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# Bamboo shoot: Microbiology, Biochemistry and Technology of fermentation - a review

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Dried-fermented, fermented-canned and fermented-sliced bamboo shoots form a customary grace of different cookeries of the South-East Asian countries. Bamboo shoots are high moisture product, low in fat, cholesterol and high in carbohydrates and dietary fibers. Many nutrients and active materials can be extracted from them. Hence, bamboo shoots are more valuable in pharmaceutical and food processing industries, and can be processed into different beverages, medicines, additives and health foods. The production of bamboo shoots is however, very seasonal and processing of bamboo shoots into various fermented products is too rudimentary, unorganized, non-standardized, region specific and lacks quality control over the final products. There is hardly any product that has created their way into the national and international markets, which is due to the lack of technological advancement in the field of bamboo shoot processing. In this article, the quality attributes of bamboo shoot, its biochemistry and microbiology with note on various traditional fermented food items has been well documented. It is expected that, further study on these aspects help to promote establishment of a bamboo shoot based processing units and will boost the socio-economic and cultural status of the people, along with preservation of the diverse dietary cultures of various ethnic tribes of the country.

**Keywords:** Bamboo shoots, Canned bamboo shoots, Fermentation, Bamboo shoot bitterness, Hydrogen cyanine

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Bamboo shoots are consumed as food items after harvesting. Bamboo shoots form a traditional delicacy of many countries like China, Japan, US, North East India, Thailand, Nepal, Bhutan, Korea, Australia, New Zealand, Malaysia and Indonesia. The freshly harvested shoot is cream yellow in color, has a strong smell and tastes sweet, if eaten on the day of harvest. However, all species of bamboo shoots available worldwide are not edible. The utilization pattern of the bamboo shoots in most of the countries indicates that it is consumed in the forms of raw, dried, canned, boiled, fermented or medicinal, which is traditional, non-standardized, unorganized and region-specific with little value addition. Bamboo shoots are seasonal, perishable, short-lived and unpreserved. At the same time, they are becoming one of the preferred food items among the people all over the world; thus, implying that there is a need to explore a well organized bamboo shoot processing venture making them available all throughout the year.

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## Bamboo shoots

Bamboo shoots are the young, edible bamboo plants that have just emerged from the ground. Bamboo shoots are generally 20-30 cm long, tapering at one end and weigh almost to a pound[1]. The shooting period of bamboo varies from species to species; their size and weight depending noticeably on location, depth and nutrition of the soil, watering and drainage conditions, temperature, pH and soil fertility. Broadly, the temperate climate bamboos are runners, which shoot in the spring, while the tropical and sub-tropical varieties are clumpers, which shoot in the late summer and fall. Growing of their own, no transparent above ground growth is noticed in the first few budding years and then in one brief season they are seen to burst out with growth. It is during this period that, the plant puts its utmost energy into the root system, and in the following summer and fall, the species manufactures and stores sugars in their rhizomes that produce the roots, insist on top growth, and bear new rhizomes. If allowed to grow well above the surface, they become tough and woody and lose their

delicate taste and aroma. The sheaths covering the shoots are black, brown, yellow or purple, in some species and are covered with tiny hairs.

Bamboo shoots are found in China, Japan, US, North East India, Thailand, Nepal, Bhutan, Korea, Australia, New Zealand, Malaysia and Indonesia. Bamboo is spread in over 1250 species under 75 genera in the world with 136 species under 23 genera in India[2-3]. Nearly 300 species are found in China, 237 in Japan, 90 in Burma, 55 in Philippines, 50 in Thailand, 44 in Malaysia, 33 in Bangladesh, 31 in Indonesia, 30 in Nepal and 30 in Sri Lanka[3].

Bamboo shoots are important constituents in stir fry and some traditional items in the Asian countries. Presently Asia consumes over 2 million tonnes of edible bamboo shoots each year[4]. India is the second richest country for bamboo, after China. About 426.8 tonnes of bamboo shoots are harvested every year in the North eastern states of India[5], with 26.2 tonnes, 435 tonnes and 426.8 tonnes of bamboo shoots are harvested in Sikkim, Meghalaya and Mizoram, respectively[6]. The utilization of fermented, roasted and boiled shoots was estimated to be 680 tonnes approximately in the North eastern states; the highest being in Arunachal Pradesh at 481 tonnes annually and the lowest in Nagaland at 19.5 tonnes annually[6].

The total potential of bamboo worldwide is estimated at $10 billion and the current market for bamboo shoots in India is Rs 5 crores. In the international market, China earns US$130 million every year from exports of edible bamboo shoot, with imports of US at around 44000 tonnes accounting for 14.5% of the total world imports) and import of Australia is at 8000 tonnes per annum[7]. It has been observed that every year US imports 30000 tonnes of canned bamboo shoots from Taiwan, Thailand and China to be consumed as food items[8]. Taiwan consumes 80000 tonnes of bamboo shoots annually constituting a value of US$ 50 million[9]. Thailand covers 30000 hectare of land of bamboo shoots under cultivation, producing 380000 tonnes per year[9]. In Singapore, mostly consumed are the canned shoots; however, frozen cooked shoots are also used[10]. In Japan, the annual per capita consumption of bamboo is now 3 kg per person, compared to 1.2 kg per person in 1950s.

India's size of domestic bamboo economy currently is estimated at US$ 41 crores. The market potential of bamboo in India is, however, estimated at US$ 90 crores, which will grow to US$ 520 crores by 2015, thus enabling 5 million families of artisans and farmers, crossing the poverty line. To add, the uses of bamboo shoots have, for the most part, been local, unorganized and traditional with very little value addition. According to the projection of INBAR, India, with value addition of only two time,s about US$ 160 crores of money can be generated in Assam from rattan and bamboo on an annual basis.

**Quality attributes of Bamboo shoots**

Bamboo shoots are becoming one of the most favorite food items among people all over the world, but there is hardly any organized bamboo shoot processing and marketing industry. The products are, therefore, far off from standardization or globalization. In the following sub-sections, an attempt has been made to highlight the quality attributes, i.e. physical, chemical, nutritional, sensory, and anti-microbial qualities of bamboo shoots and the subsequent qualities of the products derived or to be derived from them.

**Physical qualities of bamboo shoots**

Bamboo shoots are generally 20-30 cm long, taper to one end, grow extraordinarily, at about 121 cm a day and weigh almost to a pound[1]. However, their size and weight depend considerably upon the location, depth and nutrition of the soil, watering and drainage conditions, rainfall, temperature, pH and soil fertility. Depending upon the indication of the tips budding from the soil, the edible bamboo shoots are harvested just at the point of attachment of the rhizome. If they are allowed to grow well above the surface, they become tough and woody and lose their delicate taste and aroma. Broadly, the temperate climate bamboos are runners, which shoot in the spring, while the tropical and sub-tropical varieties are clumper, which shoot in the late summer and fall.

The leaves covering the shoots are black, brown, yellow or purple, in some species and are covered with tiny hairs. Bamboo shoots look like coiled springs and have an acerbic flavor. They are normally sheltered in specialized coverings called culm sheaths that are often multi-colored, when young. The white meat, that is revealed, once the culm sheath is peeled off, it turns yellowish when cooked, and is very sweet if it is cooked on the

day of harvest. However, shoots of some species are known to contain cyanogenic glycosides, called taxiphyllin, [2-(b-D-glucopyranosyloxy) -2-(4-hydroxyphenyl) acetonetrile] and are therefore very bitter[11].

**Chemical qualities of bamboo shoots**

Bamboo shoots are low in fat and cholesterol contents, but very high in potassium, carbohydrates and dietary fibers. Many nutritious and active materials-such as vitamins, amino acids, and anti-oxidants such as flavones, phenols and steroids are present in the bamboo shoots. They are valuable in pharmaceutical and food processing industries and can be processed into beverages, medicines, additives or health foods. Hardly any product has created its way into the markets. Table 1 presents the major composition of commonly edible bamboo shoots.

**Nutritional qualities of bamboo shoots**

Bamboo shoots are low in cholesterol and saturated fats contents (total fats 0.5%), and high in carbohydrate (5.70%), protein (3.9%), minerals (1.1%) and moisture (88.8%)[13]. It has been reported that bamboo shoots can significantly decrease the total serum and serum LDL cholesterol in rats and total liver lipids including liver cholesterol by 16.1 mg/dl. With 17 different types of amino acids, it contains over 10 kinds of mineral elements- Co, Cr, Zn, Mn, Mg, Ni, Co, Cu, etc; Lysine, of amino acids, called 'one limited amino acid' is helpful for growth and development of children; Germaclinium, reported in the shoots are known to carry anti-aging properties[12]. Many nutritious and active materials-such as vitamins, amino acids, and anti-oxidants such as flavones, phenols and steroids can be extracted from the bamboo shoots. Table 2 shows the detailed nutrients of some of the important edible bamboo shoot species.

**Sensory qualities of bamboo shoots**

Bamboo shoots are soft and crispy and develop an acrid flavor, if not harvested as soon as they come out of the ground[14]. They contain a potentially toxic cyanoglycoside, called taxiphyllin[15], which is turned on by the hydrolytic enzyme: β-glycosidase, upon disruption of the plant cell[16-17]. Taxiphyllin further breaks down into cyanohydrin and sugar, which rapidly decomposes into hydrocyanic acid and an aldehyde or a ketone[18]. The quantity of cyanides in bamboo shoots varies depending upon genetic and environmental factors, location of cultivation, season and soil type, parts of the shoot and time of and from harvest[15-16,19]. In *D. giganteus*, it varies up to 894 mg/kg, in *M. bambusoides*, 0.14 mg/gm, in *B. pallida*, 0.04 mg/gm, respectively[20]. The new shoots are almost free from acridity and are brilliant for human consumption. Homogentisic acid is, however, also responsible for the pungent taste of the shoots[21]. But the taste also depends on the total sugar content, total amino acid content like aspartic acid (Asp), glutamic acid (Glu), glycine (Gly) and tannin contents; while the amino acids increase the deliciousness of bamboo shoots, tannins decrease the same by increasing the offensive taste[22].

**Antimicrobial qualities**

With different flavones[23] and glycosides[24] in bamboo, the bamboo shoots have excellent anti-microbial qualities, and can be extracted to make capsules and tablets. In the traditional system of Indian medicine, the silicious concretions found in the shoots are called *banslochan*; and in the Indo-Persian and Tibettan system of medicine, it is called *tabashir* or *tawashir*; commonly in English, it is called '*bamboo manna*'. Earlier obtained from *M. bambusoides*, it is known for its unique healing properties, but is very hard to get. Presently it is replaced by synthetic salicic acid. *B. arundinacea* is described as the best source of bamboo manna[25]. Shoots of *B. arundinacia / B. bambos* contain choline, betain, nuclease, urease, cyanogens, glucosides and are used in the treatment of diarrhoea, thread worm and cough; shoots and dried pith of *D. strictus* contain silicious matter and have tonic and astringent action.

Boiled bamboo shoots are used as appetizers and the decoction of shoots are used for cleaning wounds and maggot infected sores, ulcers, etc. mixed with palm-jaggery, it is known to induce parturition and abortion[26]. In Java, sap from inside the shoots of *B. vulgaris* is used for curing jaundice[27]. Bamboo is filled with antimicrobial qualities and its shoots are used in preparation of steroidal drugs[28].

Bamboo is used as a medicine in the form of anti-oxidant, anti-free-radical, anti-aging and anti cancer activity in South east Asia. In Japan, the antimicrobial property of crushed bamboo shoot sheath /bark prevents bacterial growth and used as natural food preservative. In China, the green shoots

of *P. glauca* were roasted to produce fresh bamboo juice in treating infections. *Bamboo salt tablets*, prepared by sealing salt in hollow bamboo culms followed by baking in specially designed furnaces is used in Korea, which is a natural detoxifying agent and absorbs highly therapeutic trace elements including Cu, Zn and Fe.

Dietary flavonoids in bamboo shoot have anti proliferative activity that help to protect the body from diseases like cancer and cardiovascular diseases[23]. In the long Chinese history, bamboo shavings have been traditionally used as a clinical medicine for alleviating and curing stomach ache, diarrhea, vomiting, chest, diaphragm inflammation, restlessness and excessive thirst. The fermented succulent shoots of *B. balcooa* and *D. strictus* are an improved source of phytosterol[28]. It is also used to increase the appetite and decrease blood pressure and cholesterol. As a widely consumed vegetable, Bamboo shoot can be labeled as a heart protective vegetable and its component phytosterols may be suitable as nutraceuticals.

**Biochemistry of bitterness in Bamboo shoots**

Bamboo shoots contain cyanogenic glycosides, which are nitrogeneous phytoanticipins[24] and are used by various plants as effective defensive mechanism against predators[29-31]. A mechanisms responsible for the formation of HCN in most of the species it is the degradation of the cyanogenic glycosides[32-33] that produces HCN; and the enzyme responsible for this are found to be β-cyanoalanine synthase (EC 4.4.1.9) which is found in a number of plant species[34-35], apart from Rhodanese (thiosulphate-cyanide sulphur transferase EC 2.8.1.1) and Formamide hydrolyase (EC 4.2.1.66). The steps that catalyze the reaction through β-cyanoalanine synthase are shown below[32]:

$$HSCH_2CHNH_2CO_2H + HCN \rightarrow NCCH_2CHNH_2CO_2H + H_2S$$

Cystein β-cyanoalanine

$$S_2O_3^{2-} + CN \rightarrow SO_3^{2-} + SCN^-$$

$$HCN + H_2O \rightarrow HCONH_2$$

Bamboo shoots contain 0.3 to 0.8% hydrogen cyanine[36-37,17]. Of which, up to 0.16% of the total cyanide is contained in the tip, reducing to 0.01% in the base[38], with highest in leaves of young plants, but dropping rapidly after pollination. However, subsequent processing helps in fighting the cyanide concentration, though incomplete cooking result in glycoside hydrolysis and higher release of HCN, but the total amount of HCN in the shoots can be eliminated/ detoxified by boiling/cooking for two hours[15]. Table 3 shows the HCN content of edible bamboo shoot species.

Cyanogenic glycosides were assessed by various authors and organizations[39-42,12-13,19]. Subsequent detoxification and potential toxicity of cyanoglycosides resulting in acute cyanide poisoning in human, bird, fish, wildlife and livestock has been documented[43-45]. The intermediate degradation of cyanogenic glycosides and their products – the cyanohydrins – are only addressed in some of the reviews and articles[46-49]. Functionally, taxiphyllin in the presence of β-glucosidase breaks down to form HCN and aldehyde or ketone. The HCN, so formed, inhibits cytochromoxidase which then stops the oxidative phosphorylation and utilization of intracellular oxygen ceases and there is cardiac arrest in human body.

**Remedies for bitterness**

Cyanide content, naturally, is reported to decrease substantially following harvesting[50]. Different indigenous methods of reducing acidity/bitterness from fresh bamboo shoots has been reported and some of them include chopping of tender shoots into small pieces, partial drying of fresh shoots, boiling in water/salt water and draining or keeping shoots in hot water for 10 - 15 minutes or in water for a week at ambient temperature.

'*Adi*' women of Arunachal Pradesh used banana leaves for semi-fermentation of shoots and pressed under stones near water stream for 3 - 4 months to reduce bitterness[51-52]. Similarly, traditional processing of bamboo shoot fermentation has been reported to reduce the cyanide percentage[6]. Also, the optimum cooking conditions that resulted in 97% reduction of HCN were 98 - 102°C for 148 - 180 minutes[20]. Subsequently, removal of HCN can be done by steaming bamboo shoot[37]. Figure 1 presents the process flow chart for traditional method of removal of HCN in bamboo shoot. The removal of HCN can be done during cooking shoots by changing water several times or by pre-soaking for a long time by subsequent changing 2% salt solution[21]. Superheated steam drying under low temperature has also been reported to remove the HCN content from bamboo shoot as Taxiphyllin decomposes at around 116°C[53].

Table 1—Chemical compositions of commonly edible bamboo shoot species[12]

| Nutrients | Bamboo species | | | | | | |
|---|---|---|---|---|---|---|---|
| | *B. balcooa* | *B. polymorpha* | *M. bambusoides* | *D. strictus* | *D. hamiltonii* | *D. giganteus* | *B. pallida* |
| Water (%) | 91.65 | 91.65 | 91.22 | 85.98 | 92.37 | 91.19 | 92.29 |
| Protein (%) | 2.74 | 2.10 | 3.29 | 1.98 | 2.60 | 2.59 | 2.31 |
| Minerals (%) | 0.99 | 0.91 | 0.98 | 1.14 | 1.01 | 0.89 | 1.12 |
| Hydrocyanic acid (%) | 0.071 | 0.032 | 0.056 | 0.13 | 0.070 | 0.044 | 0.106 |
| Carbohydrates (%) | 3.90 | 4.86 | 3.93 | 9.94 | 4.00 | 4.78 | 3.83 |

Table 2—Major nutrient composition of four important edible bamboo species[6]

| Species | Food Energy (MJ/kg) | Moisture (% *wb*) | Protein (% *db*) | Fat (% *db*) | Carbohydrates (% *db*) |
|---|---|---|---|---|---|
| *B. balcoa* | 15.64 | 84.0 | 3.87 | 0.60 | 5.23 |
| *C. hookeriana* | 15.96 | 79.0 | 3.56 | 0.62 | 5.94 |
| *D. hamiltonii* | 16.40 | 87.0 | 3.90 | 0.50 | 5.70 |
| *M. baccifera* | 15.80 | 75.5 | 3.62 | 0.57 | 6.12 |

Table 3—Hydrogen cyanine content of commonly edible bamboo shoot species (in mg/gm)

| Region of the shoot | Bamboo species | | | | |
|---|---|---|---|---|---|
| | *D. hamiltonii* | *B. pallida* | *B. tulda* | *B. balcooa* | *M. bambusoides* |
| Tip | 2.42 | 0.27 | 0.17 | 2.15 | 1.81 |
| Middle portion | 0.86 | 0.17 | 0.83 | 1.38 | 0.68 |
| Base | 0.15 | 0.13 | 0.28 | 0.62 | 0.35 |

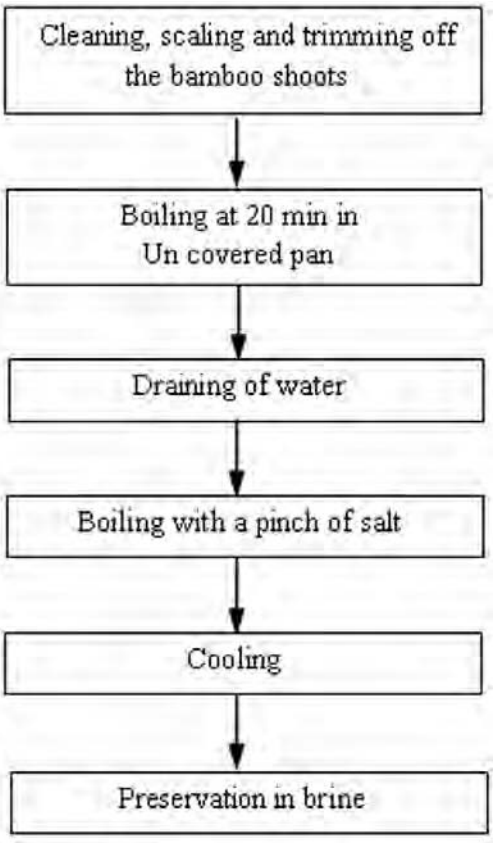


Fig.1—Traditional method of removal of HCN

**Bamboo shoot fermentation**

Fermentation is one of the oldest and most economical methods of producing and preserving traditional foods. People living in the bamboo growing areas of Asia consume various fermented bamboo shoot based food items. Dried-fermented, fermented-canned and fermented-sliced bamboo shoot items are a traditional delicacy of various cookeries of the South East Asian countries.

Traditionally, people consume fermented bamboo shoots in various forms. In Indonesia, bamboo shoots are eaten with thick coconut milk and spices, which is called *gulei rebung*, sometimes also mixed with other vegetables, called *sayur ladeh*. Sweet pickles, chutney or candies, used as condiment are prepared from the pith of the bamboo shoots. The sap of young stalks tapped during the rainy season is fermented to prepare *ulanzi* (a sweet wine), or simply made into a soft drink, called, *Zhuyeqing jiu*, a green colored Chinese liquor.

People in North East India, Nepal and Bhutan consume various wild and domesticated bamboo tender shoots[54] and their fermented products[55]. A delicacy of Indian cuisine is *ushoi* among the *Manipuris* and *Apa Tanis* of Arunachal Pradesh. In Manipur, the fresh bamboo shoots or often the fermented ones, called *soibum*, sometimes prepared

Table 4—Traditional fermented bamboo based food products

| Country | Items |
|---|---|
| Indonesia[56] | *Gulei rebung, Sayur ladeh* |
| Thailand[9,57] | *Naw-mai-dong, naw-mai-dorng* |
| Vietnam[14] | *Used as vegetables, in stir-fry dishes* |
| Philippines[57] | *Labong, Ginataang Labong, Dinengdeng na Labong* |
| Nepal and Bhutan[58,3] | *Alu-tama, Tchang, Mesu* |
| India (NE States and Orissa) [27,58 ,59] | *Khorisa-tenga, Ushoi, Soibum, Soidon, Iromba, Ekung, Hiring, Kardi, Amil, Hendua* |

with dry fish, called *soidon* is consumed locally. In Assam, bamboo shoots are commonly called *khorisa*, sourced along hillside, crushed and packed in bamboo containers by local tribes and brought in to urban areas for sale. This *khorisa tenga* is preserved either with crystal salt, in brine or in mustard oil. In Sambalpur, India, the young shoots are grated and fermented to prepare *kardi* or *amil*, a sour vegetable soup. In the region, shoots that have turned a little fibrous are fermented, dried, ground into powder and used as a garnish called *hendua*, which is quite commonly preferred liquor among the tribal people. The edible bamboo species in the Western Ghats of India are extensively used as pickles, snacks, fried food stuffs, curries and other preparations with rice. In Nepal, bamboo shoots are fermented with turmeric and oil, and cooked with potatoes to prepare an item called *alu tama*. In Bhutanese cuisine, *Tchang* a millet beer is served in bamboo mugs to preserve its flavor. In certain other parts of the country, they are taken as fries, cooked with oil and spices in open pans. Table 4 presents the traditional fermented bamboo based products available in different countries.

## Microbiology of fermented Bamboo shoot based food products

Lactic acid fermentation is a widely applied, low cost fruit and vegetable processing method used for enhancing quality and shelf-life of foods[60]. Each fermented product is associated with unique group of microflora that increase the level of protein, vitamins, essential amino acid and fatty acids[61]. A total of 327 strains of LAB representing *L. plantarum, L. brevis* and *P. pentosaceus* were isolated from samples of mesu[59]. Mesu is found to be dominated by *L. plantarum* followed by *L. brevis; P. pentosaceus* was isolated less frequently and recovered from only 40-50% of the mesu samples[59]. *B. subtilis, B. licheniformis, B. coagulans* and *M. luteus* from 'soibum exudates' involved in microbial bioconversion of phytosterol during fermentation of succulent shoots was isolated[27]. Biochemical characterization of LAB obtained from other pickeled vegetables was carried out and the degradation of sensory quality of fermented bamboo shoot pickles, has been reported to be due to production of surface film of yeast[62-63].

The chemical changes and sensory attributes of soibum during fermentation has been studied[27,64-68,] Similar fermented bamboo shoot product called naw-mai-dong or nor-mai-dorng of Thailand also contained *Lactobacilli, Leuconostocs* and *Pediococci*[56,67].

## Conclusion

The following conclusions can be drawn from the foregoing account:

i. The consumption pattern of bamboo shoots in most of the countries is in dried, canned, boiled, fermented or medicinal form. The production of bamboo is very seasonal, but its demand is high throughout the year. Therefore, there is a requirement of extensive R&D work to develop plausible process technologies to preserve the bamboo shoots in consistent and imperishable forms to be used during the off-seasons.

ii. A thriving economy exists around bamboo and bamboo shoot based food items in the international market in terms of food security and nutrition. There exists great opportunity especially in an organized sector to take up plantation, harvesting, processing and marketing of bamboo and bamboo shoots-based food products. It should, however, be noted that, in selecting an appropriate process technology for processing of bamboo shoots, it is important to examine energy, environment as well as cost issues in order to explore a bamboo shoot based processing sector.

iii. In spite of its vital role in improving the socio-economic and cultural status of people, bamboo resource is receiving less attention day-by-day. The research relating to bamboo and bamboo-based products are lacking in the international scenario. Therefore, there is a need of the hour to develop appropriate process technologies in order to conserve this renewable and yet unexplored natural resource.

iv. In order to establish a successful and sustainable bamboo shoot based industry, focus may be directed for bamboo plant management, post harvest management of bamboo, processing and value addition, and by-product utilization of bamboo and bamboo shoot based products for sustainable development of bamboo and bamboo-based products sector.

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