

Fermented bamboo shoots: a riche niche for beneficial microbes

Abstract

Recent reports and studies have witnessed the evolution of bamboo shoots (BS) from grass to health foods. Bamboo shoots contribute to traditional delicacy of majority of Asian countries like China, Japan, US, North East India, Thailand, Nepal, Bhutan, Korea, Malaysia and Indonesia. In India, bamboos are harvested annually in Sikkim, Meghalaya, and Mizoram. Besides, low in fat and cholesterol, but very high in potassium, carbohydrates and dietary fibres, these are lately being recognized foods of health importance. These also contain nutritious and active materials (vitamins and amino acids) and antioxidants (flavones, phenols and steroids). Fermented bamboo shoots not only have extended shelf life but fermentation also enhances the safety of foods using the natural microflora and their antibacterial compounds. Lactic acid bacteria (LAB) are the dominant microorganisms in ethnic fermented vegetables and bamboo shoot products of the Himalayas. Various tradition foods prepared from fermented bamboo shoots can be a potential source of LAB. LAB prevalent during fermentation process, produce various aroma component, acid, bacteriocins and exopolysaccharides which contribute to the development of some characteristic properties such as taste, visual appearance, texture, shelf life and safety. The present review aims to deliberate over the nutritional and medicinal properties of bamboo shoots, their industrial importance and how these offer to be a rich niche for bioprospecting LAB. The article also emphasizes on the functional and technological attributes of natural microbial flora of different fermented bamboo shoot products which position them as one of the most suitable traditional foods with immense health benefits for human consumption.

Keywords: lactic acid bacteria, health, nutrition, probiotic, functional foods

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Introduction

Although the use of bamboo shoots in tribal diet continues to be an age-old traditional practice, yet the food potential of the bamboo shoot *per se* remained little known all these years. There arises immense need to explore them as a food source, their nutritive and medicinal values, microbiological and economic importance of bamboo shoots with a holistic perspective. These are popular in Asiatic countries and constitute a major component of their traditional cuisine and now it is slowly gaining attention even in western countries. Being low in fat, high in dietary fibre and rich in mineral content, like an ideal vegetable, these have been used traditionally by tribal people for decades globally.¹ In recent years, these have attracted many research groups in Asia and evidences showed the immense nutritive and medicinal potential of Bamboo as it has been used in various traditional systems of medicine like Ayurveda.² A deep insight into the biological and biochemical basis of indigenous knowledge of the ethnic people of Northeast India for production of non-perishable bamboo shoots by lactic acid fermentation helps to develop both low-cost functional foods, and understand the functionality of microbial diversity.

Any edible product prepared from raw or cooked materials of plant or animal origin by adding microorganism deliberately forms fermented food.^{3,4} The utilisation of locally available agricultural and livestock produces into edible products is a common practice among the tribal people of Asian countries.⁵ Particularly in India, varieties of fermented foods and beverages are traditionally prepared and consumed, and even marketed locally in North East India.⁶ Among them, bamboo shoots

based fermented foods contain *Lactobacillus plantarum*, *L. brevis*, *L. Corniformis*, *L. fermentum*, *Leuconostocfallax*, *Lactococcuslactis*, *L. mesenteroides*, *Enterococcus durans*, *Streptococcus lactis*, *L. Casei* and *Tetragenococcusshalophilus* (Table 1).⁷⁻¹¹ Being as predominant LAB species in fermented bamboo shoots products, they also possess functional probiotic properties as well as B-vitamin supplier to human body.¹²⁻¹⁴ Fermented bamboo shoot forms a rich ecological niche which harbours a plethora of microorganisms.¹⁵ Hence these indigenous acidic non-salted fermented products can be considered as a natural repository of diverse LAB with desirable functional and technological attributes.

Prevalence of LAB in fermented bamboo shoots

LAB is widespread and found commonly in nature. Due to their essential role in fermentation and biopreservation ability, they seem to be of utmost significance in the research community.¹⁶ Besides their starter properties, they are also known as cell factories for the production of various metabolites including B vitamins.⁷ Jeyaram et al.,¹⁴ have reported the characterization of mixed lactic microflora involved in bamboo fermentation.¹⁴ LAB is the dominant microorganisms in ethnic fermented vegetables and bamboo shoot products.¹⁵ *Pediococcuspentasaceous*, *L.cellubiosus*, *L. plantarum*, *L. fermentum*, *L. brevis*, *L. mesenteroides*, *Lactococcuslactis*, *Enterococcus faecium*, and *P. Acidilactici* are predominant LAB species found in fermented vegetables. Tamang et al.,¹⁷ determined the functional properties of lactic acid bacteria isolated from ethnic fermented vegetables (*gundruk*, *sinki*, *khalspiand inziangsang*) of the Himalayas.¹⁴ Same authors have reported *L. brevis*, *L. plantarum*, *L.*

curvatus, *P. pentosaceus*, *Leuc. mesenteroides* subsp. *mesenteroides*, *Leuc. fallax*, *Leuc. lactis*, *Leuc. citreum* and *E. durans* in ethnic fermented tender bamboo shoot products, mesu, soidon, soibum and soi-jim of the Himalayas.¹⁸ The microbes involved in the fermentation determine the characteristic of the fermented bamboo shoot.¹⁹ Based on the reports, *L. plantarum* is the main LAB present during the fermentation of *jiang-sun* (fermented bamboo shoots), a traditional fermented food in Taiwan.²⁰ In addition, LAB such as *Enterococcus faecium*, *Pediococcus pentosaceus*, *Tetragenococcus halophilus*, *Weissella* spp., *Lactobacillus* spp. and *Leuconostoc* spp. have been

isolated from various fermented Taiwanese foods.^{21–24} In another study, *Methylobacterium pseudosasa* was isolated from the bamboo phyllosphere.²⁵ Some of the LAB strains may also possess protective and functional properties, which render them interesting candidates for use as starter culture for controlled and optimised production of fermented vegetable products. Though ethnic fermented foods are widely prepared and consumed in the Himalayas, application of standard starter culture is not a tradition except for production of alcoholic beverages.²⁶ The functional properties of LAB are important for selection of appropriate strains to be used as starter culture.^{27–29}

Table 1 Prevalence of lactic acid bacteria in indigenous fermented bamboo products

Products	Lactic acid bacteria	Country	References
Mesu	<i>Lactobacillus plantarum</i> , <i>Enterococcus faecium</i> , <i>Lactococcus lactis</i>	India, Nepal	35,11
Soibum	<i>Lactobacillus brevis</i> , <i>L. plantarum</i> , <i>Leuconostoc mesenteroides</i> , <i>L. fallax</i>	India	37,11,18
Soidon	<i>Lactobacillus brevis</i> , <i>L. lactis</i> , <i>L. curvatus</i> , <i>Leuconostoc fallax</i> , <i>L. Plantarum</i>		37,11,18, 15
Soijim	<i>Lactobacillus brevis</i> , <i>Leuconostoc lactis</i> , <i>L. fallax</i> , <i>L. mesenteroides</i>	India	18
Ekung	<i>Lactobacillus plantarum</i> , <i>L. brevis</i> , <i>L. casei</i> , <i>L. fermentum</i> , <i>Tetragenococcus halophiles</i>	India	11,14
Heccha	<i>Lactobacillus plantarum</i> , <i>Leuconostoc</i> sp.	India	37
Eup	<i>Lactobacillus brevis</i> , <i>L. plantarum</i> , <i>L. xylosum</i> , <i>L. casei</i> , <i>L. fermentum</i> , <i>Leuconostoc mesenteroides</i> , <i>L. fallax</i>	India	37,11
Hirring	<i>Lactobacillus brevis</i> , <i>L. plantarum</i> , <i>L. curvatus</i> , <i>L. lactis</i>	India	37,11,18
Lung-seij	<i>Lactobacillus brevis</i> , <i>L. curvatus</i> , <i>Leuconostoc mesenteroides</i> , <i>L. fallax</i> , <i>L. lactis</i> , <i>L. citreus</i>	India	18
Tuaithur	<i>Lactobacillus brevis</i> , <i>L. curvatus</i> , <i>L. plantarum</i> , <i>Bacillus circulans</i> , <i>B. firmus</i> , <i>B. sphaericus</i> , <i>B. subtilis</i>	India	7
Soidonmahi	<i>Bacillus subtilis</i> , <i>B. cereus</i> , <i>B. pumilus</i> , <i>Lactobacillus brevis</i> , <i>L. plantarum</i> , <i>Enterococcus faecium</i>	India	15
Tabah bam Shoot pickel	<i>Lactobacillus plantarum</i> , <i>L. brevis</i>	Indonesia	36
Naw-maidong	<i>Lactobacillus buchneri</i> , <i>L. plantarum</i> , <i>L. brevis</i> , <i>L. fermentum</i>	Thailand	82
Jiang-sun	<i>Lactobacillus plantarum</i> , <i>Lactococcus lactis</i> , <i>Enterococcus faecium</i>	Taiwan	20
Bamboo leaves	<i>Methylobacterium pseudosasa</i> sp. nov.	India	25
phylloplane of leaves (Bambusa bambos)	<i>Methylobacterium</i> strain BL44T	India	83
Khorisa	<i>Lactobacillus</i>	India	9
Soibum	<i>Lactobacillus plantarum</i>	India	8

According to Badwaik et al.,¹⁵ fermentation of bamboo shoots displays various changes in physicochemical compositions i.e. (minor changes in fat, protein, crude fibre, ash and vitamin C), marked decrease in carbohydrates concentration and pH), (Increase in acidity).¹⁶ Significant increase in total phenolics and antioxidant activity during fermentation reveals its nutritional status and importance. Effects of bamboo shoot fermentation and aging on nutritional and sensory qualities of Soibum, a traditional fermented bamboo shoot product of Manipur (India) were studied by Giri and Janmejey.²⁹ The changes in nutrient contents and texture of bamboo shoots during pickling process were also studied by Zheng et al.³⁰

Rationale behind using LAB in bamboo shoot fermentation

Many authors have investigated that LAB have important role in the fermentation of pickle^{31–34} because they provide a rapid acid accumulation in the raw material with the production of several organic acids. LAB are known to produce various aroma component, bacteriocins and exopolysaccharides which contribute to the development of some characteristic properties such as taste, visual appearance, texture, shelf life and safety. Tamang & Sarkar³⁴ also reported that the LAB which play important role in fermentation of Mesu (North East Himalayan fermented bamboo shoots).³⁵ The occurrence of LAB during the fermentation also contribute to the development of organoleptic and sensory characteristic of pickle. The production of organic acid (such as lactic acid and acetic acid) and other metabolites raising some characteristic like aroma, taste, texture, appearance, etc.³⁶ Sonar & Halami³⁶ have studied that *L. brevis*, *L. xylosus* and *L. plantarum* (SM2) isolated from fermented bamboo shoots showed phytic acid degradation ability, protease, lipolytic activity as well as cell hydrophobicity respectively.³⁷ The same study also reported putative probiotic as well as antagonistic properties of LAB against the selected pathogenic bacteria.³⁷ Tamang & Tamang,³⁷ Thakur et al.,²⁸ reported the various technological properties of LAB isolated from fermented bamboo shoots such as acidifying capacity, antimicrobial activities, degradation of phytic acid and oligosaccharides, bile-salt tolerance, enzymatic activities, biogenic amines production, and degree of hydrophobicity.^{9,38} Badwaik et al.,¹⁴ observed that *Lactobacillus* isolated from fermented bamboo shoot (Khorisa) had shown anti-Bacterial biometabolites against *Staphylococcus aureus*.¹⁶ Above mentioned techno-functional attributes of LAB render them as ideal candidates for the improvisation of value added functional fermented bamboo shoots products.

Diversity in bamboo shoots consumption among people of North East India and worldwide

The bamboo shoot as edible product in most countries have been consumed in the form of raw, dried, canned, boiled, fermented or as medicine.³⁹ In Australia, New Zealand and Japan boiled bamboo shoots are consumed.⁴⁰ These are used as a salad in Thailand and Vietnam. Recently, traditional methods of bamboo shoot processing by indigenous community in China and Thailand have been reported.⁴¹ The Sao community, Sai Yoke district of Bangkok preserves shoots by packing them in plastic bag and steaming by different processes and durations.⁴²

In India, their use as a food component is limited only in North Eastern states viz., Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Arunachal Pradesh and Tripura which are home to different ethnic communities with diverse cultural and religious beliefs.

Some important traditional fermented shoot popularly consumed are soibum, soidon, soijim, bastangapani, ekhung, herring, bastangapani, eup, khorisa and mesu.^{38,43} People consume fermented bamboo shoots in different forms and indigenous names are assigned to different fermented products based on ethnic communities consuming it, nature of products and their mode of preparation. These are consumed as pickle in many parts of Sikkim whereas in Manipur, these find their use in the preparation of special local dish called Irombaor cooked with fish and meat. In Nagaland, these are mainly used as used as condiment and flavouring agent. People from neighbouring state, Arunachal Pradesh, have the practice of consuming bamboo shoots by preparing traditional curry and soup.^{38,43,44} Khorisa is a traditional fermented bamboo shoot product of Assam, another state of India, and is important part of diet of both rural and urban people and is extensively used as a main ingredient in different food items like meat, fish preparations, preparing pickles etc.⁹ The edible bamboo species in Western Ghats of India are extensively used as snacks, fried food stuffs, and curries.⁴⁵ Tama, a non-fermented bamboo shoot curry is very familiar among the people of Sikkim.⁴⁶ In Singapore, people consume bamboo shoots in form of canned or frozen.⁴⁷ Pan C et al.,⁴⁶ in Indonesia, bamboo shoots are eaten with thick coconut milk and spices, which are called guleirebung; sometimes also mixed with other vegetables, called sayur lade.⁴⁵ Sweet pickles, chutney and candies are prepared from the pith of the bamboo shoots in the region. The sap of young stalks tapped during the rainy season is simply made into a soft drink in China.⁴⁸

Health benefits and medicinal value

Bamboo shoots have immense potential of being used as important health food (Figure 1).⁴³ Bamboo plants play a significant role in traditional Asian medicine, especially in China and Japan.⁴⁹ The usefulness of bamboo shoots as health food has been recognized in the recent past due to interests of various research groups promoting their nutritional values and health aspects. It is worth by all means to create awareness among the general public about their nutritional health benefits for their wider acceptance for their consumption at present is limited to tribal people in India.

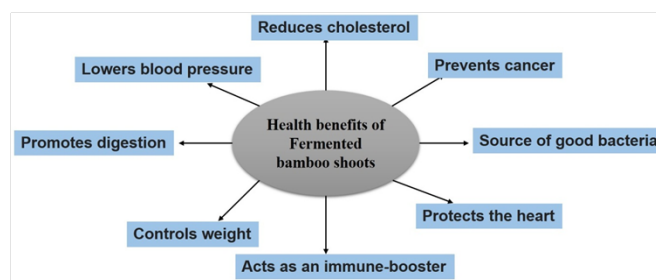


Figure 1 Overall health benefits of fermented bamboo shoots.

The bamboo shoots have been recognised to be associated with an array of health benefit likes anti-oxidant, anti-free radical, anti-aging, anti-cancer, prevent cardiovascular disease, weight loss, to improve digestion, decrease blood pressure, and anti-microbial activity due to the presence of different flavones, glycosides.^{36,39,50–53} Since time immortal, Ayurveda has recommended bamboo shoots for patients having piles and burning sensation during urination) with honey.⁵⁴ Bamboo shoots are considered as nutraceuticals medicines,⁵⁴ because these have low fat, high edible fibre content, and vitamins such as vitamin C and vitamin E.⁵⁵ Singh et al.,⁵⁵ reported that medicinal

values of bamboo leaves such as use in counteracting spasmodic disorders, and in arresting secretion of bleeding, treatment of stomach troubles and stimulation of menstruation as well they are useful in killing intestinal worms, especially threadworms.⁵⁵ Singh et al.,⁵⁶ also reported the antioxidant potential of leaves of fermented bamboo shoots (Soibum).⁵⁶ Supan et al.,⁵⁷ have reported the anti-fatigue effects of *Bambusa blumeana* (Kawayangtinik), a native vegetable in the Philippines which has two active components proven to manifest anti-fatigue effects.⁵⁸

In the Indo-Persian and Tibetan system of medicine, bamboo manna prepared from *Bambusa arundinacea* species is known to be a good tonic for respiratory disorders.⁵⁹ The juice of pressed bamboo shoots has protease activity that helps in digestion of protein,³⁹ cleaning wounds and maggot infected sores, ulcers etc. when mixed with palm-jaggery.^{52,58} In Java, sap from inside the shoots of *Bambusa vulgaris* used for curing jaundice.⁶⁰ Bamboo salt tablets used in Korea are known to help the salt to absorb highly therapeutic trace elements including Cu, Zn and Fe and also eliminate any impurities and heavy metals.³⁹ It serves as an appetizer, natural detoxifying agent as well as provides energy and nutrients to the body.⁶¹ Bamboo shoots are also being used in cosmetics industry besides their food potentials. Particularly, Korea has promoted delicious bamboo sea salt, which can replace the table salt in cooking as well as works as cleansing agent called bamboo bath salts.⁶²

Industrial importance

In general, bamboo could be a new candidate feedstock for the production of biomolecules of industrial importance through value-added applications due to its higher growth rate and annual biomass yield.⁶³ He et al.⁶² Bamboo shoots have been used for production of bioethanol,⁶³ as a source of natural products such as potassium, carbohydrate, dietary fibres, vitamins and other active materials.^{39,64-66} As a lignocellulosic biomass, bamboo may be used for functional xylo-oligosaccharides production. Xylo-oligosaccharides are xylose-based oligomers, which have multiple applications in fields related to the food, pharmaceutical industries, biodegradable plastics or nanoparticles.^{67,68} Bio-ethanol and methane production can be a valuable strategy for combining both the processes by hydrolysis of bamboos and may be considered as a novel source for bio-methane production for its high holocellulose content, biomass yield and other environmental issues.^{63,69} Thomas et al.,⁶⁹ and Chavhan et al.,⁷⁰ have reported the antioxidant and antimicrobial effects of bamboo (*Bambusa polymorpha*) shoot extract (powder and paste) in pork nuggets and Pork pickles respectively and found that these have a great potential to be used as natural preservative in meat products.^{70,71} In another study, bamboo shoot powder fortification has significantly influenced the physico-chemical, textural and organoleptic characteristics of biscuits.⁷² Choudhury et al.,⁷¹ and Mohamed et al.,⁷² reported that bamboo biochar, especially at its highest rate (1.5%) could be recommended as a safe amendment in the immobilization of Cd in contaminated agricultural soils and then reduced its threat on the food chain and human health.⁷³ In another study in China, bamboo tar is reported as a new natural insecticide and acaricide in the agricultural field to reduce the dependence on synthetic pesticides.⁷⁴ Wang et al.⁷³ During the preparation of hawijjar (alkaline-fermented soybean product consumed daily as a source of

protein in Manipur) and Indian yoghurt (Dahi) bamboo baskets or bamboo containers are used which helps in fermentation and results in better quality of product.^{75,76} The bamboo used in the preparation has certain antifungal agents such as dendrocin, which help to increase the shelf life of curd.⁷⁶ Bioconversion ability *Bacillus sp.* found in metabolites of fermented succulent shoots of bamboo makes them ideal source of bioactive compounds like phytosterols (precursors of many pharmaceutically active steroids).⁷⁷ Wu et al.,⁷⁷ have reported the purification and structural identification of polysaccharides from Bamboo Shoots (*Dendrocalamus latiflorus*).⁷⁸

Being one of the fastest growing plants, its shoots can be utilized for feeding the ever increasing human population and address the food security threat at national and international food markets and also because of its nutritional and therapeutic values, the shoots can be used to make up for the dietary deficiencies of nutrients in the diet as well as impart several health benefits by inoculating LAB through fermentation process.⁷⁹ Besides this they act as a good source of thiamine, niacin, vitamin A, vitamin B₆, and vitamin E.^{80,81} They also more nutrient components than those found in commonly consumed vegetables.⁸¹

Conclusion

The consumption of bamboo shoots varies from place to place with their different names because of their highly multipurpose properties. For example, Chinese reckoned bamboos as “Friends of the people,” Vietnamese as “My brother,” Japanese as “King of Forest Vegetables” and Indians as “Green Gold.” Bamboo shoots are a delicacy in Asia, and are available fresh, fermented, dried or canned.^{82,83} Besides their long history as a food and traditional medicine since ages, they are gaining scientific importance due to their health benefits which have been highlighted recently. Their abundance, delicious nature, nutritive, medicinal and scientific values make them more popular in the present situation and could be helpful in mitigating the problem of malnutrition. They have a vast potential to be developed as a novel, innovative and promising health food all over the world (Figure 2). In very near future, Bamboo shoots are going to be recognized as healthy and nutritionally supplemented edibles among the consumers.⁸⁴

Besides its immense health role, its consumption may lead to toxicity. Due to the presence of cyanogenic glycosides named taxiphyllin in bamboo shoots, Cyanide poisoning has been reported after inhalation of hydrogen cyanide gas (HCN) produced from pickled shoots.⁸⁵

Though, the preparation of various fermented food products is traditional, local, unorganized and based on the taste of the local people all over the world (Middle Asia and Middle East).⁸⁶ In the near future, bamboo shoots hold the prospect of value added importance in the food industry. Bamboo shoots no doubt form an important food source from the plant origin in Asian countries but these have a great potential to be widely accepted in several other dishes all over the world. There is an urgent need to exploit the inherent values of bamboos which are rich in all the goodness of nature to be promoted as health foods. Bamboo is not just a poor man's timber but regarded as delicacy of rich men. In international food market in terms of food and nutritional security, a thriving economy revolves around bamboo shoots, its nutritional values, health aspects, its microbiology and the

prospect of bioprospecting various microflora which bring out natural fermentation. The LAB isolated from fermented bamboo shoots can be of great interests as novel starters for the scientific community actively engaged in the development of functional and health foods.

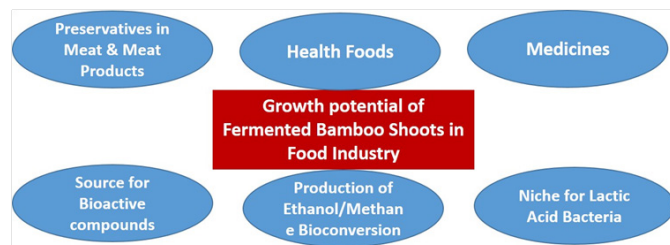


Figure 2 Growth potential of fermented bamboo shoots in food industry.

Authors' contribution

KT, RCS and SKT made substantial contributions to conception and design of this review. KT and RCS were involved in drafting the manuscript. SKT revised it critically for important intellectual content. AP has contributed towards traditional knowledge of fermented bamboo shoots consumption in NE India. All authors read and approved the final manuscript.

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Conflict of interest

The author declares no conflict of interest.

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