



Fermented bamboo shoots: A complete nutritional, anti-nutritional and antioxidant profile of the sustainable and functional food to food security

Poonam Singhal^{a,b,*}, Santosh Satya^b, S.N Naik^b

^a St. Ann's College for Women, Hyderabad, India

^b Centre for Rural Development and Technology, Indian Institute of Technology, Delhi, India

ARTICLE INFO

Keywords:

Bamboo shoot
Fermentation
Antioxidant
Traditional knowledge

ABSTRACT

Bamboo shoot fermentation is a traditional process carried out in different communities of the North-Eastern region. To understand the mechanism involved in the traditional process, its scientific validation was done in laboratory. The shoots were fermented for a period of 30 days with the addition of inoculum. Initial investigation showed that the acidity increased and cyanogenic toxicity decreased. The final fermented bamboo shoot product was further analyzed for the proximate composition, minerals and antioxidant capacity. An increase in the protein content (+17.28%) was found in the fermented sample while fat and vitamin C were found to decrease i. e. 90.2% and 35.77% respectively. A significant increase in the phenol, flavonoid content and antioxidant capacity was also found to increase indicating their potential to protect human health. Bamboo shoot serves a great means to food security and a source of functional food. Commercializing fermented shoot products will preserve traditional knowledge and provide livelihood and achieve development goals.

1. Introduction

Bamboo is a long-lived, strong, versatile and highly renewable woody-stemmed perennial species of grasses found mostly in moist deciduous, semi-evergreen, tropical, subtropical and temperate areas of forest (Tewari, Negi, & Kaushal, 2019). More than 1250 species belonging to 75 genera have been reported to be distributed worldwide. Bamboo shoots exhibit a great potential as a food resource and is one of the commonly collected, consumed and sold nutritious vegetable amongst the tribal and rural communities of the North Eastern India. They have been reported to be a good source of nutrition being high in fiber and low in fat. They are not only a storehouse of nutritional elements but also contain some important antioxidants and medicinal components which can help prevent the onset of metabolic disorders (Singhal, Bal, Satya, Sudhakar, & Naik, 2013). They are consumed in fresh, fermented, canned and dried forms (Singh et al. 2007).

Fermentation of bamboo shoots not only makes it palatable in terms of flavor, aroma, texture and appearance but also makes it highly nutritious and extends its shelf life because of the action of lactic acid bacteria making the product acidic and good for digestion (Singhal, Singh, Satya, & Naik, 2017). Fermented bamboo shoots are widely eaten by many tribal communities of the North-Eastern region with varied

preparation method. In India, the fermentation of bamboo shoot has extensively been carried out in the states of Manipur, Meghalaya, Sikkim, Mizoram etc. since ancient times. They are eaten as curry, pickle or soup in different communities. Fermented shoots have also been supplemented in the preparation of nuggets enhancing its physicochemical, microbiological and keeping quality (Das, Nath, Kumari, & Saha, 2013)

Research on the different preparation style of fermented bamboo shoots has been reviewed and compiled by various researchers in the past. But there is no systematic approach which has documented the investigation of the nutrients, antinutrients and anti-oxidant potential of a locally available and edible species of India. Therefore the present study was undertaken to examine the physicochemical changes occurring during the fermentation of young bamboo shoots and presents a detailed report aiming to determine and compare the nutritional and functional qualities of fresh and fermented bamboo shoot.

2. Materials and method

2.1. Sample procurement and preparation

Bamboo shoots of *Bambusa. vulgaris* species was procured from the

* Corresponding author.

E-mail address: singhalpoonam6@gmail.com (P. Singhal).

<https://doi.org/10.1016/j.fochms.2021.100041>

Received 24 June 2021; Received in revised form 30 August 2021; Accepted 12 September 2021

Available online 15 September 2021

2666-5662/© 2021 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

botanical garden of Tata Energy Resource Institute Gram, Haryana, India. The shoots which have attained a height of 20 to 30 cms were harvested and collected in the laboratory. Outer sheath of the shoots was removed and the soft, white portion was washed and grated for fermentation. The process of fermenting the bamboo shoots was learnt from the traditional knowledge and the same process was repeated under the laboratory conditions. Hundred grams of shoots were mixed with 10% inoculum (traditionally fermented 2 year old bamboo shoot) to fasten the process. The shoots were sealed in a glass jar and were kept for fermentation at ambient temperature (29.4–32.4 °C) and relative humidity (52–72%) in triplicates. The study was conducted in the month of September. Sample was withdrawn every 0, 6, 12 and 24 h for the first day and then at 2, 5, 8, 13, 18, 24 and 30 days and tested for change in pH, titratable acidity and cyanogenic toxicity. The 30 day fermented sample was analyzed for proximate composition, minerals and antioxidant assays. All the experiments were done in triplicates.

2.2. Determination of pH and acidity

A 10 g sample was homogenized in 20 ml of distilled water and pH of the sample mixture was determined using a pH meter (Hanna Instruments, HI 2211, Italy). Titratable acidity was calculated by titrating the filtrate with 0.1 N sodium hydroxide using phenolphthalein indicator (Tamang & Sarkar, 1996).

2.3. Cyanogenic toxicity assay

Cyanogenic toxicity determination was done using the Picrate Kit obtained from Dr Howard Bradbury, Australia. The picrate method used is simple, convenient and quick (Haque & Bradbury, 2002). Raw and cooked samples of bamboo shoot were ground using pestle-mortar method. A small amount (25–50 mg) was weighed to which 0.5 ml of 0.1 M phosphate buffer was added. A picrate paper {supplied in the picrate kit prepared by dipping filter paper in a solution of moist picric acid (0.5%w/v in 2.5% w/v sodium carbonate) and allowing the paper to dry in air and then cutting it to 1X10 cm size} was inserted and the vial immediately closed. After about 16–24 hrs at 30 °C, the picrate paper was removed and immersed in 5.0 ml water for 30 min (Figure 3.1). The absorbance was measured at 510 nm and the total cyanide content (ppm) determined by the equation:

$$\text{Total cyanide content (ppm)} = \frac{396 \times \text{absorbance} \times 100}{z}$$

where z is the weight of sample in mg

2.4. Determination of nutritional composition

The moisture content of the shoots was determined by hot-air oven method (AOAC, 1990). Ash content was determined by dry ashing in muffle furnace at 600 °C until grayish white ash was obtained (AOAC, 1990). Crude protein content was determined using a CHN elemental analyzer (Vario EL III, Elementar Analysen Systeme GmbH, Germany). The crude protein (%) was calculated using a conversion factor as N X 6.25 (Uthayakumaran, Newberry, Keentok, Stoddard, & Bekes, 2000). Fat content was determined using the soxhlet system where petroleum ether (B.P. 60 °C– 80 °C) is used as solvent (Sadasivam & Manickam, 1992). Crude fiber was determined by acid-base digestion with 1.25% H2SO4 (W/V) and 1.25% NaOH (W/V) solutions (AOAC, 1990). The total soluble sugars were determined by the anthrone method (Rehman, 2007). The reducing sugars were determined by Nelson-Somogyi's method (Rehman, 2007). Non-reducing sugars were calculated from the difference between the total soluble and reducing sugars. The total vitamin C content was measured by titration method using the dye 2,6-dichlorophenol indophenol (AOAC, 1990)

2.5. Mineral matter estimation

Minerals like Ca, Mg, P, Na, K, Zn, Fe, Cu and Se were determined using Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) (Varian-Vista MPX), Australia after digesting the powdered sample by wet ashing (Ozcan, 2009).

2.6. Antioxidant activity assays

2.6.1. Sample extraction

The fresh and fermented samples of bamboo shoot were homogenized in 80% methanol. The extract was centrifuged at 10000 rpm for 20 min at 4 °C. The residue was re-extracted under the same conditions. The supernatant was pooled together and the methanolic extract was used for antioxidant analysis (Koley, Kaur, Nagal, Walia, & Jaggi, 2016)

2.6.2. Total phenolic content (TPC)

100 µl of the methanolic extract was diluted to 3 ml with distilled water and 0.5 ml of Folin-Ciocalteu reagent was added. After 3 min, 2 ml of 20% sodium carbonate was added and the contents were mixed thoroughly. The color was developed and after 30 min absorbance was measured at 765 nm using gallic acid as a standard. The results were expressed as mg gallic acid (GAE) /100 g (Koley et al., 2016)

2.6.3. Total flavonoids

Total flavonoid content was determined by using a colorimetric method. Briefly, 250 µl of diluted extract was mixed with 1.25 ml of distilled water in a test tube, followed by the addition of 75 µl of 5% NaNO₂ solution. After 6 min, 150 µl of 10% AlCl₃·6H₂O solution was added and allowed to stand for 5 min after which 0.5 ml 1 M NaOH was added. The mixture was adjusted to 3 ml with distilled water and was thoroughly mixed. The absorbance was measured immediately against the blank at 510 nm using a UV spectrophotometer. The results are expressed as mean mg catechin (CE) equivalents/100 (Koley et al., 2016)

2.6.4. Ferric reducing antioxidant power (FRAP)

FRAP assay was performed according to the procedure described by Koley et al. (2011). The FRAP reagent included 300 mM acetate buffer (pH 3.6), 10 mM tripyridyltriazine (TPTZ) in 40 mM HCl and 20 mM FeCl₃ in the ratio 10:1:1 (v:v:v). 3 ml of the FRAP reagent was mixed with 100 µl of sample extract in a test tube and vortexed. Absorbance readings were recorded after 4 min of sample reagent mixing at a wavelength of 593 nm. Results of FRAP were expressed as µmol Trolox Equivalent (TE)/g.

2.6.5. Free radical scavenging activity

The free radical scavenging activity was determined using DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical (Koley et al., 2016). Methanolic extract was added to 3.9 ml of DPPH (25 mg/L) in methanol, and absorbance was measured at 515 nm using methanol without DPPH as the blank. The absorbance was measured until the reaction reached a plateau (steady state). The inhibition percentage (IP) of the DPPH[•] radical was calculated by the following formula:

$$\% \text{ Inhibition} = 100 \times (A_0 - A)/A_0$$

where A₀ was the beginning absorbance at 515 nm

and A was the final absorbance of the test sample at 515 nm.

2.6.6. Trolox equivalent antioxidant capacity (TEAC) assay

The ability of the extract to quench ABTS^{•+} cationic radical (2, 2'-azinobis (3-ethylbenzthiazoline-6-sulphonic acid) in reference to Trolox was described by Koley et al. (2016). The ABTS^{•+} was firstly generated by overnight interaction between ABTS (7 mM) and

potassium persulphate (2.45 mM) which was then kept in dark at 5 °C in refrigerator. The intense colored ABTS stock solution was diluted by ethanol with ratio 1:70 and its absorbance was adjusted to 0.7 ± 0.01 at 734 nm. Finally 100 μ l of the methanolic extract was mixed with 1 ml of ABTS solution and the reduction in absorbance was measured after 2.5 min against blank sample. The percentage inhibition of the sample and the standard were calculated by the following formula:

$$\% \text{inhibition} = 100 \times (A_0 - A) / A_0$$

where A_0 was the beginning absorbance at 734 nm and A was the final absorbance of the test sample at 734 nm.

The radical-scavenging activity of the test samples was expressed as Trolox equivalent antioxidant capacity (TEAC μ molTrolox/g).

2.7. Data analysis

Data is presented as mean \pm standard deviation. The differences between treatments were analyzed using ANOVA. Significant differences between mean values were determined using Duncan's Multiple Range Test ($p < 0.05$). All statistical analysis was performed using Microsoft Excel 2013.

3. Results and discussion

3.1. Effect of fermentation on pH and acidity

The shoots were fermented for a period of 30 days. Fermentation was fastened with the addition of inoculum (2 year previously fermented shoot). The change in the pH and acidity are depicted in Table 1. pH was observed to decline and acidity was found to increase constantly with the fermentation time. The initial pH was low at 4.84 due to the presence of already fermented bamboo shoot and it dropped to 3.88 on the 30th day. The results of the study were in alignment with a report in which the mean pH value for production of *mesu* decreased from 6.1 at 0 day to 3.5 at 24th day while acidity increased significantly from 0.28% (zero day) to 1.16% (9th day) after which the rise was not significant (Devi & Chakma, 2014). Another study also reported that the pH dropped to 3.8 at the end of fermentation for getting *mesu* and the titratable acidity increased significantly from 0.62 to 1.33 (Tamang & Sarkar, 1996). In another study on processing of *tabah* bamboo shoot as fermented pickle decrease in pH value from 5.01 (fresh shoot) to 3.09 on the 4th day of fermentation was reported (Darmayanti, Duwipayana, Putra, & Antara, 2014). Another study reported the pH of different fermented shoots which ranged from 3.9 to 5.3 (Sonar et al., 2015). The pH of khorisa (a traditional fermented bamboo shoot product of Assam) decreased during fermentation, from initial values of 6.40 to 4.52 and 4.09 for two different batches respectively (Badwaik et al., 2014). A very recent report also revealed that traditional fermentation process of bamboo shoot (*Dendrocalamus latiflorus*) studied for 42 days decreased the pH value of the fermentation broth (Chi et al., 2020).

Table 1
Change in pH and acidity with fermentation time.

Fermentation time (hrs and days)	pH	Titratable acidity (% lactic acid)
0 hrs	4.84 \pm 0.22 ^d	0.62 \pm 0.05 ^a
6 hrs	4.72 \pm 0.10 ^d	0.67 \pm 0.07 ^a
12 hrs	4.46 \pm 0.20 ^c	0.73 \pm 0.05 ^b
24 hrs	4.48 \pm 0.10 ^c	0.75 \pm 0.04 ^b
2 day	4.37 \pm 0.61 ^c	0.76 \pm 0.05 ^b
5 day	4.27 \pm 0.44 ^b	0.84 \pm 0.07 ^c
8 day	4.13 \pm 0.29 ^b	0.87 \pm 0.07 ^c
13 day	4.07 \pm 0.32 ^b	1.01 \pm 0.09 ^d
18 day	3.99 \pm 0.14 ^a	1.16 \pm 0.08 ^d
24 day	3.92 \pm 0.16 ^a	1.19 \pm 0.14 ^d
30 day	3.88 \pm 0.08 ^a	1.33 \pm 0.14 ^e

3.2. Effect of fermentation on cyanogenic toxic content

The bitter taste of young shoots is due to the cyanogenic compound called Taxiphyllin which can be reduced by fermenting the shoots. In the present study, the toxic content reduced from 434.9 to 164.8 ppm in 30 days of fermentation (Table 2). There is a sharp decrease in the cyanogenic content starting from the first day (24 hrs) till 18th day after that process of reducing toxicity slowed down. Overall, the cyanogenic content reduced to a point which is close to the permissible limits (approx. 10 ppm, WHO standard) in 30 days fermentation period and has a scope of further reduction if fermentation is continued. During fermentation there is rapid utilization of sugars by the microbes and breakdown of large sugar molecules results into the formation of acids. The accumulated acids catalyse the degradation of taxiphyllin into hydrogen cyanide (Giri & Janmejy, 1994). Similar findings have been reported by Darmayanti et al. (2014) where a decrease in HCN content was found in the fermented pickle of *Tabah* bamboo shoot (*Gigantochloa nigrociliata* (Buese) Kurz). Sarangthem and Singh (2013) has also reported that fermentation decreases the cyanogens in bamboo shoots. Another recent study (Sonar et al., 2015) reports the cyanogenic glycosides content to be within the limit (<10 ppm) in the traditionally prepared bamboo shoot products like *hiring*, *soibum*, *soidon*, *hecche*, *ekung* and *eup*.

3.3. Effect of fermentation on the proximate composition

Fermented bamboo shoot sample after a period of 30 days was studied for various biochemical parameters as shown in Table 3. The moisture content in the fresh shoots was found to be 90.57 % which increased to 91.08% on fermentation which might be due to the release of water and other metabolites as by-products by the fermenting micro-organisms. Ash content reduced during fermentation from 0.99% to 0.8% (fw basis) suggesting a decline in the total mineral content. Similar results were also reported by Badwaik et al. (2014). Another important highlight in this study was a significant increase (17.28%) in the protein content (fw basis) from 2.98 to 3.49% in the 30 day fermented shoot sample. Fermented shoots are therefore a good source of digestible proteins. There is extensive proteolytic activity by the micro-organisms degrading the protein molecule to smaller digestible amino acids. Devi and Singh (1986) showed an increase in the soluble protein content in fermented shoot from 3.1% to 7.8% and 8.1% on the third and fifth days of fermentation, respectively. In another study by Agrahar-Murugkar and Subbulakshmi (2006), fermented bamboo *lungsiej* was found to have a better nutritive value in terms of its protein content (8.5%). Studies in the other plant products have also reported an increase in the protein content upon fermentation of soyabean (Keishing, Banu, & Umadevi, 2015), pearl millet (Inyang & Zakari, 2008) and cassava (Oboh & Akindahunsi, 2003).

In the present study there was a significant reduction in the total carbohydrate content in the fermented shoots as the sugars were the

Table 2
Cyanogenic toxic content of bamboo shoots fermented for 30 days.

Fermentation time	Toxicity (ppm) fw basis	Toxicity (ppm) dw basis
0 hrs	434.97 \pm 16.93	38.80 \pm 16.93 ^e
6 hrs	421.90 \pm 11.17 (3.01%)	37.63 \pm 11.17 ^e (3.01%)
12 hrs	374.3 \pm 15.20 (13.95%)	33.39 \pm 15.20 ^d (13.95%)
24 hrs	305.3 \pm 9.50 (29.28%)	27.23 \pm 9.50 ^c (29.28%)
2 day	283.8 \pm 12.45 (34.76%)	25.31 \pm 12.45 ^c (34.76%)
5 day	247.9 \pm 19.59 (43.01%)	22.11 \pm 19.59 ^c (43.01%)
8 day	225.6 \pm 12.19 (48.14%)	20.12 \pm 12.19 ^b (48.14%)
13 day	202.5 \pm 12.02 (53.45%)	18.06 \pm 12.02 ^b (53.45%)
18 day	167.8 \pm 13.86 (61.43%)	14.97 \pm 13.86 ^a (61.43%)
24 day	165.0 \pm 5.66 (62.07%)	14.72 \pm 5.66 ^a (62.07%)
30 day	164.8 \pm 15.27 (62.11%)	14.70 \pm 15.27 ^a (62.11%)

Results are means of triplicate \pm standard deviation, values in parentheses indicate percent reduction in cyanogenic toxicity with respect to 0th day sample.

Table 3

Proximate composition in fresh and fermented bamboo shoot.

Proximate composition (g/100 g fresh weight basis)	Fresh	Fermented (30 day)
Moisture	90.56 ± 1.314 ^a	91.08 ± 0.121 ^b (+0.57%)
Ash	0.99 ± 0.26 ^a	0.80 ± 0.04 ^b (-19.63%)
Protein	2.98 ± 0.156 ^a	3.49 ± 0.064 ^b (+17.28%)
Fat	0.51 ± 0.012 ^a	0.05 ± 0.006 ^b (-90.21%)
Crude fiber	0.64 ± 0.052 ^a	0.58 ± 0.035 ^b (-9.41%)
vitamin C (mg/100 g)	0.34 ± 0.015 ^a	0.22 ± 0.017 ^b (-35.72%)

Results are means of triplicate ± standard deviation, expressed on fw basis. Different alphabets in the same row denote significant differences ($p < 0.05$). Values in parentheses indicate the percent loss/gain with respect to the fresh sample.

main source of energy and were used up by the growing microorganisms for the metabolic activities. Total sugars decreased from 2.27 to 1.92% during the course of fermentation. Reducing and non-reducing sugars were also found to reduce by 59.5 and 25.8 % during fermentation as sugars were used up for the microbial activities. Analysis of shoots of *Dendrocalamus giganteus* bamboo species by Nirmala, Sharma, and David (2008) showed a reduction in the carbohydrate content of fermented shoot (1.504% fw basis) when compared to that of fresh shoots. Similar observation of carbohydrate reduction was reported by Devi and Singh (1986) in *soidon*, produced from fermented shoots of *Phyllostachys humilis* species. Carbohydrate content decreased in fermented shoots (1.39–1.45%) as compared to raw shoots (4.5%) (Badwaik et al., 2014). Similar pattern of decrease in total sugars was observed during the fermentation of African locust beans (Omafuvbe, Falade, Osuntogun, & Adewusi, 2004).

There was a significant reduction in the fat (90.2%) content of the fermented shoots in the present study proving that fermented shoot is an ideal nutraceutical food with high protein and low fat content. Research report by Nirmala et al. (2008) also revealed lowering (18%) of fat content in fermented (0.315% fw basis) as compared to freshly harvested shoots (0.387% fw basis) of *Dendrocalamus giganteus*. Badwaik et al. (2014) also reported decrease in the fat content during the fermentation process.

In the present study there was a reduction in the fiber content from 0.64 to 0.58%. Earlier reports by Singh, Singh, Nongmaithe, Bora, and Singh (2011) have shown high fiber content in two fermented samples of *soibum* (2.61 and 3.09%) and thus were recommended as a good source of dietary fibre. No change in the crude fiber content was observed in the natural fermentation of African locust beans (Obob, Alabi, & Akindahunsi, 2008). The presence of high fibre in bamboo shoots helps in reducing the fat and cholesterol level of blood thereby making them one of popular health foods among individuals facing modern lifestyle disease.

The present study also observed a reduction in the Vitamin C content by 35.7%. The reason for this could be the water soluble nature of the vitamin due to which most of the vitamin might have remained in the liquid portion of the substrate. Similar results were reported by Badwaik et al. (2014) in case of shoot of *Bambusa balcoo* species. Vitamin C was not detected after the fermentation of seeds of *Lupinus albus* L. var. Multolupa (Frias, Miranda, Doblado, & Vidal-Valverde, 2005). A decreasing pattern in the vitamin C content upon fermentation (1.09%) was observed as compared to the juvenile shoots (3.28%) in *D. giganteus* (Nirmala et al., 2008). Giri and Janmejey (2000) has also reported a total loss of vitamin C during fermentation of shoots of *Bambua tulda*.

Study by Kalita and Dutta (2012) has shown that fermented bamboo shoot is being used in the North-East regions for different physical

ailments attributed to the fact that bamboo shoots contain low cholesterol and fat contents but rich in potassium, carbohydrates, dietary fibers, phytosterol and have antioxidant properties.

3.4. Effect of fermentation on the mineral content

A number of minerals are regarded as absolutely essential for life's processes. They are classified as essential macro and trace (micro) elements. A deficiency of these elements in an otherwise nutritionally adequate diet can lead to very diverse and indefinite metabolic abnormalities (McDowell, 2003). In the present study the fresh shoots were fermented for a period of 30 days and the final product was evaluated for the concentration of different mineral elements using ICP Mass Spectroscopy. Data are presented in Table 4.

Major elements like Ca, Mg, P, K and Na were found to decrease on fermentation. Calcium and phosphorous are important minerals required for the growth and maintenance of bones. Both Ca and P content was decreased by 43.2% and 30.6% respectively in the fermented product. Magnesium which is a life-supporting element and has an indispensable role in body metabolism was also found to decrease almost to half the value as compared to fresh shoots i.e. from 26.7 to 14.9 mg/100 g (fw basis). Potassium is a mineral extremely important for proper heart functioning. Potassium content in the present study decreased in fermented product i.e. from 346.7 to 293.2 mg/100 g. A study by Singh et al. (2011) confirms that *soibum* is a good source of minerals and potassium is exceptionally higher in the two fermented samples (34127.5 and 29551.1 mg/kg dw). According to Nirmala et al. (2008), there was a reduction in all the macro and micro elements in the fermented shoots as compared to the freshly harvested shoots of *Dendrocalamus giganteus* Munro.

Many essential microelements like copper, manganese, selenium, iron, and zinc were also determined in the fermented sample. Iron content decreased slightly during the fermentation period from 2.92 to 2.89 mg/100 g (fw basis) but the decrease was not significant. Dietary fiber, phytates and polyphenols form complexes with iron due to which its bioavailability is hampered. During fermentation the microbes produce enzymes which help in the hydrolysis of these insoluble complexes and release the free form of the mineral (Gibson, Perlas, & Hotz, 2006). Hence the bioavailability of iron is increased during fermentation through microbial activity. Selenium required for normal growth and fertility also decreased by 21.79% in the fermented shoot. Singh et al. (2011) also reported the Se content in the range of 0.4 to 1.2 mg/kg (dw basis) in the fermented shoots. Chongtham, Bisht, and Haorongbam (2011) has also reported a higher amount of the miracle element being present in bamboo shoot as compared to other vegetables.

Table 4

Mineral contents in fresh and fermented bamboo shoot (mg/100 g fw basis).

Minerals	Fresh shoots	Fermented sample (30 day)
Ca	18.69 ± 0.86 ^a	10.61 ± 0.26 ^b (-43.24%)
Mg	26.78 ± 0.18 ^a	14.91 ± 0.32 ^b (-44.31%)
P	36.57 ± 0.29 ^a	25.38 ± 0.21 ^b (-30.61%)
Na	11.25 ± 0.15 ^a	10.84 ± 0.45 ^b (-3.69%)
K	346.72 ± 2.98 ^a	293.24 ± 4.25 ^b (-15.43%)
Fe	2.92 ± 0.17 ^a	2.89 ± 0.28 ^a (-0.95%)
Cu	0.19 ± 0.01 ^a	0.13 ± 0.03 ^b (-30.41%)
Mn	0.18 ± 0.02 ^a	0.10 ± 0.01 ^b (-44.21%)
Zn	0.74 ± 0.04 ^a	0.48 ± 0.05 ^b (-35.45%)
Se (µg/100 g)	0.32 ± 0.01 ^a	0.25 ± 0.01 ^b (-21.79%)

Results are means of triplicate ± standard deviation, expressed on fw basis. Different alphabets in the same row denote significant differences ($p < 0.05$). Values in parentheses indicate the percent loss/gain with respect to the fresh sample.

3.5. Effect of fermentation on the antioxidant properties

The antioxidant properties in bamboo shoots were determined by various antioxidant assays each focusing on the reduction/oxidation of a specific ion/metal. Assessment of the antioxidant activity help identify whether the food is capable of scavenging free radicals produced at the cellular level as a result of pollution, stress, wrong dietary habits etc.

In the present study, total phenol content increased with fermentation of bamboo shoots from 29.0 to 42 mg GAE/100 g fresh weight (Table 5). The reason for such an increase in the phenolic content may be attributed to the hydrolysis of the glycosidic bonds in the phenolic compounds due to microbial activity resulting in the liberation or formation of various bioactive compounds (Oboh et al., 2008). Similar results were reported by Badwaik et al. (2014) where a marked increase was observed in total phenolics from 97.5 mg/100 g to 255 mg and 239 mg/100 g for two different batches of fermentation respectively. The phenolic content ranged from 718.03 to 920.01 µg/g GAE/mL in different traditionally prepared bamboo shoot products like *hirring*, *soibum*, *soidon*, *hecche*, *ekung* and *eup* (Sonar et al., 2015). Park and Jhon (2010) investigated the functional properties of shoots of two bamboo species *P. pubescens* and *P. nigr*a and found a significant relationship between antioxidant activity and phenolic content. The most important phenolic compounds were protocatechuic acid, p-hydroxybenzoic acid, and syringic acid. Phenolic acids present in the tender shoots also have been shown to have mild anti-inflammatory properties and are potent antioxidants that prevent cancer and blood vessel injury that can start atherosclerosis (Belitz & Grosch, 1999).

In the present study the flavonoid activity of the fermented bamboo shoot was found to increase from 49.69 to 59.43 mg CE/100 g (Table 4). Phyto-chemical screening of fermented *Bambusa balcooa* shoots showed the presence of flavonoids in the ethyl acetate extract of the shoot (Singh, Bora, & Singh, 2012). In one of the studies the content of kaempferol (flavonoid) remained constant in the matrix of cabbage during the fermentation process (Tolonen et al., 2002).

In the present study, the scavenging effect of bamboo shoot extract was weak for the fresh shoots as compared to fermented shoots which exhibited a higher free radical scavenging activity. The fermented shoots (30 days) showed free radical scavenging potential of 2.13, 5.76 and 6.24 µmol TE/g as compared to 1.72, 5.71 and 5.82 µmol TE/g in fresh shoot when assessed by FRAP, DPPH and TEAC assays respectively. The increase in free radical-scavenging activity of the fractions during fermentation was proportional to the total phenolic content in the fractions, suggesting that phenolic compounds appear to contribute antioxidant activity. Various studies have reported an increase in the antioxidant activity during the fermentation of *kimchi* (Park et al., 2011), fermented cabbage (Harbaum, Hubbermann, Zhu, & Schwarz, 2008), chinese traditional okara (Zhu, Fan, Cheng, & Li, 2008) and fermented *bokbunja* (Ju et al., 2009) because of the high correlation existing between the phenolic compounds and antioxidant activity (Park et al., 2011). Similar results were reported by Sonar et al. (2015) where the methanolic extracts of different fermented bamboo shoot samples exhibited significant free radical scavenging activity ranging between 70.84 and 95.37%. The antioxidant activity as measured by Badwaik et al. (2014) also got increased during fermentation process and was found to be 49.20 and 55.35% in terms of DPPH free radical scavenging activity for the two batches of fermentation respectively. Another report by Waikhom, Ghosh, Talukdar, and Mandi (2012) noticed a good antioxidant potential in fermented shoot of *D. hamiltonii* species.

4. Conclusion and way forward

Bamboo shoots no doubt form an important food source from the plant origin. Consumption of bamboo shoots in various forms is evident in the North-Eastern regions, and other parts of India. This is getting global popularity not just because of its nutritional profile, but also because of its important role in providing food security, combating

Table 5

Total Phenolic content, flavonoid content and antioxidant capacity assessed by FRAP, DPPH and TEAC in fresh and fermented bamboo shoot.

Antioxidant assays (fw basis)	Fresh shoot	Fermented shoot (30 day)
Total Phenolic content (mg GAE/100 g)	29.00 ± 2.70 ^a	42.06 ± 0.93 ^b (+45.01)
Total Flavonoid content (mg CE/100 g)	49.70 ± 1.12 ^a	59.44 ± 2.68 ^b (+19.56)
FRAP (µmol TE/g)	1.72 ± 0.24 ^a	2.13 ± 0.18 ^b (+23.6%)
DPPH (µmol TE/g)	5.71 ± 0.56 ^a	5.76 ± 0.34 ^a (+0.87%)
TEAC(µmol TE/g)	5.82 ± 0.35 ^a	6.24 ± 0.24 ^b (+7.21%)

Results are means of triplicate ± standard deviation, expressed on fw basis. Different alphabets in the same row denote significant differences (p < 0.05). Values in parentheses indicate the percent loss/gain with respect to the fresh sample.

malnutrition and micronutrient deficiencies. Fermentation of bamboo shoot is the most common practice in the tribal communities. The present study helped in scientifically validating the traditional knowledge system (TKS) of fermenting shoots. The pH decreased and acidity increased at the end of the fermentation period as a result of lactic acid bacteria extending the shelf life and rendering it good for digestion. The cyanogenic toxicity also got reduced significantly by the end of fermentation due to microbial activity making it safe for consumption (permissible limits as per WHO standards). The nutrients like ash, crude fiber, fat and vitamin C were reduced during fermentation. However, there was a significant increase in the protein content. All the major and micronutrients were decreased significantly. The phenol and flavonoid content increased significantly resulting in the liberation of certain bioactive compounds and thus an increase in antioxidant content was observed. Overall, fermented shoots were found to have a better antioxidant capacity and thus considered good for health. Supplementing the diet with fermented shoots can help overcome the micronutrient deficiency and build a sound immune system against infectious diseases.

Fermented shoot processing is an ancient knowledge system existing in the tribal communities from decades and fermented shoots are not only used in homes for domestic use but also sold in the markets in the packaged form prepared by small groups of women at home. So basic fermented bamboo shoot products made by local villagers are sold in the markets but a variety of these products with proper labeling and commercial packaging is not available. India is the second largest country with Bamboo diversity and has a great potential to commercialize bamboo shoot products especially fermented shoots. We need to provide proper training to the women workforce of the villages and build their capacities to take up the preparation, packaging and marketing of fermented shoot products so as to build a global marketplace. Government policies should integrate bamboo cultivation in kitchen gardens, employment generation with bamboo shoot products by providing proper training and funding, and conservation of traditional knowledge systems pertaining to bamboo products and maintaining the food security as it remains the food of the future showing greatest environmental sustainability. Integration of such initiatives in the schemes and policies can also help in achieving targets under SDGs 13 (climate change) and 15 (land on life) also through enhancing environmental sustainability.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Authors are grateful to the Department of Microbiology, Indian

Agricultural Research Institute, Pusa, New Delhi where a part of the study was carried out. The funding support was provided by the MoRD project RP2011.

References

- Agrahar-Murugkar, D., & Subbulakshmi, G. (2006). Preparation techniques and nutritive value of fermented foods from the Khasi tribes of Meghalaya. *Ecology of Food and Nutrition*, 45(1), 27–38.
- AOAC. (1990). Official methods of analysis (15th ed.). Association of Official Analytical Chemists, Washington DC, USA.
- Badwaik, L. S., Borah, P. K., Borah, K., Das, A. J., Deka, S. C., & Sharma, H. K. (2014). Influence of fermentation on nutritional compositions, antioxidant activity, total phenolic and microbial load of bamboo shoot. *Food Science and Technology Research*, 20(2), 255–262.
- Belitz, H. D., & Grosch, W. (1999). *Food Chemistry* (2nd ed). New York: Springer Verlag.
- Chi H., Lu W., Liu G., Qin Y. (2020). Physiochemical property changes and mineral element migration behavior of bamboo shoots during traditional fermentation process. doi:10.1111/jfpp.14784.
- Chongtham, N., Bisht, M. S., & 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(3), 153–168.
- Darmayanti, L. P. T., Duwipayana, A. A., Putra, I. N. K., & Antara, N. S. (2014). Preliminary Study of Fermented Pickle of Tabah Bamboo Shoot (*Gigantochloa nigrocliliata* (Buese) Kurz). *World Academy of Science, Engineering and Technology International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, 8(10), 1073–1078.
- Das, A., Nath, D., Kumari, S., & Saha, R. (2013). Effect of fermented bamboo shoot on the quality and shelf life of nuggets prepared from desi spent hen. *Veterinary World*, 6(7), 419–423.
- Devi, Y., & Chakma, A. (2014). Reduction of cyanogenic content in bamboo shoot during mesu fermentation. *The Ecoscan*, 8(3&4), 297–300.
- Devi, S. P., & Singh, H. T. (1986). Studies on the chemical and nutritional changes of bamboo shoots during fermentation. *Journal of Food Science and Technology*, 23, 338–339.
- Frias, J., Miranda, M. L., Doblado, R., & Vidal-Valverde, C. (2005). Effect of germination and fermentation on the antioxidant vitamin content and antioxidant capacity of *Lupinus albus* L. var. Multolupa. *Food Chemistry*, 92(2), 211–220.
- Gibson, R. S., Perlas, L., & Hotz, C. (2006). Improving the bioavailability of nutrients in plant foods at the household level. *Proceedings of the Nutrition Society*, 65(2), 160–168.
- Giri, S. S., & Janmejey, L. S. (1994). Release of HCN in Soibum fermentation. *Journal of Phytological Research*, 7, 169–170.
- Giri, S. S., & Janmejey, L. S. (2000). Effect of bamboo shoot fermentation and aging on nutritional and sensory qualities of soibum. *Journal of Food Science and Technology*, 37(4), 423–426.
- Haque, M. R., & Bradbury, J. H. (2002). Total cyanide determination of plants and foods using the picrate and acid hydrolysis methods. *Food Chemistry*, 77, 107–114.
- Harbaum, B., Hubbermann, E. M., Zhu, Z., & Schwarz, K. (2008). Free and bound phenolic compounds in leaves of pak choi (*Brassica campestris* L. ssp. *chinensis* var. *communis*) and Chinese leaf mustard (*Brassica juncea* Coss). *Food Chemistry*, 110(4), 838–846.
- Inyang, C. U., & Zakari, U. M. (2008). Effect of germination and fermentation of pearl millet on proximate, chemical and sensory properties of instant “fura”—A Nigerian cereal food. *Pakistan Journal of Nutrition*, 7(1), 9–12.
- Ju, H. K., Cho, E. J., Jang, M. H., Lee, Y. Y., Hong, S. S., Park, J. H., & Kwon, S. W. (2009). Characterization of increased phenolic compounds from fermented *Rubus coreanus* Miq. and related antioxidant activity. *Journal of Pharmaceutical and Biomedical Analysis*, 49(3), 820–827.
- Kalita, T., & Dutta, U. (2012). A comparative study on indigenous usage of Bambo shoot in the health care practices in NE India. *The Clarion-International Multidisciplinary Journal*, 1(2), 130–141.
- Keishing, S., Banu, T., & Umadevi, M. (2015). Effect of fermentation on the nutrient content, antioxidant and antidiabetic activities of Hawaijar, an indigenous fermented soya of Manipur, India. *Journal of Human Nutrition & Food Science*, 3(3), 1066.
- Koley, T. K., Kaur, C., Nagal, S., Walia, S., & Jaggi, S. (2011). Antioxidant activity and phenolic content in genotypes of Indian jujube (*Zizyphus mauritiana* Lamk.). *Arabian Journal of Chemistry*. doi:10.1016/j.arabjc.2011.11.005 (in press).
- McDowell, L. R. (2003). *Minerals in animal & human nutrition* (2 Ed.). Elsevier Science BV.
- Nirmala, C., Sharma, M. L., & David, E. (2008). A comparative study of nutrient components of freshly harvested, fermented and canned bamboo shoots of *Dendrocalamus giganteus* Munro. *Bamboo Science and Culture*, 21(1), 33–39.
- Oboh, G., & Akindahunsi, A. A. (2003). Biochemical changes in Cassava products (flour & gari) subjected to *Saccharomyces cerevisiae* solid media fermentation. *Food Chemistry*, 82(4), 599–602.
- Oboh, G., Alabi, K. B., & Akindahunsi, A. A. (2008). Fermentation changes the nutritive value, polyphenol distribution, and antioxidant properties of *Parkia biglobosa* seeds (African locust beans). *Food Biotechnology*, 22(4), 363–376.
- Omafuvbe, B. O., Falade, O. S., Osuntogun, B. A., & Adewusi, S. R. (2004). Chemical and biochemical changes in African locust bean (*Parkia biglobosa*) and melon (*Citrullus vulgaris*) seeds during fermentation to condiments. *Pakistan Journal of Nutrition*, 3(3), 140–145.
- Ozcan, M. M. (2009). Some nutritional characteristics of fruit and oil of walnut (*Juglans regia* L.) growing in Turkey. *Iranian Journal of Chemistry & Chemical Engineering*, 28(1), 57–62.
- Park, E. J., & Jhon, D. Y. (2010). The antioxidant, angiotensin converting enzyme inhibition activity, and phenolic compounds of bamboo shoot extracts. *LWT-Food Science and Technology*, 43(4), 655–659.
- Park, J. M., Shin, J. H., Gu, J. G., Yoon, S. J., Song, J. C., Jeon, W. M., ... Kim, J. M. (2011). Effect of antioxidant activity in kimchi during a short-term and over-ripening fermentation period. *Journal of Bioscience and Bioengineering*, 112(4), 356–359.
- Rehman, Z. U. (2007). Domestic processing effects on available carbohydrate content and starch digestibility of black grams (*Vigna mungo*) and chickpeas (*Cicer arietinum*). *Food Chemistry*, 100, 764–767.
- Sadasivam, S., & Manickam, A. (1992). *Biochemical Methods for Agricultural Sciences* (pp. 187–188). New Delhi, India: Wiley Eastern Ltd.
- Sarangthem, K., & Singh, T. (2013). Fermentation decreases the anti-nutritional content in bamboo shoots. *International Journal of Current Microbiology and Applied Sciences*, 2(11), 361–369.
- Singh, S. A., Bora, T. C., & Singh, N. R. (2012). Preliminary phytochemical analysis and antimicrobial potential of fermented *Bambusa balcooa* shoots. *The Bioscan*, 7(3), 391–394.
- Singh, S. A., Singh, H. D., Nongmaithem, R., Bora, T. C., & Singh, N. R. (2011). Comparative study of chemical properties of Soibum—A traditional fermented bamboo shoot product and its biological investigation. *International Journal of Bioscience, Biochemistry and Bioinformatics*, 1(2), 114–118.
- Singhal, Poonam, Bal, Lalit Mohan, Satya, Santosh, Sudhakar, P., & Naik, S. N. (2013). Bamboo Shoots: A novel source of nutrition and medicine. *Critical Reviews in Food Science and Nutrition*, 53(5), 517–534.
- Singhal, Poonam, Singh, Ranjay K., Satya, Santosh, & Naik, Satya Narayan (2017). Satya S and SN Naik Toxicity reduction in bamboo shoots: Field survey and scientific validation of a traditional knowledge system. *Culture, Agriculture, Food and Environment*, 39(2), 138–142. <https://doi.org/10.1111/cuag.12089>
- Sonar, N. R., Vijayendra, S. V. N., Prakash, M., Saikia, M., Tamang, J. P., & Halami, P. M. (2015). Nutritional and functional profile of traditional fermented bamboo shoot based products from Arunachal Pradesh and Manipur states of India. *International Food Research Journal*, 22(2), 788–797.
- Tamang, J. P., & Sarkar, P. K. (1996). Microbiology of mesu, a traditional fermented bamboo shoot product. *International Journal of Food Microbiology*, 29(1), 49–58.
- Tewari S., Negi H. and R. Kaushal. (2019). Status of Bamboo in India. *International Journal of Economic Plants* 6(1):030-039.
- Tolonen, M., Taipale, M., Viander, B., Pihlava, J. M., Korhonen, H., & Ryyänen, E. L. (2002). Plant-derived biomolecules in fermented cabbage. *Journal of Agricultural and Food Chemistry*, 50(23), 6798–6803.
- Uthayakumaran, S., Newberry, M., Keentok, M., Stoddard, F. L., & Bekes, F. (2000). Basic rheology of bread dough with modified protein content and glutenin-to-gliadin ratios. *Cereal Chemistry*, 77(6), 744–749.
- Waikhom, S. D., Ghosh, S., Talukdar, N. C., & Mandi, S. S. (2012). Assessment of genetic diversity of landraces of *Dendrocalamus hamiltonii* using AFLP markers and association with biochemical traits. *Genetics and Molecular Research*, 11(3), 2107–2121.
- Zhu, Y. P., Fan, J. F., Cheng, Y. Q., & Li, L. T. (2008). Improvement of the antioxidant activity of Chinese traditional fermented okara (Meitauza) using *Bacillus subtilis* B2. *Food Control*, 19(7), 654–661.