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Nutritional and functional profile of traditional fermented bamboo shoot based products from Arunachal Pradesh and Manipur states of India

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Abstract

Fermented bamboo shoot (FBS) is intricately associated with human diet. Traditionally prepared FBS products like *hirring*, *soibum*, *soidon*, *hecche*, *ekung* and *eup* collected from Arunachal Pradesh and Manipur states were analyzed for nutritional and functional composition. All products were acidic with high crude fibre content (3.79-20.84%) and very low fat content (2.19-3.64%). The protein content was significantly high (19.53-27.55%), carbohydrates, moisture and ash content (%) was found to be in the range of 7.27-25.88, 31.05-52.58 and 6.22-14.36, respectively. Phenolics, flavonoids and tannin varied between 718.03 and 920.1.01, 308.72-568.54 and 20.093-33.602 µg/g, respectively. All products exhibited significant radical scavenging activity and α-glucosidase inhibitory activity; IC_{50}values found to be in the range of 23.70-31.16 ppm. Volatile organic compounds (VOCs) and vitamins (B_9, B_{12} and vitamin C) were also detected. Cyanogen glycosides content was within the limit (<10 ppm). This study provides potential evidence for FBS products as health enhancing foods due to its rich nutritional and functional properties.

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Introduction

North East India (NEI) comprises eight states with different ethnic groups of diverse population. Fermented bamboo shoot (FBS) based products are consumed by native people of Arunachal Pradesh (geographically situated near to eastern Himalaya) and Manipur (*Purvanchal* Himalayan region), as a routine traditional diet in NEI from time immemorial (Choudhury *et al*., 2012). Bamboo belongs to the *Poaceae* family and is widely distributed in wild and in mountains from temperature zone of Japan to tropical zone of India (Singh *et al.*, 2011a). Size and weight of fresh bamboo shoot depends upon climate, pH and nutrition of soil, rainfall, drainage condition and harvesting period of bamboo shoot (Singh *et al*., 2011b). Bamboo shoot products are consumed in various forms including boiled, fermented, roasted and canned (Chongtham *et al.*, 2011).

Bamboo shoot is rich in both amino acids and antioxidants and tastes fresh, crisp with aromatic quality and are delicious with all essential nutritive components. Therefore, it is usually called as "the top grade vegetable" (Zhang *et al*., 2008). The edible portion of bamboo shoot consists of meristematic cell tissue with regions of rapid cell division and differentiation, which is enveloped in protective, non-edible leaf sheaths (Kleinhenz *et al*., 2000). In Manipur, bamboo shoot is consumed fresh or after fermentation, locally called *Soibum*. *Soidon,* fermented apical meristems of succulent bamboo shoots, is also popular. *Eup*, *hirring*, *hecche* and *ekung* are the other indigenous FBS based products popular in Arunachal Pradesh with their precise types of fermentation practice. These products combine with ingredients like ginger, garlic, red chilli, onion and different spices for making various side dishes (Fu *et al.*, 2002). Bamboo shoot fermentation is carried out in traditionally designed bamboo chamber with batch fermentation. *Mesu* and *ekung* are rich sources of protein and carbohydrate. Hence, these are popular in NE India (Tamang and Tamang, 2009). Many essential microelements like cobalt, copper, cadmium, lead, manganese, nickel, selenium, iron, and zinc have been found in different bamboo species (Nirmala *et al*., 2007). The feasibility of integrating raw/processed bamboo shoot in the modern diet and lifestyle for enhancing food-nutritional security is also explored (Satya *et al*., 2010, 2012). FBS is used for its antioxidant, anti-free radical, anti-aging and

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anticancer activity in several regions. Recently, the nutritional quality of bamboo shoots was reviewed (Nirmala *et al.*, 2011). Supplementation of FBS during the preparation of nuggets enhanced the physico-chemical, microbiological and keeping quality of the nuggets (Das *et al*., 2013).

Although bamboo shoot based products are popular and existed from several centuries, there are no systematic studies on its quality and nutritional profile. Hence, the present work, which is the first detailed report, was planned with an aim to determine the nutritional and functional qualities of different bamboo shoot based products available in the market.

Material and Methods

Chemicals and reagents

Folin-Ciocalteu (FC) reagent, 1,1 diphenyl-2 picryl hydrazyl (DPPH), gallic acid, p-nitrophenyl α-D-glucopyranoside and α-glucosidase enzyme, water soluble vitamins i.e., ascorbic acid (vit-C), folic acid (vit-B_9), cyanocobalamin (vit-B_{12}), methanol (HPLC grade) and trifluoroacetic acid (TFA) of protein chemistry grade (>99.5%) were purchased from Sigma-Aldrich (Sigma Chemical Co., USA). All the other chemicals employed were of standard analytical grade.

Sample collection and storage conditions

FBS products prepared using different bamboo species were collected from different parts of Arunachal Pradesh and Manipur. Samples were placed in LDPE (low density polyethylene) bags and stored at -20°C until analysis.

Preparation of methanolic extracts

The FBS samples were cut into small pieces and weighed. Methanol extract of these samples was prepared according to the protocol of Eun and Deok (2010) and stored at 4ºC in airtight bottles for further analysis.

Proximate analysis

Proximate analysis of FBS products was determined by relevant standard procedures (Ranganna, 1977). Nitrogen content was determined by micro-kjeldahal and percentage of nitrogen was converted to crude protein by multiplying by 6.25. Total carbohydrate content was determined by phenol-sulfuric acid method (Dubois *et al*., 1956).

Polyphenol estimation

The total phenolic content (TPC) in FBS products was determined by Folin-Ciocalteau's (FC) method (Policegoudra *et al.*, 2007) using a standard curve of gallic acid. Total flavonoid content (TFC) was measured using colorimetric assay (Kim *et al*., 2002) and expressed as milligrams per serving of epicatechin equivalents (ECE). The total tannin content (TTC) was estimated by FC method according to Tamilselvi *et al*. (2012) using a standard plot of tannic acid.

Anti-oxidant activity assay

The hydrogen atom or electron donation abilities of some pure compounds were measured by the bleaching of a purple-coloured methanol solution of 1,1-diphenyl-2-picryl-hydrazyl (DPPH). The free radical scavenging activity of FBS products was measured by DPPH activity as reported earlier (Lin et al., 2012). The % capability to scavenge the DPPH radical was calculated using the following equation: $\{1- OD_{sample} – OD_{blank}/OD_{control}\}^*100$

Hydrogen peroxide scavenging activity of the methanolic extract was estimated by replacement titration method by Kumar *et al.* (2011). The percentage of scavenging hydrogen peroxide was calculated as: H_2O_2 scavenged (%) = $[(A_{con} – A_{test})/A_{cont}]^*100$

where, A_{cont} was volume of sodium thiosulfate used to titrate the control sample in the presence of hydrogen peroxide (without extract), A_{test} was the volume of sodium thiosulfate solution used in the presence of extract.

α-glucosidase inhibitory activity

The inhibitory activity of α-glucosidase in FBS products was determined using the method of Anam *et al.* (2009) and the activity was calculated using the following formula: $[C-S]/C^*$ 100%. Where, C is absorbance of positive control and S is absorbance of sample after reduced by absorbance of negative control of sample. The IC_{50} value was defined as the concentration of α-glucosidase inhibitor that inhibited 50% of α-glucosidase activity.

Multi-elemental determination of metals

Elemental analysis of FBS products was done for Mg, K, Cu, Na, Mn, Zn and Fe standard using atomic absorption spectrometer (AAS) (Shimdazu AA-6701F) by the method reported earlier (Meret and Henki, 1971). The FBS samples were dried in an oven at 60-80ºC till constant weight. Sample as well as standards preparation was done as per SOPs. Appropriate dilutions of sample as well as standards were made.

Quantification of vitamins

HPLC chromatographic method was used

for the quantification of vitamins present in FBS products. Samples were processed using the method reported earlier (Thomas *et al.*, 2008). Vitamins were separated on a reversed-phase chromatographic MetaGuard column C18-A (5 µm, 250 mm × 2.1 mm) using combined isocratic and linear gradient elution with a mobile phase consisting of 0.01% aqueous trifluoroacetic acid (pH 2.9, solvent A) and 100% methanol (solvent B). All chromatographic conditions followed were as indicated by Giorgi *et al*. (2012). Identification of resolved peaks in HPLC (Shimadzu, Japan) was done by comparing their spectra with those derived from standard solutions.

Volatile organic compound analysis

GC-MS analysis was carried out using a Perkin Elmer turbo mass instrument with the conditions indicated earlier by Takahashi *et al.* (2010). The samples were analysed on fused-sillica capillary column HP-5MS (polydimethylsiloxane, 30 mX 0.25 mm i.d., film thickness 0.25 mm) and DB-WAX (15 m X 0.25 mm i.d., film thickness 0.25 mm). The retention time and spectra of particular compounds were confirmed by comparing mass spectral data published by the National Institute of Standards and Technology (NIST98) library.

Cyanogenic glycosides detection assay

The detection of toxic cyanogenic glycosides in FBS products was done by picrate-impregnated paper method (Harborne, 1972). Small pieces of samples were placed, individually, in test tubes with 1.5 ml of distilled water, and 6 drops of chloroform were added and crushed the material with a glass rod. The tubes were stoppard with a cork containing a strip of picrate-impregnated paper hanging down from the stopper, and incubated at 37° C for 2 h. Change of colour from yellow to brown-red, indicated the release of HCN by the plant. If there was no release of HCN within 2 h, the tube was left there and re-examined after 24 and 48 h. Quantification of cyanogen was done by spectrophotometric method (Bradbury *et al.*, 1999). The absorbance was measured at 510 nm and total cyanogen content was calculated as per the equation, Total cyanogen content (ppm) = (396*absorbance*100)/z, where, z is the weight of sample.

Statistical analysis

The experimental results are expressed as mean ± standard deviation (SD) of triplicate measurements and the results were processed using Microsoft Excel and Origin 2011.

Results and Discussion

Proximate composition

All the FBS samples were tested for the carbohydrate, protein, fat, ash and moisture contents and the results are presented in Table 1. The pH, nature and colour of samples were also checked. The FBS products were found to be a good source of proteins (19.53-27.55%) and carbohydrates (7.76-25.88%). *Eup* and *soidon* had half of the carbohydrate content of other FBS products tested. Among the products analyzed, hirring had highest amount of carbohydrate and which may be due to fermentation process carried out by LAB. Since LAB utilizes carbohydrates as a main source of energy for metabolism. The variation may be due to difference in lactic flora or varietal difference of bamboo as well as storage period of the products. Presence of 27.8% of protein (on dry basis) in fresh bamboo shoots was reported earlier (Muchtadi and Adawiyah, 1996).

Table 1. Proximate analysis of fermented bamboo shoot products of North East India

Product	Carbohydrate	Protein	Fibre	Fat	Ash	Moisture	pH	Nature	Colour
Eup	9.50±0.1	19.53±0.52	6.69±0.16	2.24±0.22	14.36±0.25	31.05±0.24	3.9	Dried	Dark brown
Soibum	14.63±0.23	23.61±0.37	5.92±0.16	2.58±0.14	6.55±0.49	38.25±0.22	4.3	Thick sticky	Cream
Hecche	18.66±0.17	27.55±0.16	20.84±0.14	3.35±0.40	6.22±0.10	44.62±0.47	4.2	non sticky	Whitish
Hirring	25.88±0.12	25.57±0.20	19.71±0.40	2.14±1.72	12.93±0.12	32.98±0.18	4.3	Sticky dried	Dark brown
Soidon	10.25±0.06	20.65±0.21	4.38±0.19	3.65±0.11	10.99±0.21	50.79±0.28	5.3	Sticky	Blackish
Ekung	17.34±0.19	24.62±0.10	12.75±0.26	2.80±0.14	15.74±0.40	51.65±1.22	4	Sticky	Yellowish

Note: All value, except for pH, expressed in %; dry weight basis *All experiments were replicated three times and results are presented as mean SD

High protein content can act as a source of amino acids for the consumers. Increase in soluble protein content with increase in fermentation period was reported (Satya *et al.*, 2010). FBS was found to be a good source of dietary fiber and product like heccke had 20% dietary fiber content. Our results are in tune with the report of Nirmala *et al*., (2007), that juvenile bamboo shoots had lower fiber content in comparison to matured shoots. Consumption of such fiber rich food can be beneficial substance to decrease serum and hepatic lipids (Park and Jhon, 2009), especially cholesterol.

Composition analysis also suggested that the fat content was less than 4%. However, in matured shoots up to 10% fat content was noticed (Nirmala *et al.*, 2007; Chongtham *et al*., 2011). The main fatty acids present are palmitic, linoleic, and linolenic acids (Kozukue and Kozukue, 1981). Total ash content was found to be high in FBS (6.22-14.36%) in comparison to the raw bamboo shoots (1.11%) (Tamang *et al.*, 2012). However, the moisture content ranged between 31 and 52% when compared with raw bamboo, which was reported to have a moisture content of around 80%. All FBS products were acidic in nature (pH 3.9-5.3), which is due to the fermentation by lactic acid bacteria (LAB).

Polyphenol content

The extraction of polyphenols from fermented food is a crucial step for the phytochemical analysis and evaluation of antioxidant properties. The use of methanol extraction method is preferred, since it offer an advantage of shorter extraction time, higher repeatability and better polyphenols yield. The total phenolic content ranged from 718.03-920.01 g/g GAE/mL of FBS products. High phenolic content was observed in *eup* (920 µg/g), whereas, the lowest phenolic content (718.03 µg/g) was observed in soidon. Phenolic compounds, also, are antioxidants and have been isolated from fruits, vegetables, grains, medicinal plants, nuts, herbs and edible oils (Goli *et al*., 2005; Hayouni *et al.*, 2007). However, it was observed that the total phenol content, flavonoids and tannins were found to be very much higher than the non-polar constituents like steroids (Table 2). TPC, TFC and TTC of methanolic extract were found to be in the range of 729.41-920.00 µg/g, 308.72-568.54 µg/g and 20.093-33.602 µg/g in terms of gallic acid, epicatechin and tannic acid equivalent, respectively. The flavonoids are found to have potential use in the prevention of arteriosclerosis, cancer, diabetes, neurogenerative diseases and arthritis (Noumi *et al*., 2011).

Phenolics also serve in plant defence mechanisms to counteract reactive oxygen species (ROS) in order to survive and prevent molecular damage as well as damage by microorganisms, insects and herbivores (Vaya *et al*., 1997). It has been reported that the correlation between antioxidant capacity of plant materials and their phenolic content is statistically significant (Velioglu *et al*., 1998). Recent studies have shown that phenolic compounds, such as tannins and flavonoids may be linked to the antioxidant activity of many plants.

Table 2. Total phenolic, flavonoid and tannin content of fermented bamboo shoot products of North East India

Product	Concentration (µg/g)		
	TPC	TFC	TTC
Eup	920.00±1.01	568.54±1.04	32.77±0.28
Soibum	854.70±0.60	408.16±0.71	20.09±0.30
Hecche	729.41±1.70	400.51±0.46	26.80±0.38
Hirring	781.37±1.80	308.72±0.27	21.74±0.43
Soidon	718.03±1.80	342.43±1.02	30.81±0.48
Ekung	777.0.5±1.50	346.25±1.27	33.60±0.41

Note: *All experiments were replicated three times and results are presented as mean SD

Antioxidant property of FBS products

DPPH has been used extensively as a free radical to evaluate reducing substances and it is a suitable reagent for investigating free radical scavenging activity. The methanolic extracts of FBS samples exhibited significant radical scavenging activity ranging between 70.84 and 95.37%. *Soibum* showed strongest radical activity of more than 90% and *Soidon* showed the lowest activity of 70.84% (Figure 1).

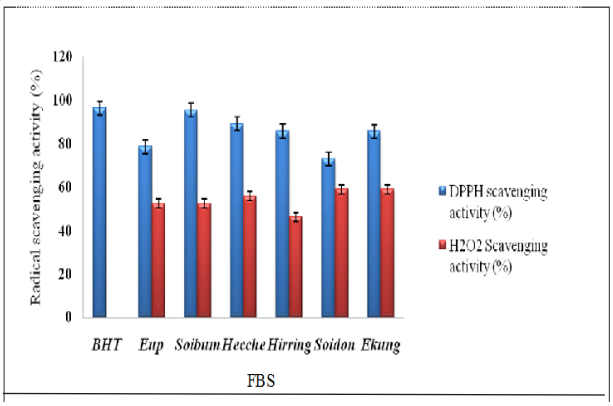

Figure 1. DPPH and H_2O_2 radical scavenging activity of different fermented bamboo shoot Products

Differences were observed in the radical scavenging activity among different bamboo

shoot products and products of the same species obtained from different places. Diverse fermentation processes of FBS and their method of preparation could contribute for the higher antioxidant activity. For eg. *Soidon* fermentation takes 3-7 days and it is prepared from bamboo shoot tip under submerged water condition using previous batch sour liquid that is known to enhance the flavour. For soibum, an inner part of bamboo shoot is being sliced into pieces washed and fermented in earthen pot for about 3-12 months. For the preparation of hirring, whole crush shoot is being kept in bamboo basket, sealed and allowed to ferment for 1-3 months. *Eup* and *ekung* products are prepared using chopped bamboo shoots and are pit fermented (1-3 months) and in most of these products, *Lactobacillus plantarum* is a dominant organism (Tamang and Tamang, 2009). In our experiments, antioxidant activity of FBS was compared with the synthetic antioxidant, such as butylated hydroxytoluene (BHT) and found to be up to 90% (Figure 1). High antioxidant activity might be due to fermentation process and also biochemical changes that could promote binding of dietary fibre to polyphenols followed by decomposition into free phenolic compounds (Stewart *et al*., 2000).

Most phenolic compounds viz. ferulic acid, caffeic acid, chlorogenic acid, p-coumaric acid, catechin, syringic acid and p-hydroxybenzoic acid, which are high in antioxidant capacity, were detected in some bamboo species by HPLC, which was highly correlated with total phenolic content reported before (Singh *et al.*, 2011a). Superoxide anion is an oxygen centre radical with selective reactivity. This species produced by number of enzyme systems in auto-oxidation reaction. The highest H_2O_2 radical scavenging activity was found to be 46.20 and 58.86% for soidon and ekung, respectively. In the present study, superoxide anion scavenging activity of bamboo shoot extract was relatively low as compared to DPPH scavenging activity. The extraction method of antioxidants also affects the total phenol and flavonoid contents and antioxidant capacities (Waterhouse *et al*., 1996).

Table 3. IC_{50} value of α-glucosidase inhibitory activity of fermented bamboo shoot products of North East India

Sample	IC_{50} in ppm
Eup	23.70±2.39
Hecche	27.65±0.26
Ekung	30.95±0.41
Soibum	31.16±0.42
Soidon	29.78±0.45
Hirring	29.84±0.32
(standard) *Polygonum hyrcanicum*	15.30 ±0.15

*All experiments were replicated three times and results are presented as mean SD

α-glucosidase inhibitory activity of FBS products

The α-glucosidase produced in small intestine and is responsible for the catalytic cleavage of a glycosidic bond of carbohydrates (Kimura *et al*., 2004). If an inhibitor acts on this enzyme, it delays the intestinal absorption of glucose into the blood and thus plays a role in diabetics. This prevention will decrease the sugar level in blood. Hence, all the FBS

Table 4. Trace metals in fermented bamboo shoot products of North East India

Sample	Metal concentration in mg/g						
	Fe	Zn	Na	K	Mg	Cu	Mn
Eup	0.90±1.10	3.12±0.10	3.43±0.02	13.31±0.10	2.88±0.04	0.38±0.50	1.19±0.20
Soibum	0.01±0.01	0.25±0.01	1.75±0.08	13.45±0.01	2.53±0.01	0.14±0.10	0.39±0.40
Hecche	0.55±0.01	0.63±0.08	4.83±0.02	13.36±0.40	3.58±0.01	0.09±0.02	0.48±0.01
Hirring	2.45±0.10	0.77±0.10	5.66±0.09	14.57±0.30	3.46±0.10	0.17±0.02	0.34±0.02
Soidon	0.68±0.02	0.49±0.01	2.65±0.02	14.35±0.02	3.14±0.10	0.066±0.05	0.15±0.04
Ekung	0.76±0.03	0.39±0.01	2.18±0.02	12.72±0.10	2.85±0.01	0.11±0.10	0.19±0.01

Note: *All experiments were replicated three times and results are presented as mean SD

products were assayed for α-glucosidase inhibitory activity and it was expressed as IC_{50} value. Eup had lowest IC_{50} inhibitory value (23.70 ppm) and in other products it was in the range of 27.5-31.16 ppm (Table 3). Very low IC_{50} value of 15.30 ppm in the methanolic extract of *Polygonum hyrcanicum* was reported (Moradi-Afrapoli *et al*., 2012). So far, no reports are available on testing of NEI fermented products (vegetables, soybean and fish products) for α-glucosidase inhibitory activity. In this perspective, identifying this α-glucosidase inhibitory activity for the first time in traditional fermented food source (FBS products) might be interesting. This activity is useful in preventing or mitigating cellular damages related to diabetes, thus FBS products can play a greater role in controlling diabetes.

Elements in FBS products

AAS analysis of the FBS products revealed the presence of many elements in these products (Table 4). Potassium, magnesium and sodium were found to be higher in all FBS products. Potassium is involved in electrical and cellular body functions. Its content in FBS ranged from 12.72-14.57 mg/g, which is enough to provide a fifth of daily potassium requirements, and it is 3-8 times higher than sodium content, which is a good indication that the FBS can be safely recommended for people with high blood pressure, as it can lower the blood pressure. *Hirring* was found to contain significant iron content (2.45 mg/g) as compared to other FBS products as well raw bamboo leaf (Owokotomo and Owoeye, 2011). Considerable amount of zinc, copper and manganese were also present in all the FBS products. Based on the results it can be concluded that all FBS products contain significant amount of minerals, which can be beneficial to consumers, thus indicating its importance in our diet.

Vitamins in FBS products

The identification of vitamins and purity were investigated by comparing UV spectra of each individual vitamin as well as its retention time. The isocratic mobile phase used for the vitamins resulted in high detection limits and good resolution within a minimum analysis time of 37 min. The most abundant vitamins in all FBS products were found to be ascorbic acid, cyanocobalamin and folic acid (Table 5). Ascorbic acid content was found to be highest in *hirring* and *soidon* with 4.73 and 3.20 mg/g, respectively, whereas, folic acid content was almost similar and maximum in *soibum* and *soidon,* both having around 3 to 3.5 mg/g. The ascorbic acid content in soibum was found to be 0.23 mg/ml

Table 5. Vitamin concentrations in the fermented bamboo shoot products of North East India

Product	Vitamin content (mg/g)		
	Ascorbic acid (Vit C)	Folic Acid (Vit B_9)	Cyanocobalamin (Vit B_{12})
Eup	0.174	0.1681	0.067
Soibum	0.225	3.2489	0.310
Hecche	0.067	0.1794	0.756
Hirring	4.730	1.0420	0.257
Soidon	3.197	3.2247	0.288
Ekung	1.064	0.5657	0.145

which was in accordance with the earlier report by Singh *et al.* (2011b). Cyanocobalamin was found to be in small quantity (0.07-0.76 mg/g) in all FBS products. Vitamin content in bamboo shoot is less when compared to that of the FBS products, which is due to the production of vitamins by LAB during fermentation (Ysheng *et al*., 2010). Folate production by LAB such as *Lactococcus lactis*, *Str. thermophilus*, *Leuconostoc* spp. in combination with other microbes is reported (Sybesma *et al*., 2003; Leblanc *et al*., 2007). Folate is known to play a significant role in reducing the risk of neural-tube defect in newborns and certain types of cancers (Wald, 1991; Ames, 1999).

Volatile organic compounds in FBS products

The amount of volatile compounds formed during the fermentation depends mainly on the strains, fermentation conditions and types of bamboo species. All FBS products were found to have more than 55 volatile compounds (Table 6). On extraction, volatile oil was obtained which was yellowish in colour with pleasant odour. A variety of alkanes, alkenes, aldehydes, esters and phenolic aromatic compounds were identified in the FBS samples by comparison of retention times of VOCs given in the literature (Takahasi *et al*., 2010). The distribution of compounds observed in bamboo FBS were esters 40%, alcohols 25%, aldehydes 18% and ketones 6%.

Six most important VOCs were p-cresol, 2-methyl naphthalene, 2-heptanol, acetic acid, linalool and phenyl acetaldehyde. These VOCs are responsible for giving a characteristic odour, taste and texture to these foods. Ester compounds, which have significant effect on the organoleptic characteristics of FBS products, may contribute for providing a pleasant fruity fragrance to food. Aromatic compounds like benzyl alcohol and methyl naphthalene are responsible for giving metallic and fatty flavour,

Table 6. Volatile organic compounds in fermented bamboo shoot products of North East India

Compound	Aroma descriptor	Retention time
Octanal	NK	35.22
Hexanal	Green	15.26
2-nonanone	NK	31.28
1-Hepatadecene	NK	9.15
Octadecane	Musty	36.92
Petacosane	NK	59.45
Tetradecane	NK	25.66
cyclohexadecane	NK	4.39
9-Eicosene	Pugent	31.05
11-BromouNKecanoic acid	leafy	30.24
Eicosane, 7- hexy,-	NK	40.14
Otanol	Mushroom like	45.12
Tetracontane	NK	45.26
Tetracontane,11Decyl	NK	59.39
Hexacosane	NK	52.09
1- iododec-1-ene	Puffy	50.48
Hexacosane-2 methyl	NK	45.26
Ocatadecane 2- methyl,5 - ethyl	NK	58.15
Tetratriconate, 17- Hexadecyl	NK	48.60
1-2- benzenedicarboxylic acid	NK	25.44
Diisoocytyl ester	oil	22.16
Acetic acid	Vinegar	9.65
Nonanoic acid	Waxy	52.57
Phthalic acid, allyl ethyl ester	Acrid	37.56
Decanoic acid	Rancid, fatty	52.36
9,12- octadecanoic acid (Z,Z)	NK	44.35
Carboxylic acid, butyl phenyl ester	Fatty	56.90
Carbonic acid,butylphenyl ester	NK	10.75
Octanic acid	Woody	15.98
Tetradecanoic acid	Fried potato	18.20
Tridecanoic acid	NK	35.77
Carboxylic acid, butyl phenyl ester	Fatty	56.90
Carbonic acid,butylphenyl ester	NK	10.75
Octanic acid	Woody	15.98
Tetradecanoic acid	Fried potato	18.20
Tridecanoic acid	NK	35.77
12- bromodeacnoic acid	NK	35.48
Tricosanoic acid	NK	45.08
Benzenedicarboxy acid, decyl hexyl ester	NK	46.59
Linoleic acid	NK	49.54
Octadecanoic acid, methyl ester	NK	51.48
Heptadecanoic aid	NK	22.08
Tridecanoic acid, ethyl ester	NK	45.26
Propanediyl ester	Oily	40.56
Penol,2- methyl	Metallic	14.19
Benzyl alcohol	Alcohol	14.21
2.6-dimethyl cyclohexane	NK	42.54
p-cresol	barn-like/medicine	25.8
Naphthalene	NK	58.6
Lonalool	Floral	19.38
2-methyl naphthalene	Fatty, waxy	37.56
Indole	Mohtball-like	45.25
Benzaldehyde	Floral	35.98
Phenol	NK	10.75
2(3H) furanone, dihydro-5-pentyl	NK	23.09
Naphthalene, 1,2,3,4- tetrahydro-6,7-Dimethyl	NK	34.84
Coumarin, 5,7,8 - Trimethyl	NK	35.23
Di-N- Octyl phthalate	NK	40.21
1- Hexyl- 2- Nitrocyclohexane	NK	15.65

NK* – not known

respectively. These compounds have important role like phytoalexin, auxin and antioxidant. Among these compounds some can inhibit bacterial growth by altering the cell permeability (Brehm and Johnson, 2003).

Cyanogenic glycosides in FBS products

The cyanogenic glycosides are amino acid-derived plant constituents which are chemically called as glycosides of α-hydroxynitriles. Cyanogenic glycosides usually correspond to hydrolytic enzyme (β-glycosidase), which are brought together when the cell structure of the plant is disrupted by a predator, with subsequent breakdown to sugar and a cyanohydrin that rapidly decomposes to HCN and an aldehyde or a ketone (Moller and Seigler, 1999). As per standards (Anon, 2004; WHO, 1993) bamboo shoot based foods are considered as safe for consumption only when the cyanogenic glycosides content is less than 10 ppm. Hence, all FBS products were analysed for its cyanogenic glycosides content. Change in colour was not observed in picrate paper test up to 24 h. However, appearance of reddish brown colour after 24 h of reaction was observed and it was considerably higher for Hecche. Other FBS, such as *hirring*, *eup*, *soibum* and *soidon* have shown very low concentrations of cyanogenic glycosides (1.4454, 1.3266, 0.9504 and 0.7722 ppm, respectively) and therefore, can be considered safe for consumption.

Conclusions

This study presents the characteristic features of FBS based products of North East India, which are an imperative broad source of food from the plant origin having great potential with distinct nutritional profile. These are very good reservoirs of carbohydrates, protein, fibres, folic acid, vitamin C, fibre and low fat content. Along with a variety of important elements like potassium, sodium, zinc, magnesium, copper, manganese and ferrous etc., they play crucial and defined role in metabolism of human body. Significant antioxidant and α-glucosidase inhibitory activities, besides permissible level of cyanogenic glycosides make it healthy and safe for human consumption. Hence, these products can be used to address malnutrition in the developing countries. Present study indicates that these products show a potential for being used for health-promotion and for therapeutic benefits. Studies are underway to examine the functionalities of these products in *in vivo* system. In addition, future work is undertaken on the standardization of fermentation process for obtaining uniform and more nutritive products

through defined starter cultures.

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References

Ames, B.N. 1999. Micronutrient deficiencies cause DNA damage and cancer. Food Science and Agricultural Chemistry 1: 1-15.

Anam, K.R.M. and Widharna, K.D. 2009. α-glucosidase inhibitory activity of *Terminalia* species. International Journal of Pharmacology 17: 277-280.

Anonnymous. 2004. Cyanogenic glycosides in cassava and bamboo shoots: A human health risk assessment. Technical report no. 28. Food Standards Australia New Zealand, Australia.

Bradbury, M.G., Egan, S.V. and Bradbury, J.H. 1999. Picrate paper kits for determination of total cyanogens in cassava roots and all forms of cyanogens in cassava products. Journal of Science Food and Agriculture 79: 593-601.

Brehm, S.B.F. and Johnson, E.A. 2003. Sensitization of *Staphylococcus aureus* and *Escherichia coli* to antibiotics by sesquitepenoids nerolidol, farnesol, bisabolol and pritone. Antimicrobial Agents and Chemotherapy 47: 3357-3360.

Chongtham, N., Singh, M.B. and Haorongbam, S. 2011. Nutritional properties of bamboo shoots: potential and prospects for utilization as a health food. Comprehensive Reviews in Food Science and Food Safety 16: 12-18.

Choudhury, D.B., Sahu, J.K. and Sharma, G.D. 2012. Bamboo shoot: Microbiology, biochemistry and technology of fermentation- a Review. Indian Journal of Traditional
Knowledge 11: 242-249.

Das A., Nath, D.R., Kumari, S. and Rupu Saha R. 2013. Effect of fermented bamboo shoot on the quality and shelf life of nuggets prepared from desi spent hen. Veternary World 6: 419-423.

Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Smith. F. 1956. Colorimetric method for the determination of sugars and related substances. Analytical Chemistry 28: 350-356.

Eun, P.K. and Deok, Y.J. 2010. The antioxidant, angiotensin converting enzyme inhibition activity and phenolic compounds of bamboo shoot extracts. LWT–Food Science and Technology 43: 655-659.

Fu S.G., Yoon, Y. and Bazemore, R. 2002. Aroma-active components in fermented bamboo shoots. Journal of Agriculture and Food Chemistry 50: 549-554.

Goli, A.H., Barzegar, M. and Sahari, M.A. 2005. Antioxidant activity and total phenolic compounds of pistachio *(Pistachia vera)* hull extracts. Journal of Food Chemistry, 92: 521-525.

Harborne J.B. 1972. Cyanogenic glycosides and their function. Phytochemical Ecology London: Academic Press, 104-123.

Hayouni, E.A., Abedrabba, M., Bouix, M. and Hamdi, M. 2007. The effects of solvents and extraction method on the phenolic contents and biological activities *in vitro* of Tunisian *Quercus coccifera* L. and *Juniperus phoenicea* L. fruit extracts. Journal of Food Chemistry 105: 1126-1134.

Kim, D.O., Lee, K.W., Lee, H.J. and Lee, C. Y. 2002. Vitamnin C quivalent antioxidant capacity (VCEAC) of phenolic phytochemicals. Journal of Agricultural and Food Chemistry 50: 3713-3717.

Kimura, A. Lee, J.H., Lee, I.S., Lee, H.S., Park, K.H., Chiba, S. and Kim. D. 2004. Two potent competitive inhibitors discriminating alpha-glucosidase family I from family II. Carbohydrate Research 339: 1035-1040.

Kleinhenz, V., Gosbee M., Elsmore, S., Lyall T.W., Blackburn, K., Harrower, K. and Midmore, D.J. 2000. Storage methods for extending shelf life of fresh, edible bamboo shoot [*Bambusa oldhamii (*Munro)]. Journal of Postharvest Biology and Technology 19: 253-264.

Kozukue, E. and Kozukue, N. 1981. Lipid content and fatty acid composition in bamboo shoots. Journal of Food Science 46: 751-755.

Kumar, H., Goswami, M., Yadav, S. and Rao, C.H. 2011. Evaluation of *in-vitro* antioxidant activity in *Ficus religiosa* (L.) leaves. International Journal of Research in Pharmacy and Science 1: 102-110.

LeBlanc, J.G., de Giori, G.S., Smid, E.J., Hugenholtz, J. and Sesma, F. 2007. Folate production by lactic acid bacteria and other food-grade microorganisms. Current Research and Educational Topics and Trends in Applied Microbiology. Pp- 329-339.

Lin, S., Yang, B., Chen, F., Jiang, G., Li, Q., Duan, X. and Jiang, A. 2012. Enhanced DPPH radical scavenging activity and DNA protection effect of litchi pericarp extract by *Aspergillus awamori* bioconversion. Chemistry Central Journal 6: 108-115.

Giorgi, M.G., Howland, K., Martin, C. and Bonner, A.B. 2012. A Novel HPLC method for the concurrent analysis and quantitation of seven water-soluble vitamins in biological fluids (plasma and urine): a validation study and application. The Scientific World Journal Volume 2012 Article ID 359721, *http://dx.doi.org/*10.1100/2012/359721

Meret, S. and Henkin, R.I.1971. Simultaneous direct estimation by atomic absorption spectrophotometry of copper and zinc in serum, urine, and cerebrospinal fluid. Journal of Clinical Chemistry 17: 369-373.

Moller, B.L. and Seigler, D.S. 1999. Biosynthesis of cyanogenic glycosides, cyanolipids and related compounds. In: Singh, B. Plant Amino Acids: Biochemistry and Biotechnology. Pp. 563-609. New York: Marcel Dekker Inc.

Moradi-Afrapoli, F., Asghari, B., Saeidnia, S., Ajani, Y.,

Mirjani, M., Malmir, M., Bazaz, R.D., Hadjiakhoondi, A., Salehi, P., Hamburger M. and Yassa N. 2012. *In vitro* α-glucosidase inhibitory activity of phenolic constituents from aerial parts of Polygonum hyrcanicum. DARU Journal of Pharmaceutical Sciences 20: 37-42.

Muchtadi, T.R. and Adawiyah, D.R. 1996. Bamboo shoot drying technology. In: Ganapathy P. M., Janssen, J. A., Sastry, C.B. Engineering and utilization INBAR Technical report No. 8, Proceedings of the 4th international bamboo workshop and congress, Bali, Indonesia, 3: 239-245.

Nirmala, C., Bisht, M.A. and Haorongbam, S. 2011. Nutritional properties of bamboo shoots: Potential and prospects for utilization as a health food. Comprehensive Reviews in Food Science and Food Safety 10: 153-169.

Nirmala, C., David, E. and Sharma, M.L. 2007. Changes in nutrient components during ageing of emerging juvenile bamboo shoots. International Journal of Food Science and Nutrition 58: 612-618.

Noumi, E., Hajlaoui, H., Trabelsi, N., Ksouri, R., Bakhrouf, A. and Snoussi, M. 2011. Antioxidant activities and RP-HPLC identification of polyphenols in the acetone extract of *Salvadora persica*, African Journal of Pharmacy and Pharmacology 5: 966-971.

Owokotomo, I.A. and Owoeye, G. 2011. Proximate analysis and antimicrobial activities of *Bambusa vulgaris* L. leaves' beverage. African Journal of Agricultural Research 6: 5030-5032.

Park, E.J. and Jhon, D.Y. 2009. Effects of bamboo shoot consumption on lipid profiles and bowel function in healthy young women. Journal of Nutrition 25: 723-728.

Policegoudra, R.S., Abiraj, K., Gowda D.C. and Aradhya, S.M. 2007. Isolation and characterization of antioxidant and antibacterial compound from mango ginger (*Curcuma amada* Roxb.) rhizome. Journal of Chromatography B Analytical Technologies in Biomedical and Life Sciences 852: 40-48.

Ranganna, S. 1977. Handbook of analysis and Quality Control for Fruit and vegetable products. pp7-88. New Delhi: Tata McGraw-Hill Publishing Company Ltd.

Satya, S., Bal, L.M., Singhal. P. and Naik, S.N. 2010. Bamboo shoot processing: food quality and safety aspects (a review). Trends in Food Science and Technology 12: 14-19.

Satya, S., Singhal, P., Bal, L.M. and Sudhakar, P. 2012. Bamboo shoot: a potential source of food security. Mediterranean Journal of Nutrition and Metabolics 5: 1-10.

Singh, S.A., Singh, H.D., Nongmaithem, R., Bora, T.C. and Singh, R. 2011a. Comparative study of chemical properties of Soibum- A traditional fermented bamboo shoot product and its biological investigation. International Journal of Biosciences, Biochemistry and Bioinformatics 1: 114-118.

Singh, H.D., Singh, S.A., Singh, N.R. and Singh, R. 2011b. Biochemical composition of Soibum-A fermented bamboo shoot and its dynamics during fermentation in real time model. In proceedings of 9th International Conference on Food Engineering and Biotechnology, Bangkok, Thailand 9: 11-18.

Stewart, A.J., Bozonnet, S., Mullen, W., Jenkins, G.I., Lean, M.E.J. and Crozier, A. 2000. Occurrence of flavonols in tomatoes and tomato-based products. Journal of Agriculture and Food Chemistry 4: 2663-2669.

Sybesma, W., Starrenburg, M., Tijsseling, L., Hoefnagel, M.H.N. and Jeroen Hugenholtz, J. 2003. Effects of cultivation conditions on folate production by lactic acid bacteria. Applied and Environmental Microbiology 69: 4542-4548.

Takahashi, T., Mizuib, K. and Miyazawa, M. 2010. Volatile compounds with characteristic odour in *moso*-bamboo stem (*Phyllostachys pubescens* Mazel ex Houz. De ehaie), Phytochemical Analysis 21: 489-495.

Tamang, J.P., Tamang, N., Thapa, S., Dewan, S., Tamang, B., Yonzan, H., Rai, A.K., Chettri, R., Chakrabart, J. and Niki Kharel N. 2012. Microorganisms and nutritional value of ethnic fermented foods and alcoholic beverages of North East India. Indian Journal of Traditional Knowledge 11: 7-25.

Tamang, B. and Tamang J.P. 2009. Traditional knowledge of biopreservation of perishable
vegetable and bamboo shoots in Northeast India as food resources. Indian Journal of
Traditional Knowledge 8: 89-95.

Tamilselvi, N., Krishnamoorthy, P., Dhamotharan, R., Arumugam, P. and Sagadevan, E. 2012. Analysis of total phenols, total tannins and screening of phytocomponents in *Indigofera aspalathoides* (Shivanar Vembu) Vahl EX DC. Journal of Chemical and Pharmaceutical Research 4: 3259-3262.

Thomas, S., Kumar, R., Sharma, A., Issarani, R. and Nagori, B. P. 2008. Stability-indicating HPLC method for determination of vitamins B_1, B_2, B_3 and B_6 in pharmaceutical liquid dosage form. Indian Journal of Chemical Technology 15: 598-603.

Vaya, J., Belinky, P.A. and Aviram, M. 1997. Antioxidant constituents from Licorice roots: Isolation, structure elucidation and antioxidative capacity toward LDL oxidation free radical. Biology Medical 23: 302-313.

Velioglu, Y.S., Mazza, G., Gao, L. and Oomah, B.D. 1998. Antioxidant activity and total phenolics in selected fruits, vegetables, and grain products. Journal of Agricultural and Food Chemistry 46: 4113-4117.

Wald, N. 1991. Prevention of neural tube defects- Results of the Medical Research Council vitamin study. The Lancet 338: 131-137.

Waterhouse, A.L., Shirley, J.R. and Donovan, J.L. 1996. Antioxidants in chocolate. The Lancet 348: (9030) 834.

World Health Organization 1993. Toxicological evaluation of certain food additives and naturally occurring toxicants. WHO Food Additive Series: 30. World Health Organization, Geneva.

Ysheng, S., Hui-chung, W., Chi-hua, L., Hung-chiehchen and Yanagida, F. 2010. Isolation and characterization of lactic acid bacteria from *jiang-sun* (fermented

bamboo shoot), a traditional fermented food in Taiwan. Journal of Science Food Agriculture 90: 1977-1982.

Zhang, J.F., Zhang, L.L. and Du, L.F. 2008. Analysis and determination of the nutritive composition in the *Phyllostachy spraecox* shoot. Journal of Anhui Agricultural Sciences 36: 841-842.