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

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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 physico-chemical, 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...
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 at ambient temperature (29.4°C) to fasten the process. The shoots were sealed in a glass jar and were kept with 10% inoculum (traditionally fermented 2 year old bamboo shoot) to ferment the process. The shoots were sealed in a glass jar and were kept for fermentation at ambient temperature (29.4°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 hr 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 (Tamag & 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. 60–80°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–Ciocalteau 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 g (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 (v:c: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:

\[
\text{IP} = \frac{A_0 - A}{A_0}
\]

where \( A_0 \) 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 with ethanol with ratio 1:70 and its absorbance was adjusted to 0.7 ± 0.01 at 734 nm. Finally 100 μl 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:

\[
\%\text{inhibition} = 100 \times \left(\frac{A_0 - A}{A_0}\right)
\]

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 μmol Trolox/g).

### 2.7. Data analysis

Data is presented as mean ± 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) during fermentation, from initial values of 6.40 to 4.13 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 ± 0.22c | 0.62 ± 0.05c |
| 6 hrs | 4.72 ± 0.10b | 0.67 ± 0.07b |
| 12 hrs | 4.46 ± 0.20b | 0.73 ± 0.05b |
| 24 hrs | 4.48 ± 0.10a | 0.75 ± 0.04a |
| 2 day | 4.37 ± 0.61a | 0.76 ± 0.05a |
| 5 day | 4.27 ± 0.44b | 0.84 ± 0.07b |
| 8 day | 4.13 ± 0.29b | 0.87 ± 0.07b |
| 13 day | 4.07 ± 0.32b | 1.01 ± 0.09b |
| 18 day | 3.99 ± 0.14c | 1.16 ± 0.08c |
| 24 day | 3.92 ± 0.16b | 1.19 ± 0.14b |
| 30 day | 3.88 ± 0.08a | 1.33 ± 0.14a |

### 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 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 & Janmejay, 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 nigroclada (Busee) Kurs). 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 hirring, solbum, soidon, hecche, ekung and eup.

| 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 ± 16.93 | 38.80 ± 16.93 |
| 6 hrs | 421.90 ± 11.17 (3.01%) | 37.63 ± 11.17 (3.01%) |
| 12 hrs | 374.3 ± 15.20 (13.95%) | 33.39 ± 15.20 (13.95%) |
| 24 hrs | 305.3 ± 9.50 (29.28%) | 27.23 ± 9.50 (29.28%) |
| 2 day | 283.8 ± 12.45 (34.76%) | 25.31 ± 12.45 (34.76%) |
| 5 day | 247.9 ± 19.49 (43.01%) | 22.11 ± 19.49 (43.01%) |
| 8 day | 225.6 ± 12.19 (48.14%) | 20.12 ± 12.19 (48.14%) |
| 13 day | 202.5 ± 12.02 (53.45%) | 18.06 ± 12.02 (53.45%) |
| 18 day | 167.8 ± 13.86 (61.43%) | 14.97 ± 13.86 (61.43%) |
| 24 day | 165.9 ± 5.66 (62.07%) | 14.72 ± 5.66 (62.07%) |
| 30 day | 164.8 ± 15.27 (62.11%) | 14.70 ± 15.27 (62.11%) |

Results are means of triplicate ± standard deviation, values in parentheses indicate percent reduction in cyanogenic toxicity with respect to 0th day sample.
Similar pattern of decrease in total sugars was observed 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 (1.50% 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 (2.61 and 3.09%) and thus were recommended as a good source of dietary fiber. No change in the crude fiber content was observed in the natural fermentation of African locust beans (Oboh, Alabi, & Akinda-hunsi, 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 balcoa* 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 Janmejay (2000) has also reported a total loss of vitamin C during fermentation of shoots of *Bambusa 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, phytotherapies and have antioxidant properties.

### 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 ± 1.31 b | 91.08 ± 0.12 a |
| Ash                                              | 0.99 ± 0.026 b | 0.80 ± 0.004 a |
| Protein                                          | 2.98 ± 0.156 a | 3.49 ± 0.064 b |
| Fat                                              | 0.51 ± 0.05 ± 0.006 a | 0.012 ± 0.001 b |
| Crude fiber                                       | 0.64 ± 0.58 ± 0.035 b | 0.052 ± 0.91 ± 0.41 b |
| vitamin C (mg/100 g)                             | 0.34 ± 0.22 ± 0.017 b | 0.015 ± 35.72 a |

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.

### 3.4. 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 also 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 (341.27 and 295.51 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 Mauro*.

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, Perlis, & 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 ± 0.26 a | 10.61 ± 0.26 b (~34.24%) |
| Mg       | 26.78 ± 0.18 a | 14.91 ± 0.32 (~44.31%) |
| P        | 36.57 ± 0.29 a | 25.38 ± 0.21 (~30.61%) |
| Na       | 11.25 ± 0.15 a | 10.84 ± 0.45 (~3.69%) |
| K        | 346.72 ± 2.98 b | 293.24 ± 4.29 (~15.43%) |
| Fe       | 2.92 ± 0.17 b  | 2.89 ± 0.28 (~9.95%) |
| Cu       | 0.19 ± 0.01 a  | 0.13 ± 0.03 (~30.41%) |
| Mn       | 0.18 ± 0.02 a  | 0.10 ± 0.01 (~44.21%) |
| Zn       | 0.74 ± 0.04 b  | 0.48 ± 0.05 (~35.45%) |
| Se (ug/100 g) | 0.32 ± 0.01 a | 0.25 ± 0.01 (~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 harring, 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. nigra 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 (flavanoid) 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, DPH 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 DPH free radical scavenging activity for the two batches of fermentation respectively. Another report by Waikhom, Ghes, Talukdar, and Mandi (2012) noticed a good anti-oxidant 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 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 anti-oxidant 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.

Table 5

| Antioxidant assays (fw basis) | Fresh shoot | Fermented shoot (30 day) |
|-------------------------------|------------|-------------------------|
| Total Phenolic content (mg GAE/100 g) | 29.0 ± 0.34 | 42.06 ± 0.93a (+45.01) |
| Total Flavonoid content (mg CE/100 g) | 49.70 ± 0.26 | 59.44 ± 2.68b (+19.56) |
| FRAP (µmol TE/g) | 1.12a | 2.13 ± 0.24a (+23.6%) |
| DPH (µmol TE/g) | 5.71 ± 0.56a | 5.76 ± 0.34a (+8.7%) |
| TEAC(µmol TE/g) | 5.82 ± 0.35a | 6.24 ± 0.24a (+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.

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.

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脂质过氧化在发酵后的笋尖中被测定。尽管各种抗氧化剂的测定方法各有侧重，主要集中在对特定金属离子的还原/氧化能力上。评估抗氧化活性有助于确定该食物是否具有清除自由基的能力。这在细胞水平上表现为对污染、压力、不良饮食习惯等的抗性。

在本研究中，总酚含量随着竹笋的发酵而增加。两个不同批次的发酵竹笋的总酚含量分别为29.0到42 mg GAE/100 g。相似的结果由Badwaik et al. (2014)报道。该研究中总酚含量从97.5 mg/100 g增加到255 mg和239 mg/100 g。两个批次分别进行了两次发酵。

在本研究中，对竹笋中黄酮的活性进行了研究。新鲜笋尖的自由基清除活性较弱。发酵笋尖（30天）的自由基清除能力分别为2.13, 5.76和6.24 µmol TE/g，而新鲜笋尖分别为1.72, 5.71和5.82 µmol TE/g。这表明，发酵过程会导致总酚含量的增加，从而导致自由基清除活性的增加。Park et al. (2011)对发酵的苦瓜也进行了类似研究。Sonar et al. (2015)注意到竹笋中的抗氧化活性的增加显著性。Waikhom, Ghes, Talukdar, and Mandi (2012)观察到D. hamiltonii笋尖的抗氧化能力。

4. 结论与未来方向

竹笋无疑是一种重要的食物来源。竹笋的消费方式在不同的地区明显不同。这是获得全球欢迎的原因，不仅因为其营养成分，而且因为其在提供食物安全、应对营养不良和微量营养素缺乏方面的重要作用。

Table 5

| 抗氧化剂（干物质基础） | 新鲜笋尖 | 发酵笋尖（30天） |
|-----------------|---------|-----------------|
| 总酚含量（mg GAE/100 g） | 29.0 ± 0.34 | 42.06 ± 0.93a (+45.01) |
| 总黄酮含量（mg CE/100 g） | 49.70 ± 0.26 | 59.44 ± 2.68b (+19.56) |
| FRAP (µmol TE/g) | 1.12a | 2.13 ± 0.24a (+23.6%) |
| DPH (µmol TE/g) | 5.71 ± 0.56a | 5.76 ± 0.34a (+8.7%) |
| TEAC(µmol TE/g) | 5.82 ± 0.35a | 6.24 ± 0.24a (+7.21%) |

结果是三重的 ± 标准偏差，以湿物质基础表示。在同一行中不同的字母表示显著差异（p < 0.05）。括号内值表示与新鲜样本的百分比变化。

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作者声明他们没有已知的竞争性财务利益或个人关系，这些可能会对所报告的工作产生影响。

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