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Nutritional values of some commercial edible bamboo species of the North Eastern Himalayan region, India

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Abstract—The North Eastern Himalayan (NEH) region of India has a great diversity of bamboo resource and the tribal communities of the region use young succulent shoots of various bamboo species as vegetable, pickles, salad, etc., from May to September every year. Out of 25 edible bamboo species identified for the region, 11 species, i.e., *Bambusa balcooa* Roxb., *B. nutans* Wall. ex Munro, *B. tulda* Roxb., *Dendrocalamus giganteus* Munro in Trans., *D. hamiltonii* Nees et. Arn, *D. hookerii* Munro in Trans., *D. longispathus* Kurz, *D. sikkimensis* Gamble, *Melocanna baccifera* (Roxb.) Kurz, *Phyllostachys bambusoides* Sieb. and Zucc. and *Teinostachyum wightii* Beddome have been found as potential species, which are sold in the markets by primary or secondary vendors in fresh, fermented, boiled or roasted form. Besides their occurrence in forests, these edible species are also cultivated in home gardens. This paper reports the nutritional values on some major edible bamboo species of the region. For different species, food energy ranged from 14.6 to 16.9 MJ/kg and ash content from 2.1 to 3.7%. For different species, crude fibre content ranged between 23.1 and 35.5%, fat between 0.6 and 1.0%, and carbohydrate between 4.5 and 5.2%. Among various species, the protein content was determined to be high in *D. hamiltonii*, *P. bambusoides*, *T. wightii* and *B. balcooa*. Young edible bamboo shoots were also found rich in macronutrients, particularly in calcium with a range of 1.2–1.9 g/100 g. The potassium content ranged from 0.02 to 0.03 g/100 g, phosphorus from 0.5 to 1.0 g/100 g and magnesium from 0.04 to 0.05 g/100 g. Edible shoots were also rich in vitamins. Among species, the ascorbic acid ranged from 3.0 to 12.9 mg/100 g, tryptophan from 0.4 to 1.7 g/16 g N and methionine from 0.3 to 0.8 g/16 g N. Hydrocyanic acid (HCN) content was also available in edible shoots; however, the range varied from 0.01 to 0.02%. The study showed that *Dendrocalamus* spp, *M. baccifera* and *P. bambusoides* need to be included in various afforestation programmes in the region where shifting cultivation has already caused serious environmental degradation. It will serve the twin purpose of restoration of degraded lands and production of edible shoots for consumption of various ethnic groups of the region.

Key words: Young bamboo shoot; nutritional values; macronutrients; micronutrients; India.

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INTRODUCTION

Bamboo is one of the most important resources on the earth. Over 1250 species of bamboo are found belonging to 75 genera. India is the third-largest country in the world as far as bamboo species diversity is concerned. On average, 300, 237 and 125 bamboo species have been reported, respectively, from China, Japan and India. India is also one of the leading countries of the world; second to China in bamboo production, with bamboo species covering an area of around 10.03 million ha, which contributes 12.8% of the total forest cover of the country. Within India, the North Eastern Himalayan (NEH) region represents 58 species belonging to 16 genera and tribal communities of the region use this potential resource for shelter, furniture, handicraft, medicines and various ethno-religious purposes [1–6]. According to legal classification of forests, the percentage of reserve forests, protected forests and unclassed forests varies from state to state in the study area and the bamboo is mainly harvested from unclassed forests. On average, 10–15 year jhum fallow allows luxurious growth of bamboo species but as the jhum cycle has reduced to 3–5 years in the recent past, it is affecting adversely the production of young bamboo shoots in these states. Nevertheless, as many as 25 bamboo species are used as food by various ethnic groups of the region, and tender bamboo shoots supplement to nutrition of the local population to a great extent.

Although information is available on bamboo resource of the region [7–10], very few attempts have been made so far to evaluate the consumption pattern of young bamboo shoots as food and production potential of bamboo species [11, 12]. The present paper describes the nutritive values of some commercial edible bamboo species of the NEH region, India.

STUDY AREA

The NEH region of India comprises the states of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, including Sikkim, and lies between 21.5 and 29.5°N latitude and 85.5 to 97.5°E longitude. It has a total geographical area of 18.4 million ha and a population of 9.5 million people, representing 6.0 and 1.3% of the country, respectively. The region falls under the high rainfall zone and the climate ranges from subtropical to alpine. The region is characterized by difficult terrain, wide variations in slopes and altitude and cultivation practices. Being rich in biodiversity, it is recognized as one of the 18 'hot spots' of the world. The region is inhabited by diverse ethnic groups, which have their unique lifestyle and are dependent on forests to a great extent for their subsistence. The agriculture production system in the region is mostly rain fed, monocropped and at subsistence level.

Shifting cultivation is mainstay of subsistence in the region, excluding Sikkim. Until 3 decades ago, shifting cultivation was not so alarming, as its cycle was 20–30 years, but of late it has been reduced to 3–5 years, partly due to the population explosion and partly to loss of fertile soil owing to over-exploitation of forest resources. The area under shifting cultivation has been reported to be between 2.8 million and 7.4 million ha by various agencies [1]. On average, 3869 km^2 is put under shifting cultivation every year and an estimated 443 000 households earn their livelihood from shifting cultivation. The extent of area under shifting cultivation is maximal in Nagaland, followed by Mizoram and Manipur [13]. Large-scale deforestation has brought 36.6% of the total geographical area of the NEH region under degraded lands, which is 1.8-fold higher than the national average of 20.2%.

MATERIALS AND METHODS

A preliminary survey was conducted to identify the important edible bamboo species at different places in the states of the NEH region. In all 4567 primary and 567 secondary vendors, including 314 marketplaces, were surveyed to gather the information on young shoot consumption, their uses and other information. As production of young shoots of all the bamboo species begins at the onset of the rainy season, i.e., May–June, a continuous survey of randomly selected market places of all the states was done to find out the major edible bamboo species. The entire primary as well as secondary vendors available in each market place explored were interviewed through pre-prepared questionnaires to understand the annual rate of bamboo shoot consumption and to identify the commercial edible bamboo species.

After completing the survey work, fresh shoots were collected and brought to the laboratory. Ascorbic acid, tryptophan and methionine were determined in freshly collected samples. For proximate nutrient analysis, macronutrient estimation and HCN analysis, the tender shoots were chopped into small pieces and oven-dried at 80 ± 5°C for 24 h. The dried samples were crushed in a mechanical grinder and fine powder was made for further analysis.

Various recommended methods for analyses of nutrients were used as given in the literature [14–20]. Quantitative analysis of the edible bamboo shoots was broadly done for proximate analysis, as well as ultimate analysis. The methods used in the analysis are been mentioned below.

Proximate nutrient analysis

The food energy value of young edible shoots was estimated after burning the oven-dried samples in a bomb calorimeter. The ash content was determined by combusting the plant material in silica crucibles in a muffle furnace at 600°C for 3 h. Nitrogen was estimated by multiplying the percent nitrogen estimated by Kjeldhal method [14]. Acidity of the samples was determined by using phenolphthalein indicator [15]. Carbohydrate content was estimated by the colorimetric method using anthrone reagent, which turns green to a dark green colour in hot acidic medium [19]. Crude fibre was determined by acid and alkaline digestion methods [20].

Crude fat in plant samples was determined by extracting a known weight of plant material with petroleum ether using a Soxhlet apparatus.

Determination of minerals (macronutrients), vitamins and HCN

Calcium and magnesium in plant samples was determined by EDTA (the disodium salt of ethylene diaminetetraacetic acid) titration method. Potassium was determined by the wet digestion method through a flame photometer, whereas phosphorus was estimated colorimetrically by the molybdenum blue method.

HCN in plant samples was estimated using the alkaline titration method [16]. Methionine content was determined by colorimetry using sodium nitroprusside solution that turns red on acidification [17]. Tryptophan in the edible shoots was estimated following the methodology of Spies and Chamber [18]. Ascorbic acid was determined by volumetric method using a dye (2,6-dichlorophenol indophenol), which turns pink in acid solution [19].

RESULTS

Bamboo, being a constituent of natural resources, is harvested almost every day either for household consumption or marketing (in any form). The major share of young edible shoot goes to food purposes, as fresh, fermented or roasted, or boiled, and the rest for making pickles. Out of 125 species reported from India, 58 species are found in the region. Mizoram is the state with the highest area under bamboo cover (30.8%), followed by Tripura (27.1%) and Meghalaya (26.0%). However, the highest numbers of major edible bamboo species are found in Manipur state, followed by Tripura and Arunachal Pradesh (Table 1). The details of the nutritive values are presented in Tables 2 and 3. Table 4 gives the data on species-wise consumption and annual supplement to nutrition provided by edible bamboo shoots to tribal communities of the region.

Proximate nutrient analysis

The food energy was highest in *D. sikkimensis* (16.9 MJ/kg) and lowest in *T. wightii* (14.6 MJ/kg). Food energy of the rest of the species ranged in-between these two extremes. The moisture content was high (>90%) in *B. nutans*, *B. tulda*, *Dendrocalmus* spp. and *M. baccifera*. The rest of the species had comparatively lower moisture percentage. The ash content in the different edible bamboo species varied from 2.1 to 3.7%. *T. wightii*, closely followed by *D. longispathus*, *D. hookerii* and *B. balcooa*, showed maximum deposition of mineral matter at tender shoot stage. The lowest ash content, however, was recorded in *P. bambusoides.* Crude fibre content was recorded to be highest in edible shoots of *M. baccifera* (35.5%), followed by *D. hookerii* (34.7%) and *B. nutans* (28.5%). Among various species, *P. bambusoides* exhibited the lowest crude fibre content (23.1%, Table 2).

Table 1.
Area under bamboo cover and distribution of major edible bamboo species in NEH region, India

State	Area under bamboo forest (%)*	Major edible bamboo species
Arunachal Pradesh	9.5	*Dendrocalamus giganteus*, *D. hamiltonii*, *D. hookerii*, *Melocanna baccifera* and *Phyllostachys bambusoides*
Manipur	14.6	*Bambusa balcooa*, *Dendrocalamus giganteus*, *D. longispathus*, *D. hamiltonii*, *D. sikkimensis*, *Melocanna baccifera* and *Teinostachyum wightii*
Meghalaya	26.0	*Bambusa balcooa*, *Dendrocalamus hamiltonii*, *Melocanna baccifera* and *Teinostachyum weightii*
Mizoram	30.8	*D. longispathus* and *Melocanna baccifera*
Nagaland	22.2	*Dendrocalamus gigantus*, *D. hamiltonii*, *D. membranaceous* and *Gigantochloa rostrata*
Sikkim	Not known	*Chimonobambusa hookeriana* and *Dendrocalamus hamiltonii*
Tripura	27.1	*Bambusa balcooa*, *B. polymorpha*, *B. tulda*, *Dendrocalamus hamiltonii*, *Melocanna baccifera* and *Schizostachyum dullooa*

* Calculated on fresh weight basis.

The protein content determined for edible shoots of various bamboo species varied from 2.4 to 3.7%. *D. hamiltonii* contained maximum protein content, which was at par with *P. bambusoides*. Out of 11 species, 8 had a protein content of more than 3%. Carbohydrate content ranged from 4.5% (*D. hookerii*) to 5.2% (*B. balcooa*). Acidity in young edible shoots ranged between 3.3 and 5.2%. *B. tulda* possessed maximum acidity among all the species, followed by *D. giganteus*, and it was lowest in *T. wightii*. Fat content was very low in all the edible bamboo species. However, it was found to be highest in tender shoots of *B. balcooa* and *D. hookerii* (1.0% in both the species). Among various species, the lowest fat percentage was noticed in young shoots of *D. longispathus* (0.6%).

Mineral contents

Among the various macronutrients, calcium content was observed to be highest in tender shoots of *D. sikkimensis* (1.9 g/100 g), followed by *D. hookerii* (1.6 g/100 g). However, lowest value was noticed in edible shoots of *D. giganteus* (1.2 g/100 g). Potassium content in 11 edible bamboo species ranged from 0.02–0.03 g/100 g, with the highest value in *B. balcooa* and *B. nutans*, and lowest in *D. hamiltonii*. The phosphorus content determined in various species varied from 0.5 to 1.0 g/100 g. The highest phosphorus content was determined in *D. hookerii* (1.0 g/100 g), followed by *B. balcooa* and *B. nutans* (0.9 g/100 g in both species). The magnesium content in young shoots of various bamboo species ranged from 0.04 to 0.05 g/100 g (Table 3).

Table 2.
General chemical analysis (% dry matter) of major edible bamboo species of NEH region, India

Species	Food energy (MJ/kg)	Moisture %	Ash	Crude fibre	Protein	Carbohydrate	Acidity*	Fat
Bambusa balcooa	15.5 ± 0.07	86.3 ± 3.50	3.1 ± 0.020	26.4 ± 1.17	3.3 ± 0.82	5.2 ± 0.10	4.0 ± 0.03	1.0 ± 0.01
B. nutans	15.4 ± 0.08	94.7 ± 2.30	2.7 ± 0.010	28.5 ± 1.40	3.3 ± 0.54	4.9 ± 0.12	4.4 ± 0.05	1.0 ± 0.03
B. tulda	15.9 ± 0.10	92.8 ± 1.20	3.0 ± 0.021	24.6 ± 0.45	3.4 ± 0.25	4.7 ± 0.07	5.2 ± 0.03	0.9 ± 0.02
Dendrocalamus giganteus	16.9 ± 0.12	92.0 ± 2.00	2.2 ± 0.060	27.6 ± 2.87	2.8 ± 0.11	4.9 ± 0.03	4.8 ± 0.07	0.8 ± 0.04
D. hamiltonii	16.4 ± 0.06	93.6 ± 1.40	2.8 ± 0.060	25.4 ± 2.26	3.7 ± 0.25	4.8 ± 0.06	4.5 ± 0.06	0.9 ± 0.03
D. hookerii	16.8 ± 0.13	93.5 ± 1.50	3.2 ± 0.050	34.7 ± 2.32	3.4 ± 1.70	4.5 ± 0.13	3.8 ± 0.03	1.0 ± 0.02
D. longispathus	16.6 ± 0.10	91.7 ± 1.25	3.4 ± 0.030	26.7 ± 4.81	2.6 ± 0.36	4.7 ± 0.05	3.9 ± 0.06	0.6 ± 0.01
D. sikkimensis	16.9 ± 0.07	92.4 ± 1.30	2.6 ± 0.020	23.5 ± 3.91	3.1 ± 0.18	4.7 ± 0.06	4.4 ± 0.01	0.6 ± 0.03
Melocanna baccifera	15.8 ± 0.08	93.0 ± 1.50	2.3 ± 0.004	35.5 ± 3.12	2.4 ± 0.80	4.5 ± 0.09	4.1 ± 0.04	1.0 ± 0.01
Phyllostachys bambusoides	16.3 ± 0.07	85.6 ± 2.35	2.1 ± 0.040	23.1 ± 2.66	3.7 ± 0.22	4.8 ± 0.04	4.2 ± 0.04	0.7 ± 0.02
Teinostachyum wightii	14.6 ± 0.08	78.6 ± 2.36	3.7 ± 0.040	23.7 ± 2.12	3.6 ± 1.97	4.9 ± 0.11	3.3 ± 0.04	0.9 ± 0.03
Average	16.1	90.4	2.8	27.2	3.2	4.8	4.2	0.9

Data are means ± SD.
* Calculated on fresh weight basis.

Table 3.
Determination of minerals, vitamins and HCN content in major edible bamboo species of NEH region, India

Bamboo species	Calcium (g/100 g)	Potassium (g/100 g)	Phosphorus (g/100 g)	Magnesium (g/100 g)	Ascorbic acid* (mg/100 g)	Tryptophan* (g/16 g N)	Methionine* (g/16 g N)	HCN (%)
Bambusa balcooa	1.4 ± 0.08	0.03 ± 0.001	0.9 ± 0.01	0.04 ± 0.006	3.8 ± 0.32	1.1 ± 0.05	0.5 ± 0.02	0.02 ± 0.03
B. nutans	1.5 ± 0.07	0.03 ± 0.008	0.9 ± 0.02	0.04 ± 0.004	5.3 ± 0.41	0.5 ± 0.01	0.6 ± 0.03	0.02 ± 0.00
B. tulda	1.3 ± 0.04	0.02 ± 0.006	0.7 ± 0.02	0.04 ± 0.001	7.6 ± 0.94	1.4 ± 0.08	0.3 ± 0.02	0.01 ± 0.00
Dendrocalamus giganteus	1.2 ± 0.07	0.03 ± 0.005	0.7 ± 0.03	0.05 ± 0.007	6.8 ± 0.62	1.7 ± 0.01	0.5 ± 0.04	0.01 ± 0.03
D. hamiltonii	1.5 ± 0.08	0.02 ± 0.010	0.6 ± 0.05	0.04 ± 0.004	12.9 ± 0.57	1.2 ± 0.07	0.6 ± 0.03	0.01 ± 0.01
D. hookerii	1.6 ± 0.10	0.02 ± 0.012	1.0 ± 0.03	0.04 ± 0.007	9.9 ± 0.64	1.2 ± 0.00	0.6 ± 0.04	0.02 ± 0.05
D. longispathus	1.3 ± 0.04	0.02 ± 0.013	0.6 ± 0.06	0.04 ± 0.006	5.3 ± 0.71	0.7 ± 0.04	0.3 ± 0.03	0.02 ± 0.02
D. sikkimensis	1.9 ± 0.06	0.02 ± 0.014	0.7 ± 0.01	0.04 ± 0.004	3.0 ± 0.54	1.4 ± 0.07	0.6 ± 0.10	0.01 ± 0.01
Melocanna baccifera	1.4 ± 0.03	0.02 ± 0.004	0.8 ± 0.03	0.04 ± 0.002	7.6 ± 1.07	1.4 ± 0.12	0.3 ± 0.05	0.01 ± 0.00
Phyllostachys bambusoides	1.3 ± 0.12	0.02 ± 0.009	0.7 ± 0.06	0.04 ± 0.010	6.1 ± 0.70	1.1 ± 0.03	0.8 ± 0.01	0.01 ± 0.00
Teinostachyum wightii	1.3 ± 0.03	0.02 ± 0.007	0.5 ± 0.04	0.04 ± 0.005	6.6 ± 0.45	0.4 ± 0.00	0.5 ± 0.09	0.02 ± 0.01
Average	1.4	0.02	0.7	0.04	6.8	1.1	0.5	0.01

Data are means ± SD.
*Estimated on fresh weight basis.

Table 4.
Species-wise consumption of young bamboo shoots and annual supplements of nutrition (kg/year*) provided to tribal communities of NEH region, India, irrespective of states

Species	Consumption of young shoots*	% to total consumption	Energy (MJ)	Protein (kg)	Fat (kg)	Carbohydrate (kg)
Bambusa balcooa	37 300	8.6	576 700	1225	620	1940.0
B. nutans	3800	0.9	58 900	130	55	188.0
B. tulda	31	0.01	500	1	0.3	1.5
Dendrocalamus giganteus	87 500	20.3	1 478 000	2430	630.0	4300.0
D. hamiltonii	117 300	27.2	1 924 000	4320	1350.0	5255.0
D. hookerii	21 200	4.9	355 300	720	445.0	1020.0
D. longispathus	410	0.1	6900	11	2.0	20.0
D. sikkimensis	82 000	19.0	1 386 000	2575	525.0	3800.0
Melocanna baccifera	45 300	10.5	715 700	1100	435.0	2050.0
Phyllostachys bambusoides	32 300	7.5	525 000	1200	225.0	1550.0
Teinostachyum wightii	4400	1.0	64 200	155	49.0	215.0
Total	431 540	100	7 091 200	13 867	4339.0	20 344

* Productivity and nutritive value was calculated on dry weight basis.

Vitamins

Ascorbic acid content was found to be highest in tender shoots of *D. hamiltonii* (12.9 mg/100 g), followed by *D. hookerii* (9.9 mg/100 g) and *M. baccifera* and *B. tulda* (7.6 mg/100 g in both species), whereas it was lowest in tender shoots of *D. sikkimensis* (3.0 mg/100 g). Tryptophan content was recorded highest in edible shoots of *D. giganteus* (1.7 g/16 g N), followed by *B. tulda*, *D. sikkimensis*, *M. baccifera* (1.4 g/16 g N in all the three species) and *D. hookerii* (1.2 g/16 g N). Among the various species, the lowest value of tryptophan was observed in *T. wightii* (0.4 g/16 g N). Methionine content was also estimated in young edible shoots of various bamboo species and it was recorded highest in tender shoots of *P. bambusoides* (0.8 g/16 g N), followed by *B. nutans*, *D. sikkimensis* and *D. hookerii* (0.6 g/16 g N in all the species). The lowest methionine content was recorded in young shoots of *D. longispathus* (0.3 g/16 g N) (Table 3).

HCN content

HCN is one of the important anti nutritional factors available in young bamboo shoots. HCN content was highest (0.02%) in edible shoots of *B. balcooa*, followed by *D. longispathus* (0.018%), *D. hookerii* (0.017%), *B. nutans* (0.016%) and *T. wightii* (0.015%). Among the various species, lowest HCN (0.009%) was recorded in tender shoots of *P. bambusoides* (Table 3).

Annual supplement to nutrition through bamboo species

The productivity of fresh shoots was recorded to be highest for *D. hamiltonii*, as the species is used as food almost in all the states of NEH, followed by *D. giganteus*. Edible *B. tulda* was found only in the Tripura states of the region; hence, it has the lowest consumption rate. On average, *Dendrocalamus* spp. contributes 71.5% to young shoot consumption and the rest is contributed by *M. baccifera* (10.5%), *Bambusa* spp. (9.5%), *P. bambusoides* (7.5%) and *T. weightii* (1.0%). Among the various species, most of the energy content, protein, fat and carbohydrate content has also been supplemented by *D. hamiltonii* as compared to other species. *Dendrocalamus* spp. alone supplemented 72.7, 72.0, 68.0 and 70.8% of energy, protein, fat and carbohydrate, respectively. On average, the edible bamboo species analyzed in the present communication supplemented 7 091 200 MJ of energy, 13 867 kg of protein, 4336 kg of fat and 20 330 kg of carbohydrate, respectively, to the nutrition of tribal populations (Table 4).

D. hamiltonii also contributed most of the calcium, potassium, phosphorus, magnesium, ascorbic acid and methionine contents as compared to other species. However, young shoots of *D. giganteus* supplemented most of the tryptophan. Thus, bamboo species were particularly found to be rich in minerals and vitamins compared to protein, fat and carbohydrates.

DISCUSSION

Although poverty in India has shown a decline over time, the absolute numbers have increased substantially, from 180 million in the early 1950s to 350 million by the end of the 1990s. The different criteria for poverty include malnutrition, underemployment, poor reproductive health care and associated infant mortality, high birth rates and illiteracy. Malnutrition is particularly witnessed in far-flung areas of the Himalayas due to the remoteness of the area, coupled with the fact that more than 64% of the total rural population lives below the poverty line. Thus, traditionally, wild plants are gathered in the form of fruits, shoots, leaves, twigs, flowers, roots, tubers, stem, pith, etc., and these plants still share a good proportion of tribal dishes world over [21–24], thereby meeting the protein, carbohydrate, fat, vitamin and mineral requirement of tribal communities to a great extent [25, 26]. Among the various edibles, bamboos play a great role in nutrition of tribal folk. Tribal communities are so weaned with bamboo resources that without bamboo their existence is unthinkable. Studies have also been conducted on the chemical composition and nutritional value of wild edibles from the Himalayan zone of India [27–31], but no such reports are available for edible bamboo species, probably because consumption of tender bamboo shoots is witnessed only in the NEH region [32]. Therefore, information on the chemical constituents of major edible bamboo species adds to the existing knowledge about the nutritional values of edible bamboo species in eastern Himalayas. Young bamboo shoots have a domestic market for consumption for a period of almost 4–5 months. Besides, bamboo shoots are an intercontinental delicacy and Thailand, China, Denmark, Philippines, Taiwan, Tanzania, Puerto Rico, Malaysia, Singapore and Japan are extensively using it as vegetable, pickle, salad and for various other purposes.

For most of the studies, fibres, protein and food energy are considered as the main determinants of food type, and very few studies are available on the elemental composition of the wild edible species. Food energy, protein and crude fibre in edible bamboo shoots were well within the range as reported by earlier workers for other wild edibles [24, 27, 28, 30]. Edible shoots were also found to be rich in minerals, particularly calcium. Phosphorus content was also high in bamboo shoots. Between species, fat, ascorbic acid and tryptophan was 3–4-fold higher and the rest of the values were 1–2-fold higher. Although no single species did exhibit average higher values for all the parameters studied, however, *D. sikkimensis* exhibited the highest value of calcium. Phosphorus was recorded to be highest in *D. hookerii* shoots. Potassium was estimated to be comparatively higher in young shoots of *B. balcooa* and *B. nutans*, whereas comparatively higher magnesium content was recorded in young shoots of *D. giganteus*. Young bamboo shoots were also rich in vitamins, particularly in ascorbic acid and tryptophan. On average, carbohydrate and fat was less in edible bamboo shoots compared to other wild edible species. In an earlier study, Young [33] reported average nutritive values for various bamboo species as: total digestive carbohydrate 4.5, protein 2.6, fat 0.3 and ash 0.9%. In the present investigation, the average energy value, moisture, ash, crude fibre, protein, carbohydrate, acidity and fat were recorded to be 16.1 MJ, 90.4%, 2.8%, 27.2%, 3.2%, 4.8%, 4.2% and 0.9%, respectively. Similarly, the average values for calcium, potassium, phosphorus, magnesium, ascorbic acid, tryptophan and methionine contents were 1.4, 0.02, 0.7, 0.04, 6.8, 1.1 and 0.5, respectively, irrespective of bamboo species. Besides, bamboo shoots contain cynogenic glucosides, which on endogenic hydrolysis yield hydrocyanic acid (HCN). It is considered as one of the most important anti-nutritional factor. HCN in bamboo shoots has been reported to vary from 0.05 to 0.30% [34]. However, in the present study, the HCN content in edible shoots varied from 0.009 to 0.02% (average value 0.014%), which seems much less than the earlier reported values. Thus, HCN factor could be exploited to select out the species containing lower levels of this toxic constituent. However, the tribal have their own indigenous technical knowledge to reduce the HCN in edible shoots. During cooking of bamboo shoots, the water is changed 2–3 times, which destroys the enzyme responsible for the endogenic hydrolysis of the cyanogenic glucosides to a great extent [35].

Indigenous technical ingenuity of tribal people since time immemorial is also revealed in the preparation of food items from bamboo shoots. As such no preservative is used for storage lives of 6 months to 2 years in fermented products of bamboo shoots. Various indigenous methods of reducing acidity/bitterness from fresh bamboo shoots have also been recorded and some of them include chopping of tender shoots into small pieces, partial drying of fresh shoots, boiling in water/water added with salt and drain out boiled water or keeping the tender shoots in hot water for 10–15 min or in water for a week at ambient temperature, etc.

CONCLUSIONS

The Government of India is carrying out a large number of programmes for community development on a nutritional status to overcome the problem of malnutrition. Malnutrition in children has come down by 15% in 1975–1979 to 87% in 1988–1990 [36], which is remarkable by any standard. Despite food self-sufficiency at the national level, the country has not attained food security at a household level, particularly in these tribal states. Hence, a considerable proportion of rural population is still undernourished and they meet their nutritional requirement through no conventional means, i.e., by consuming various wild plants and animal resources [37] and bamboo shoots constitute the diets of tribal communities to a great extent.

The high diversity of bamboo resource plays a significant role in the food and nutritional security of the tribal population of the NEH region. The nutritive values of young succulent shoots of bamboo species were at par with various other wild edible fruits, leaves, twigs, roots and tubers. Further research is needed to study the microelements in various edible species besides studies on homogentisic acid, which is reported to be responsible for the disagreeable pungent taste of bamboo shoots.

In view of ongoing shifting cultivation practice in the region on the one hand and decreasing forests on the other, concerns are being expressed over erosion of bamboo germplasm [38]. Some of the research involves bamboo-based agroforestry systems highlighting the capacity of bamboo in increasing the soil moisture, nutrients, reducing water run off and soil erosion [39]. But the edible characteristics have not been given due importance perhaps because consumption of tender shoots of bamboo is witnessed only in northeast India [11, 12, 32]. Natural death of some of the potential edible bamboo species due to flowering is also serious threat in the region. Mass flowering is expected in *M. baccifera* by 2005–2007 [40]. Bamboo species have also been found to be the best for restoration and short rotation forestry. Owing to fast growing nature of bamboo species, they constitute complete colony within 4–5 years of plantation with production of young shoots after 3 year of plantation [41]. Moreover, there is no systematic documentation of edible bamboo and their utilization pattern in NEH region. Hence, planning priorities should be fixed for mass multiplication and production of edible bamboo species for domestic consumption of economically poor tribal communities of the region.

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