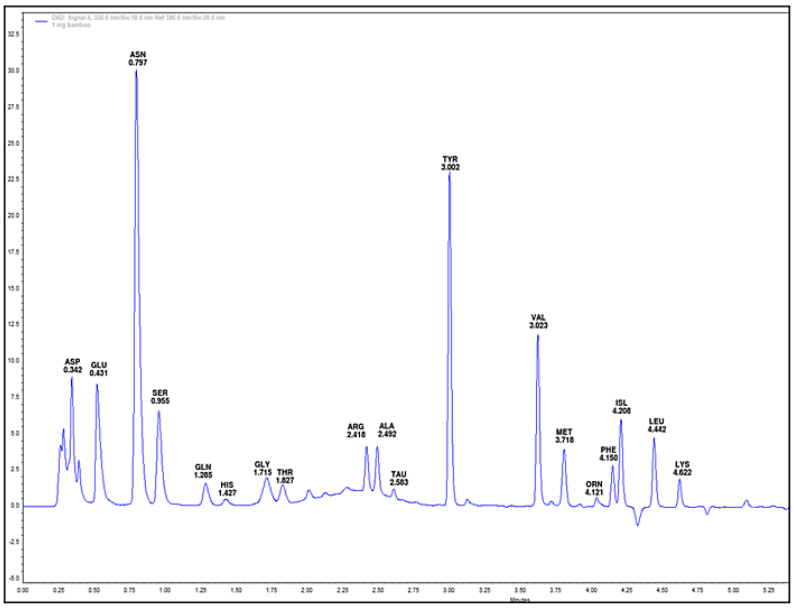

Fig. 2: HPLC chromatogram of fresh shoots of *Phyllostachys mannii* showing peaks of different amino acids with retention time in minutes

The concentration of identified nineteen amino acids of *P. mannii* and its comparison with widely studied bamboo (*P. pubescens*) is presented in Table 3. It was observed that asparagine (111.04 ± 9.59 µg/mg DW) and tyrosine (41.21 ± 3.21µg/mg DW) had the highest concentration while ornithine (1.05 ± 0.19 µg/mg DW) recorded the lowest. The highest content of asparagine and tyrosine were similar to that reported in *P. pubecsens*.[11] While comparing amino acid profile of present study with profiles of other previously reported vegetables, asparagine in okra and cowpea beans, arginine in pea, glutamine in radish were found to be dominant amino acids.[44] In addition, it was found that *P. mannii* contained all the essential amino acids except tryptophan. Valine, leucine, threonine and isoleucine were found to be at higher concentration (7.80 ± 0.30 to 21.11 ± 2.40 µg/mg DW), while histidine (4.21 ± 0.26 µg/mg DW) and lysine (3.96 ± 0.14 µg/mg DW) were at the lowest concentration. Isoleucine, leucine and valine were recently studied and proved to have therapeutic potential and can be utilized for nutritional enhancements.[45]

Semi essential amino acids are those which are commonly synthesized by organisms but required from food to meet the ideal supplies at some stages of growth. Five semi essential amino acids were found in *P. mannii* (Table 3). Of five, Tyrosine (41.21 ± 3.21 µg/mg DW) and arginine (14.70 ± 1.98 µg/mg DW) were found to be at higher concentration and glycine (3.62 ± 0.11 µg/mg DW) and glutamine (5.48 ± 0.88 µg/mg DW) were at the lowest. Similar reports of high values of tyrosine and low values of glycine and contrary results of high glutamine were reported in *P. pubescens* by Park and Jhon.[11] Tyrosine is intricated in melanin synthesis, treating depression by production of catecholamines such as dopamine and adrenaline.[46] Tyrosine is essential for phenylketonuria patients who cannot produce tyrosine due to lack of the hepatic enzyme.[47] Arginine stimulates secretion of insulin and growth hormones; improve immunity, fertility, and treat obesity, diabetes and numerous other metabolic.[48,49] Taurine which is reported for the first time in *P. mannii* is allied with development and functions several bodily muscles and central nervous system and have antimicrobial and anti-inflammatory properties.[50]

Nonessential amino acids are produced de novo in the body and hence not reliant on food. The content of six non-essential amino acids analysed is presented in Table 3. The concentration ranged from 1.05 ± 0.19 to 10.22 ± 1.09 µg/mg DW. Among these, asparagine was predominant in *P. mannii* which is comparable to reports of Park and Jhon[11] in *P. pubescens*. Asparagine is vital in ammonia cleansing, fatigue relieving, improving immunity and brain functioning.[51] Due to existence of several essential and semi essential amino acids, *P. mannii* can be utilized as supplementation in other foods which lack in one or more essential amino acids as well as a dietary supplement to treat several metabolic disorders.

Table 3: Comparison of Free Amino Acids in Edible Shoots of *P. mannii* and *P. pubescens*

		P. mannii **(µg/mg DW)**	***P. pubescens*[11]** **(% DW)**
Essential amino acids	Histidine	4.21 ± 0.26	2.60
	Isoleucine	7.80 ± 0.30	2.93
	Leucine	12.84 ± 0.13	3.35
	Lysine	3.96 ± 0.14	1.92
	Methionine	6.39 ± 0.66	1.31
	Phenylalanine	7.54 ± 1.04	2.54
	Threonine	8.91 ± 1.09	1.69
	Valine	21.11 ± 2.40	3.31
Semi essential amino acids	Arginine	14.70 ± 1.98	2.37
	Glutamine	5.48 ± 0.88	16.98
	Glycine	3.62 ± 0.11	0.66
	Taurine	9.77 ± 0.47	-
	Tyrosine	41.21 ± 3.21	19.86
Non-essential amino acids	Alanine	10.22 ± 1.09	3.87
	Asparagine	111.04 ± 9.59	23.87
	Aspartic acid	16.28 ± 1.48	0.86
	Glutamic acid	10.81 ± 2.06	3.40
	Serine	9.57 ± 1.28	5.19
	Ornithine	1.05 ± 0.19	-

All values are presented in mean ± Standard deviation (n=3).

Bioactive Components

Bioactive components are plant based secondary metabolites that are known to impart several health benefits in humans.[3] Bioactive components analysed in the present study are total phenols, total phytosterols and dietary fiber components

(neutral detergent fiber, acid detergent fiber, hemicellulose, lignin and cellulose) and the content is depicted in Table 4. Shoots contain 382.23 ± 2.08 mg/100 g FW of phenols. The present values were higher than total phenols previously reported in other bamboos and brassica species.[28,52,53] Phenols are linked with antioxidant, anti-inflammatory, anti-cancerous and antimicrobial properties and prevent cerebrovascular, cardiovascular and neurodegenerative diseases.[3,54] Phytosterol content was 265.49 ± 3.16 mg/100 g DW in *P. mannii* shoots which was lower than *pubescens* (321.8 mg/100 g DW) and higher than the content reported in other species of bamboos i.e., *Pleioblastus amarus*, *P. praecox*, *Dendrocalamus latiflorus*, *D. giganteus* and *D. sikkimensis*.[55,56] Phytosterol content in *mannii* was observed to be higher than the values prior recorded in other vegetables like spinach, potato and radish.[57] Phytosterols are known to lower serum cholesterol levels in humans and have inhibitory action on stomach, lungs, breast and ovarian cancer.[58] The NDF content was 5.72 ± 0.03 g/100 g in our study which was higher than the content reported in shoots of *D. sikkimensis* (4.66 g/100 g) and *D. giganteus* (5.60 g/100g) and lower than *D. latiflorus* (5.88 g/100 g).[56] Present report showed higher content of dietary fiber compared to values prior recorded in commonly consumed vegetables.[29] The higher ADF content (1.41± 0.02 g/100 g) was found in *P. mannii* with respect to other bamboo species (0.83-0.93 g/100 g FW) reported earlier by Rawat *et al*.[56] Lignin, cellulose and hemicellulose content were found to be 0.17, 1.24 and 4.32 g/100 g FW respectively. Hemicellulose content in our study was higher than reported earlier in *D. hamiltonii.*[53]

Dietary fiber in food regime have attained great attention due to its beneficial effect on reduction in the risk of obesity, diabetes, cancer, gall stones, constipation and hypercholesterolemia.[59] High phenols, phytosterols and dietary fiber content especially the lignocellulosic biomasses which consist of cellulose, hemicellulose and lignin definitely makes the shoots as a potential ideal ingredient for function food formulations due to their several health promoting properties.

Antinutrient

The young shoots of bamboo comprise of an antinutrient, cyanogenic glycosides, which is responsible for acridity and is a major constraint for bamboo shoot consumption. Results highlighted considerably low content (36.22 ± 0.11 mg/kg FW) of cyanogenic glycosides in *P. mannii* which is relatively below the tolerable limit (500 mg/kg). Present results support the previous reports of low cyanogen content in other *Phyllostachys* species viz. *P. pubescens*, *P. nigra* and *P. makinoi*.[60,61] The content of total cyanogenic glycosides reported in the shoots of *Bambusa* and *Dendrocalamus* species were much higher than permissible limit and thus required processing to eliminate the cyanogen toxicity.[62,63] Due to very low toxicity of *P. mannii*, it can be regarded safe compared to other bamboo species for fresh consumption without any processing.

Table 4: Bioactive compounds and antinutrient content of edible shoots of *P. mannii*

	Composition	*P. mannii*
Bioactive compounds	Total Phenols (mg/100 g FW)	382.23 ± 2.08
	Total phytosterols (mg/100 g DW)	265.49 ± 3.16
	NDF (g/100 g FW)	5.72 ± 0.03
	ADF (g/100 g FW)	1.41 ± 0.02
	Lignin (g/100 g FW)	0.17 ± 0.00
	Cellulose (g/100 g FW)	1.24 ± 0.01
	Hemicellulose (g/100 g FW)	4.32 ± 0.03
Antinutrient	Total Cyanogenic glycosides (mg/kg FW)	36.22 ± 0.11

All values are presented in mean ± Standard deviation (n=3)
NDF (Neutral detergent fiber), ADF (Acid detergent fiber)

Conclusion

The present investigation has revealed that *Phyllostachys mannii* is a promising species for its edible shoots as they are notably a rich source of protein, minerals (potassium, phosphorus, iron, zinc, copper and manganese) and amino acids (valine, arginine, leucine, threonine, tryptophan, isoleucine and phenylalanine). Being nutritionally adequate, this species has great prospective in combating malnutrition and food insecurity especially in developing countries and can be promoted as healthy and nutritious food. Moreover, the low content of cyanogenic glycosides compared to other bamboo species makes the shoots safe for consumption without processing. In terms of functional and bioactive properties, the shoots are excellent source of dietary fiber, phenols and phytosterols and thus can be implemented for developing functional foods. Moreover, shoots in paste, dried, powdered and extract form have great potential to be used as raw material to supplement nutritionally essential amino acids, minerals elements, fiber, sterols in pharmaceuticals, nutraceuticals, veterinarian preparations, infant formulations as well as in food fortification. Though the shoots of *P. mannii* are rich source of nutrients and bioactive components, it is not yet well known worldwide. This monopodial bamboo is fast growing and adapts well in adverse conditions and can be promoted for cultivation, promotion and commercialization globally as a valuable food source.

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Conflict of Interest

The authors declare no conflict of interest.

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