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ORIGINAL ARTICLE

Precooking processing of bamboo shoots for removal of anti-nutrients

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Abstract Bamboo shoots being low in fat, high in dietary fiber and rich in mineral content, like an ideal vegetable have been used traditionally. Besides nutrients, bamboo shoots also contain lethal concentration of the anti-nutrient (cyanogen) that need to be removed before human consumption. Therefore an attempt has been made to find out the best processing method for confiscation of cyanogens. *B. bambos, B. tulda, D. strictus* and *D.asper* were selected for the study. Fresh and processed bamboo shoots were analyzed for their various nutritional and anti-nutritional contents. Carbohydrate content in fresh shoots of studied species ranged from 2.39%–3.6%, proteins from 1.65%–2.08%, phenols from 0.36%–0.63%, cyanogens from 0.011%–0.018%, minerals did not vary significantly among the species except potassium which ranged from 0.32%–0.52%. The shoots were processed by boiling in water and different concentrations of NaCl (1%, 5% and 10%) for different intervals (10, 15, 20 and 25 min) to achieve maximum removal of cyanogens with minimum loss of nutrients. Boiling shoots in 5% NaCl for 15 min was found to be the best method for *B. bamboos*, 10 min boiling in 1% NaCl for *B. tulda*, 15 min boiling in 1% NaCl for *D. strictus* and 10 min boiling in 5% NaCl for *D. asper*. These processing methods will be very useful in utilization of bamboo shoots as these are very simple and can be used by the local inhabitants and shoot processing industries.

Keywords Bamboo shoots · Nutritional status · Precooking processing

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Introduction

Bamboo is one of the precious and important plant resource. Worldwide there are more than 1,250 species of bamboo which are unevenly distributed in various parts of the humid tropical, sub-tropical and temperate regions of the earth (Scurlock et al. 2000). India is the second richest country in bamboo genetic resources after China, comprising of 136 indigenous and exotic species, under 23 genera, found naturally and/or under cultivation (Tiwari 1992). It plays a significant role in human civilization and is contributing to the subsistence of people living in the tropical and subtropical belts in Asia, Latin America and Africa. Since time immemorial it is being used as fuel, food, for housing and shelter by indigenous communities and its traditional uses differ from region to region.

There are a number of bamboo species available in central India and many of them are used for edible purpose. *Dendrocalamus strictus* and *Bambusa bambos* are the commonly occurring species. The other species are *B. nutans, B. tulda, D. giganteus* and *D. hamiltonii. Dendrocalamus asper* an important edible species of Thailand (Fu et al. 1987) has been introduced in India and cultivated in central India for shoot production. In central India, people harvest bamboo shoots from nearby forests as bamboos are not commercially cultivated for its edible shoot production. However, in some places it is also harvested from cultivated sources (plantations and home gardens). Normally people harvest bamboo shoots for their own consumption but in some areas it is being sold in the market.

A bamboo shoot is young, immature, expanding culm that emerges from nodes of the rhizome of plants. It is harvested in a short time as it appears above the soil surface. During harvest, shoots are cut slightly above the soil surface with a spade. Bamboo shoots have been used as

culinary item and find an important place in the food of the people of South East Asian countries. In India, particularly the people of North East regions have been consuming bamboo shoots (raw or processed) because of its exotic taste, flavour and medicinal value. Fresh bamboo shoots have a crisp and sweet flavour. They are mainly used fresh, dried, shredded, pickled, canned or fermented (Choudhury et al. 2011). However, carbohydrate and protein content were observed to decrease after canning and fermentation (Kumbhare and Bhargava 2007; Nirmala et al. 2008). It is also used as an extender because it takes on the flavor of the ingredients it is cooked with.

Bamboo shoots are low in fat and calories but rich in various nutrients *viz* vitamins, proteins, minerals and edible fiber. These are a good source of potassium (Engineering Resources Group Report 2003) and also contain flavones, total phenols and phenolic acids which possess antioxidant (Rice-Evans et al. 1997; Oboh and Ademosun 2010), anticancer, antibacterial, anti-inflammatory (Galeotti et al. 2008; Mattile and Hellstorm 2007) and antifungal activities. Besides nutrients bamboo shoots contain lethal concentration of anti-nutrient (cyanogen) that needs to be removed before human consumption (EFSA 2004). These cyanogenic glycosides on endogenic hydrolysis yield hydrocyanic acid which is harmful for human consumption (Seigler 1991).

The acute lethal concentration of hydrogen cyanide for human beings is reported to be 0.5–3.5 mg/kg body weight (EFSA 2004). The symptoms of cyanide intoxication from inadequately prepared bamboo shoots include rapid respiration, drop in blood pressure, dizziness, headache, stomach pains, vomiting, convulsions etc. (FSA 2004). By adequate processing cyanogens can be removed or reduced prior to consumption, thus significantly reducing the potential health risk (Ferreira et al. 1995).

Therefore freshly harvested bamboo shoots should be processed before cooking to remove the toxic and bitter components. The processes (peeling, slicing, washing in running water, boiling for hours etc.) adopted by the native populace are based on their traditional knowledge. However, no scientific study has been carried out on this aspect. Keeping above into consideration a study has been carried out to find the impact of various processing methods on the nutritional and anti-nutritional constituents of bamboo shoots.

Materials and methods

Chemicals All chemicals used were of analytical grade. Folin-Ciocalteu reagent, glucose and sodium cyanide were obtained from Fischer Scientific (Qualigens, India). Bovine serum albumin fraction V, L-ascorbic acid, catechol and 2, 6 dichlorophenol-indophenol were obtained from Sisco Research Laboratory Pvt. Ltd., India.

Equipments Systronic UV-Vis spectrophotometer model 118 was used for spectrophotometric analysis of bamboo shoots. R-8C DX laboratory centrifuge (REMI) was used for centrifugation. Digestion of samples for mineral analysis was performed in fume hood (Yorco, York scientific, India).

Plant material source and preparation The species selected for the study were *B. bambos, B. tulda, D. strictus and D. asper*. The newly emerging shoots were collected from the different parts of central India viz. Jabalpur and Balaghat (Madhya Pradesh) and Chandrapur (Maharashtra). After peeling the sheaths, hard nodal portions were removed and only soft inter nodal portions were taken for analysis. The internodal portions were chopped into small pieces and subjected to various treatments.

Methods used The shoots were processed by the following treatments: (a) Boiling in water, (b) boiling in 1% NaCl solution, (c) boiling in 5% NaCl solution and (d) boiling in 10% NaCl solution for different time intervals (10, 15, 20 and 25 min) to achieve proper removal of anti-nutrient. Firstly, the salt solution was allowed to boil and then shoots were added. Bamboo shoot samples were taken out at regular intervals for chemical analysis. Chemical analysis was performed for various nutritional and anti-nutritional contents of the shoots using different established methods. The total carbohydrate content was analyzed spectrophotometrically by Anthrone's method (Hedge and Hofreiter 1962), total proteins by Lowry's method (Lowry et al. 1951), total phenols by using Folin-Ciocalteau method (McDonald et al. 2001), ascorbic acid by titrimetric method (Raghu et al. 2007) and cyanogens were estimated as the hydrocyanic acid equivalents spectrophotometrically (Hogg and Ahlgren 1942).

Mineral estimation Minerals such as sodium, potassium, phosphorus, calcium and magnesium were analyzed by the methods given by Jacobs (1999).

Digestion of the sample 0.5 g of sample was taken in a conical flask to this 5 ml of conc. HNO_3 was added and heated at high temperature until the sample dissolves and acid evaporates then 5 ml of ternary mixture was added (H_2SO_4, $HClO_4$ and HNO_3 in the ratio 1:4:10). The mixture was heated till the digested material becomes clear, cooled, 5 ml HCl was added and the volume was made upto 100 ml with distilled water. This digested extract was used for further analysis.

Estimation of sodium and potassium Sodium and Potassium were read direct in flame-photometer. Standard solutions (10–50 ppm) of sodium and potassium were made for the calibrating the instrument and preparing the standard graph.

Estimation of phosphorus To 5 ml of extract 10 ml of ammonium metavanadate solution was added and volume was made upto 50 ml with distilled water. The solutions were allowed to stand for 10 min and absorbance was measured at 470 nm against blank. The standard curve was prepared by using a range of 0.02 ppm–0.2 ppm of dihydrogen potassium phosphate (KH_2PO_4). The amount of phosphorus in the samples was calculated from the standard curve.

Estimation of calcium 5 ml of extract was taken and 20 ml of distilled water was added followed by ten drops of sodium cynide, ten drops hydroxylamine hydrochloride and one drop of 1% potassium ferricyanide solution (yellow colour develops). To the solution 10% sodium hydroxide was added till yellow colour disappears. A pinch of mureoxide powder (indicator) was added to the resultant solution and titrated with EDTA (0.02 N). The end point is colour change from pink to purple. The amount of EDTA consumed is equivalent to the amount of calcium present in the sample and expressed as g/100 g of sample.

Estimation of magnesium 5 ml of extract was taken and 20 ml of distilled water was added followed by ten drops of sodium cyanide, ten drops hydroxylamine hydrochloride and one drop of potassium ferricyanide (yellow colour develops). Buffer solution ($NH_4Cl + NH_3$) was then added till colour disappears and titrated with EDTA (0.02 N) after adding 2–3 drops of EBT (Erichrome black T) indicator. The end point is colour change from blue to grey. The amount of EDTA consumed is equivalent to the total amount of calcium and magnesium present in the sample and expressed as g/100 g of sample. The amount of magnesium was calculated by substracting the amount of calcium from the total calcium and magnesium content.

Statistical analysis All the samples were analyzed in triplicates. Data are expressed as means ± SD. Data were subjected to statistical analysis using Statistix (PC DOS Version 2.0) and SPSS (Version 14.0) analytical software. One way analysis of variance (ANOVA) was performed. Statistically best treatment was determined using Duncan's multiple range test at significance level of $p<0.05$.

Results and discussion

Table 1 reveals the amount of nutrients and anti-nutrients in the fresh samples of the studied bamboo species. *D. strictus* contains 3.60±0.07 g/100 g of total carbohydrates, 2.08± 0.09 g/100 g of total proteins and 0.63±0.08 g/100 of total phenols while *D. asper*, considered as the edible bamboo all over the world contains 3.36±0.09 g/100 g of total carbohydrates, 1.74±0.1 g/100 g of total proteins and 0.58± 0.07 g/100 g of total phenols. Thus, *D. strictus* (commonly available species of central India) can also be considered as a good edible species as it contains nutrients at par with *D.asper*. *B. bambos* contains 2.39±0.09 g/100 g of total carbohydrates, 1.88±0.08 g/100 g of total proteins and 0.36±0.05 g/100 of total phenols and *B. tulda* contains 2.81±0.07 g/100 g of total carbohydrates, 1.65±0.10 g/100 g of total proteins and 0.39± 0.07 g/100 of total phenols. Bhatt et al. (2005) have also conducted a study on nutritional values of some commercially edible bamboo species of North Eastern Himalayan region of India. They analysed only fresh shoots and our results are comparable with their findings.

Table 2 represents nutritional composition of *B. bambos* shoots after processing. It reveals that the best method for reducing the concentration of cyanogens (0.011±0.003 g/100 g in fresh shoots to 0.002±0 g/ 100 g after treatment) was boiling shoots in 5% NaCl for 15 min along with the retention of 1.94±0.09 g/100 g total carbohydrates, 1.45±0.09 g/100 g total proteins, 0.28±0.07 g/100 g total phenols, 0.08±0 g/100 g calcium, 0.15±0.006 g/100 g magnesium, 0.53±0.006 g/100 g sodium, 0.25±0.006 g/100 g potassium and 0.03±0 g/ 100 g phosphorus.

Table 1 Nutritional composition in fresh samples of bamboo shoots (in g/100 g)

	B. bambos	*B. tulda*	*D. asper*	*D. strictus*
Carbohydrates	2.39±0.09 d	2.81±0.07 c	3.36±0.09 b	3.6±0.07 a
Proteins	1.88±0.08 b	1.65±0.10 c	1.74±0.10 c	2.08±0.09 a
Total phenols	0.36±0.05 d	0.39±0.07 c	0.58±0.07 b	0.63±0.08 a
Cyanogens	0.011±0.003 c	0.016±0.003 b	0.016±0.004 b	0.018±0.003 a
Ascorbic acid	0.004±0 a	0.004±0 a	0.004±0 a	0.004±0 a
Potassium	0.32±0.006 d	0.4±0.012 c	0.52±0.006 a	0.5±0.006 b
Sodium	0.07±0 b	0.07±0.006 b	0.09±0.006 a	0.09±0.006 a
Phosphorus	0.07±0 b	0.07±0.006 b	0.07±0.012 b	0.09±0.006 a
Calcium	0.08±0 b	0.04±0 c	0.16±0.006 a	0.08±0 b
Magnesium	0.17±0.006 a	0.17±0.012 a	0.17±0.012 a	0.17±0.015 a

Data are presented as mean ± SD ($n=3$). Mean values within each row followed by different letters differ significantly at $p<0.05$

Table 2 Nutritional composition in treated samples of *B. bambos* (in g/100 g)

	Treatments	10 min boiling	15 min boiling	20 min boiling	25 min boiling	SE ±
Carbohydrates	Water	2.02±0.08	1.86±0.09	0.98±0.10	0.80±0.08	0.011
	1% NaCl	2.00±0.09	1.58±0.05	1.00±0.08	0.62±0.11	
	5% NaCl	2.14±0.06	1.94±0.09	1.22±0.06	0.74±0.09	
	10% NaCl	1.97±0.10	1.12±0.08	0.94±0.09	0.82±0.09	
Proteins	Water	1.40±0.07	1.12±0.06	0.87±0.07	0.65±0.08	0.021
	1% NaCl	1.53±0.06	1.20±0.09	0.64±0.07	0.58±0.11	
	5% NaCl	1.64±0.07	1.45±0.06	0.91±0.10	0.52±0.11	
	10% NaCl	1.48±0.04	1.15±0.025	0.86±0.09	0.48±0.03	
Cyanogens	Water	0.009±0.001	0.007±0.001	0.004±0	0.000±0	0.0002
	1% NaCl	0.006±0	0.006±0.001	0.003±0	0.001±0	
	5% NaCl	0.005±0	0.002±0	0.002±0	0.001±0	
	10% NaCl	0.007±0.001	0.005±0.001	0.002±0	0.001±0	
Total phenols	Water	0.30±0.11	0.25±0.06	0.18±0.07	0.10±0.05	0.025
	1% NaCl	0.28±0.08	0.22±0.06	0.15±0.07	0.09±0.03	
	5% NaCl	0.34±0.08	0.28±0.07	0.19±0.05	0.11±0.06	
	10% NaCl	0.29±0.04	0.17±0.08	0.11±0.05	0.07±0.03	
Calcium	Water	0.08±0	0.08±0	0.08±0	0.00	0.00
	1% NaCl	0.08±0	0.08±0	0.08±0	0.00	
	5% NaCl	0.08±0	0.08±0	0.00	0.00	
	10% NaCl	0.08±0	0.08±0	0.00	0.00	
Magnesium	Water	0.15±0	0.15±0	0.12±0	0.10±0	0.002
	1% NaCl	0.14±0	0.11±0	0.08±0	0.05±0	
	5% NaCl	0.16±0	0.15±0.006	0.12±0.006	0.11±0	
	10% NaCl	0.13±0.006	0.10±0	0.10±0	0.06±0.006	
Sodium	Water	0.07±0.006	0.07±0.006	0.07±0.006	0.07±0.006	0.0067
	1% NaCl	0.26±0.006	0.25±0.006	0.38±0.02	0.42±0.006	
	5% NaCl	0.45±0.006	0.53±0.006	0.78±0.01	0.63±0.012	
	10% NaCl	0.94±0.006	1.00±0	0.96±0.006	1.15±0.006	
Potassium	Water	0.31±0.006	0.22±0.006	0.18±0.006	0.12±0.015	0.0069
	1% NaCl	0.28±0.006	0.20±0	0.15±0.006	0.09±0.006	
	5% NaCl	0.30±0.015	0.25±0.006	0.19±0.006	0.11±0.006	
	10% NaCl	0.24±0.015	0.18±0.006	0.12±0.006	0.08±0.006	
Phosphorus	Water	0.05±0.006	0.03±0.006	0.02±0	0.02±0	0.01
	1% NaCl	0.03±0	0.02±0	0.02±0	0.01±0	
	5% NaCl	0.04±0	0.03±0	0.01±0	0.01±0	
	10% NaCl	0.01±0	0.01±0	0.01±0	0.01±0	

Data are presented as mean ± SD (n=3)

Table 3 denotes the amount of nutrients and anti-nutrients in treated samples of *B. tulda*. The best method for reducing the concentration of cyanogens (0.016± 0.003 g/100 g in fresh shoots to 0.006±0.001 g/100 g after treatment) was boiling shoots in 1% NaCl for 10 min along with the retention of 2.65±0.07 g/100 g total carbohydrates, 1.59±0.08 g/100 g total proteins, 0.38±0.08 g/100 g total phenols, 0.06±0.01 g/100 g phosphorus, 0.10±0 g/100 g magnesium, 0.44±0 g/100 g sodium, 0.33±0 g/100 g potassium and 0.00 g/100 g calcium.

Table 4 depicts the amount of nutrients and anti-nutrients in the shoots of *D. asper* after treatment. It reveals that the best method for reducing the concentration of cyanogens (0.016±0.004 g/100 g in fresh shoots to 0.002±0 g/100 g after treatment) was boiling shoots in 5% NaCl for 10 min along with the retention of 1.92±0.12 g/100 g total carbohydrates, 0.28±0.03 g/100 g total proteins, 0.07±0.04 g/100 g total phenols, 0.06±0 g/100 g phosphorus, 0.02±0 g/100 g magnesium, 0.78±0 g/100 g sodium, 0.50±0 g/100 g potassium and 0.08±0 g/100 g calcium.

Table 5 shows the amount of nutrients and anti-nutrient in treated samples of *D. strictus*. It shows that the best method for reducing the concentration of cyanogens (0.018± 0.003 g/100 g in fresh shoots to 0.003±0.001 g/100 g after

Table 3 Nutritional composition in treated samples of *B. tulda* (in g/100 g)

	Treatments	10 min boiling	15 min boiling	20 min boiling	25 min boiling	SE ±
Carbohydrates	Water	2.27±0.05	2.19±0.07	2.11±0.04	1.15±0.07	0.014
	1% NaCl	2.65±0.07	2.62±0.09	2.60±0.08	1.96±0.08	
	5% NaCl	1.66±0.08	1.53±0.06	1.36±0.06	0.95±0.07	
	10% NaCl	2.72±0.08	1.92±0.12	1.48±0.05	1.40±0.08	
Proteins	Water	1.63±0.10	1.60±0.06	1.58±0.07	1.52±0.08	0.011
	1% NaCl	1.59±0.08	1.32±0.07	1.07±0.10	1.05±0.10	
	5% NaCl	1.65±0.10	1.54±0.06	1.45±0.06	1.06±0.07	
	10% NaCl	1.66±0.06	1.24±0.04	1.10±0.02	1.00±0.10	
Cyanogens	Water	0.010±0	0.005±0	0.002±0	0.002±0	0.001
	1% NaCl	0.006±0.001	0.005±0	0.005±0.001	0.002±0	
	5% NaCl	0.012±0.001	0.009±0.001	0.004±0	0.001±0	
	10% NaCl	0.010±0.001	0.006±0.001	0.002±0	0.001±0	
Total phenols	Water	0.31±0.07	0.31±0.08	0.30±0.08	0.30±0.06	0.0074
	1% NaCl	0.38±0.08	0.30±0.06	0.22±0.07	0.22±0.01	
	5% NaCl	0.33±0.07	0.28±0.04	0.25±0.06	0.25±0.07	
	10% NaCl	0.35±0.07	0.26±0.05	0.25±0.07	0.24±0.05	
Magnesium	Water	0.12±0	0.12±0.006	0.10±0	0.10±0.006	0.005
	1% NaCl	0.10±0	0.10±0.012	0.07±0	0.07±0.01	
	5% NaCl	0.10±0	0.10±0.012	0.10±0	0.02±0.006	
	10% NaCl	0.12±0	0.12±0.01	0.07±0	0.05±0.006	
Sodium	Water	0.10±0	0.10±0.006	0.10±0	0.11±0.025	0.0075
	1% NaCl	0.44±0	0.44±0.01	0.36±0	0.39±0.015	
	5% NaCl	0.80±0	0.86±0.015	1.00±0	1.02±0.006	
	10% NaCl	1.22±0	1.25±0.006	1.33±0	1.35±0.006	
Potassium	Water	0.30±0	0.28±0.006	0.15±0	0.15±0	0.003
	1% NaCl	0.33±0	0.29±0.006	0.15±0	0.13±0	
	5% NaCl	0.23±0	0.16±0.006	0.13±0	0.13±0	
	10% NaCl	0.17±0	0.14±0.01	0.12±0	0.12±0	
Phosphorus	Water	0.07±0.006	0.07±0.01	0.05±0.006	0.04±0.015	0.0071
	1% NaCl	0.06±0.01	0.04±0.006	0.04±0.006	0.04±0.006	
	5% NaCl	0.06±0.006	0.05±0.006	0.03±0.006	0.03±0.006	
	10% NaCl	0.05±0.006	0.05±0.006	0.05±0.015	0.04±0.012	

Data are presented as mean ± SD (n=3). Calcium is not tabulated as its content decreased to zero on boiling

treatment) was boiling shoots in 1% NaCl for 15 min along with the retention of 1.03±0.11 g/100 g total carbohydrates, 1.29±0.13 g/100 g total proteins, 0.16±0.04 g/100 g total phenols, 0.03±0 g/100 g phosphorus, 0.07±0 g/100 g magnesium, 0.27±0.01 g/100 g sodium, 0.23±0 g/100 g potassium and 0.00 g/100 g calcium.

The influence of each treatment was different on the concentration of nutrients and anti-nutrients. The concentration of each constituent decreases with the increase in boiling time with a significant variation. Judprasong et al. 2006 also reported the significant change in oxalate content of bamboo shoots after cooking. Ascorbic acid being a water soluble vitamin has been washed-out on boiling in all the species and therefore not tabulated. Calcium content also decreased to 0.00 in *B. tulda* and *D. strictus*, however there wasn't any significant change in *B. bambos* and *D. asper*. Vinning (1995) has also reported the removal of hydrocyanic acid on boiling. There is no single specific treatment for all bamboo species which removes cyanogens with minimum loss of nutrients. Thus, the best treatment (for removal of anti-nutrient) would be in which the nutrients are retained in significant amount with maximum reduction of cyanogens. Statistically, different method was found to be best for different species as shown by Duncan's test.

Thus cyanogens in *B. bambos, B. tulda, D. strictus* and *D. asper* were significantly reduced by boiling in 5% NaCl for 15 min, 1% NaCl for 10 min, 1% NaCl for 15 min and 5% NaCl for 10 min respectively. Rana et al. (2010) also reported the reduction in cyanide content in fresh bamboo shoots during NaCl treatment by response surface methodology. Jaiwunglok et al. (2010) reported that high heating

Table 4 Nutritional composition in treated samples of *D. asper* (in g/100 g)

	Treatments	10 min boiling	15 min boiling	20 min boiling	25 min boiling	SE ±
Carbohydrates	Water	3.14±0.14	2.20±0.09	1.27±0.07	0.94±0.10	0.14
	1% NaCl	1.88±0.17	1.45±0.14	1.27±0.08	1.27±0.08	
	5% NaCl	1.92±0.12	1.59±0.09	1.59±0.08	0.98±0.09	
	10% NaCl	2.16±0.09	1.17±0.07	1.31±0.09	0.84±0.09	
Proteins	Water	0.28±0.05	0.20±0.05	0.21±0.06	0.18±0.04	0.014
	1% NaCl	0.24±0.06	0.21±0.05	0.21±0.02	0.18±0.04	
	5% NaCl	0.28±0.03	0.18±0.06	0.26±0.06	0.17±0.06	
	10% NaCl	0.26±0.07	0.28±0.07	0.16±0.05	0.20±0.06	
Cyanogen	Water	0.004±0.001	0.004±0.001	0.002±0	0.001±0	0.0002
	1% NaCl	0.003±0	0.002±0	0.001±0	0.001±0	
	5% NaCl	0.002±0	0.002±0	0.001±0.001	0.001±0	
	10% NaCl	0.003±0.001	0.002±0	0.002±0.001	0.001±0	
Total phenols	Water	0.08±0.04	0.07±0.05	0.07±0.04	0.04±0.03	0.01
	1% NaCl	0.06±0.01	0.06±0.04	0.06±0.01	0.06±0.01	
	5% NaCl	0.07±0.04	0.07±0.04	0.06±0.00	0.05±0.03	
	10% NaCl	0.12±0.06	0.09±0.05	0.07±0.05	0.07±0.05	
Calcium	Water	0.10±0	0.08±0	0.08±0	0.00	0.00
	1% NaCl	0.08±0	0.08±0	0.08±0	0.00	
	5% NaCl	0.08±0	0.08±0	0.00	0.00	
	10% NaCl	0.08±0	0.08±0	0.00	0.00	
Magnesium	Water	0.17±0	0.17±0	0.17±0	0.10±0	0.00
	1% NaCl	0.05±0	0.10±0	0.14±0	0.02±0	
	5% NaCl	0.02±0	0.05±0	0.10±0	0.10±0	
	10% NaCl	0.05±0	0.12±0	0.10±0	0.05±0	
Sodium	Water	0.09±0	0.10±0	0.09±0	0.07±0	0.00
	1% NaCl	0.22±0	0.25±0	0.27±0	0.38±0	
	5% NaCl	0.78±0	0.80±0	0.78±0	0.93±0	
	10% NaCl	1.00±0	0.96±0	0.96±0	1.15±0	
Potassium	Water	0.40±0	0.37±0	0.33±0	0.33±0	0.00
	1% NaCl	0.45±0	0.43±0	0.40±0	0.38±0	
	5% NaCl	0.50±0	0.43±0	0.30±0	0.25±0	
	10% NaCl	0.38±0	0.35±0	0.33±0	0.30±0	
Phosphorus	Water	0.07±0.006	0.07±0.01	0.05±0.006	0.05±0	0.0042
	1% NaCl	0.06±0.006	0.04±0.006	0.04±0.006	0.04±0	
	5% NaCl	0.06±0	0.05±0.006	0.05±0.006	0.05±0.006	
	10% NaCl	0.04±0.006	0.03±0.006	0.02±0	0.02±0	

Data are presented as mean ± SD (n=3)

temperature tend to accelerate the degradation of hydrocyanic acid and only 10 min were required to reduce taxiphyllin content in bamboo shoots to 30% of the initial value. They also reported that sodium chloride affects the decomposition of taxiphyllin as it accelerates the osmosis reaction which facilitated leaching of liberated cyanide from bamboo shoot. However, in *D. giganteus* the optimum conditions that resulted in the reduction of cyanogen were boiling in water for 148–180 min (Ferreira et al. 1995). Tripathi (1998) also reported removal of hydrocyanic acid by steaming bamboo shoots. Bhargava et al. (1996) reported removal of this during cooking shoots by changing water several times or pre-soaking for a longer time by subsequent changing 2% salt solution. Wongsakpairod (2000) reported superheated steam drying under low temperature removes HCN from bamboo shoot as taxiphyllin decomposes at around 116 °C. The effect of salt on cyanide detoxification was also shown in fermented bamboo processing. Our study reveals that the edible portions of bamboo shoots contain an average of 170 mg/kg of cyanogens. However some findings states that the concentration of cyanogens in the immature shoot tip of bamboo ranges from 1,000 mg/kg to 8,000 mg/kg of hydrogen cyanide (WHO report 1993). The variation in cyanogen levels reflects the

Table 5 Nutritional composition in treated samples of *D. strictus* (in g/100 g)

	Treatments	10 min boiling	15 min boiling	20 min boiling	25 min boiling	SE ±
Carbohydrates	Water	0.52±0.05	0.47±0.07	0.45±0.05	0.40±0.08	0.01
	1% NaCl	1.27±0.09	1.03±0.11	0.80±0.06	0.65±0.008	
	5% NaCl	0.75±0.09	0.33±0.07	0.25±0.07	0.20±0.05	
	10% NaCl	1.31±0.11	0.70±0.08	0.59±0.05	0.55±0.06	
Proteins	Water	1.34±0.09	0.96±0.14	0.80±0.14	0.72±0.11	0.038
	1% NaCl	1.52±0.08	1.29±0.13	1.00±0.16	0.68±0.02	
	5% NaCl	1.46±0.07	1.00±0.16	0.70±0.12	0.56±0.14	
	10% NaCl	1.21±0.07	1.00±0.10	0.68±0.09	0.43±0.13	
Cyanogen	Water	0.016±0.001	0.002±0.001	0.000	0.000	0.0002
	1% NaCl	0.008±0.001	0.003±0.001	0.000	0.000	
	5% NaCl	0.005±0	0.003±0.001	0.000	0.000	
	10% NaCl	0.001±0	0.001±0	0.000	0.000	
Total phenols	Water	0.11±0.06	0.09±0.05	0.09±0.05	0.05±0.03	0.013
	1% NaCl	0.20±0.08	0.16±0.04	0.08±0.04	0.06±0.03	
	5% NaCl	0.15±0.07	0.14±0.06	0.09±0.05	0.08±0.02	
	10% NaCl	0.16±0.06	0.16±0.08	0.10±0.05	0.06±0.04	
Magnesium	Water	0.12±0	0.02±0	0.02±0	0.00	0.00
	1% NaCl	0.12±0	0.07±0	0.07±0	0.03±0	
	5% NaCl	0.17±0	0.07±0	0.05±0	0.03±0	
	10% NaCl	0.22±0	0.05±0	0.05±0	0.00	
Sodium	Water	0.09±0.006	0.09±0.006	0.08±0	0.08±0	0.0069
	1% NaCl	0.27±0.006	0.27±0.01	0.27±0.006	0.27±0.01	
	5% NaCl	0.75±0.006	0.67±0.01	0.5±0.006	0.5±0.01	
	10% NaCl	0.98±0.006	1.20±0.006	1.25±0.01	1.42±0.02	
Potassium	Water	0.25±0	0.25±0	0.25±0	0.25±0	0.033
	1% NaCl	0.23±0	0.23±0	0.23±0	0.23±0	
	5% NaCl	0.23±0	0.20±0	0.20±0	0.20±0	
	10% NaCl	0.23±0	0.18±0	0.18±0	0.18±0	
Phosphorus	Water	0.06±0.006	0.04±0.015	0.02±0.006	0.02±0	0.0055
	1% NaCl	0.03±0	0.03±0	0.03±0	0.03±0.006	
	5% NaCl	0.07±0.015	0.01±0	0.01±0	0.01±0	
	10% NaCl	0.01±0	0.01±0	0.01±0	0.01±0	

Data are presented as mean ± SD (n=3). Calcium is not tabulated as its content decreased to zero on boiling

large number of bamboo species growing in different agro-climatic regions.

Conclusion

The nutritional status in fresh bamboo shoots of all the species vary significantly. The amount of nutrients in *D. strictus* is higher than in *D. asper*, therefore *D. strictus* have a potential for edible shoot production in central India. Scientific validations of indigenous knowledge of tribals coupled with modern scientific inputs have provided a simple, efficient and cost effective method for processing of bamboo shoots. The processing methods used significantly reduce the amount of cyanogens and retains considerable amount of nutrients thus may be utilized for processing of bamboo shoots. Being a lesser known food product, bamboo shoot processing has vast potential to be developed as a new, innovative and promising enterprise in India. Thus, experimentation on effect of processing on nutritional status of various bamboo species growing in different agro-ecological regions needs to be carried out.

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