

Research Article

Fermented Bamboo Shoot Health Benefits and Applications

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Abstract

The term "bamboo" evokes images of a hollow stick, embodying not just a simple plant but a source of numerous health benefits. In northeast India, tribes engage in the centuries-old practice of fermenting bamboo shoots, employing a biotechnological process that not only preserves food but also unlocks a myriad of health benefits. Fermentation transforms these shoots into a powerhouse for various microorganisms, offering probiotic, anti-oxidant, anti-cancer, anti-aging, cardio-protective, and weight loss properties. Beyond their health advantages, fermented bamboo shoots hold significant commercial value in the food industry, transcending their local origins to become a global commodity akin to "green gold." Originally confined to tribal areas and local markets, these fermented bamboo stalks have gained international recognition. This article delves into the health benefits, merits, drawbacks, future perspectives, and economic value of twenty-first-century fermented bamboo shoots, positioning them as a valuable and sought-after resource. As the world embraces sustainable and natural solutions, the fermented bamboo stalks from India stand out as not only a culinary delight but also a treasure trove of health benefits, weaving a narrative of culinary tradition meeting contemporary wellness trends.

Keywords

Bamboo, Healthy Food, Microorganism, Probiotics, Biotechnology Industry

1. Introduction

Fermentation is a method of producing a product through the cultivation of a large number of microorganisms [9]. Fermented foods have been around for a very long time [39]. Fermented foods play a vital role in our lives and they rely on biotechnology to be produced and stored for a long period [39]. Enzymes or microbes are utilised in the creation of fermented foods resulting in essential biochemical changes and significant alterations in the food [9, 12]. Around 5000

years ago, these fermented foods were made and consumed and at the same time, alcohol fermentation from barley and wine fermentation from grapes were produced [28]. Bacteria, mold, and yeasts were used as microorganisms. Lactic acid bacteria, *Aspergillus* spp., and *Saccharomyces* spp. are examples of these bacteria [19, 37]. Fermented foods and drinks are made at 20 to 40% of the world's food supply. Fermented foods including bread, wine, cheese, yoghurt, idli,

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and dosa are prominent in various parts of the world including Europe, India, North Africa, and the Middle East [19].

The table below demonstrates fermented foods around the world (Table 1).

Table 1. Fermented foods International.

Class	Example of Food	World of Production	Reference
Beverages	Beer, coffee, tea, cocoa, wines, cider	All parts of the world	[44]
Cereals	Rolls, bread, doughnuts, idli, dosa, pancakes, tape ketan	All parts of the world	[16]
Dairy Farm	Cheese; Yogurt: kefir, kurut	Europe, North America, Middle East	[45]
Fish	Eastern Asia, South-East Asia, Europe	Eastern Asia, South-East Asia, Europe	[25]
Pulses	Soy sauce, miso	India, South-East Asia	[22]
Meat	Salami, jerky, pepperoni, pickled meat, country ham	Middle East, Europe, India, North America	[1]

Tribals in northeast India consume these bamboo shoots in wide range for its health benefits, and medicinal value [4]. They are repository for a variety of essential microorganisms, particularly lactic acid bacteria (LAB) and yeast strains [2]. They provide colour, aroma, flavour, taste, and texture in food products. As they are high in probiotics, they can be used as functional foods. Local tribes in northeast India manufacture a variety of fermented bamboo shoot-based food products although only a handful are commonly available in the local market such as soidon, soibum, mesu, ekung, lung-siej, herring, and eupm [24]. The nutritional value, technique of production, and existence of microorganisms of these fermented bamboo shoot food products are explained precise in this paper. This study examines the health benefits of Northeast India's fermented bamboo shoot-based foods. Since this review lists numerous benefits of fermented bamboo shoots particularly the health benefits. Bamboo shoots are progress in economic and it was referred as "ecofriendly golden" in India in the 21st century.

1.1. Fermented Foods in India

Northeast India of Arunachal Pradesh, Assam, Mizoram, Manipur, Nagaland, Tripura, Nagaland, and Sikkim have various ethnic backgrounds and 75% of the population are tribal [10, 26]. Fermentation techniques are used to improve food processing, preservation, and flavour. *Lactobacillus* sp., *Bacillus* sp., *Candida* sp., and *Saccharomyces cerevisiae* are found in fermented foods, particularly in Kinema, Hawaijar, Tungrumbai, Bekang, Peruyyan, Soibum, Soidon, Mesu, Soijim, Ekung, Herring, Ngari, Hentak, Tungtap, Gnuchi, Gundruk, Sinki, Ziang-sang, Goyang, Khalpi, Ipoh, Atingba, Kodo ko Jaanr, and Zutho [6].

1.2. Fermented Bamboo Shoots

Manipur depends on fermentation to preserve its food [32]. Mesu, soibum, soidon, soijim, ekung, heccha, eup, herring, lungseij, tuaithur, soidonmahi, tabah bam shoot pickle, naw-maidong, jiang-sun, and soibum are just a few fermented bamboo shoot-based foods. Bamboo shoots are consumed for its strong nutritional, therapeutic value which are vital for human survival. They are rich in dietary fibre and minerals, low fat, and have a high economic value. Bamboo shoots are used in traditional medical systems such as Ayurveda to treat a variety of diseases [41, 42]. They are high in xylan, also known as xylooligosaccharides. The following are some of the therapeutic uses and medical benefits. Since various glycosides and flavones are present it has anti-oxidant, anti-cancer, anti-aging, anti-free radical, weight loss, protects cardiovascular illnesses, improves digestion, has anti-microbial activity, and reduces blood pressure [40].

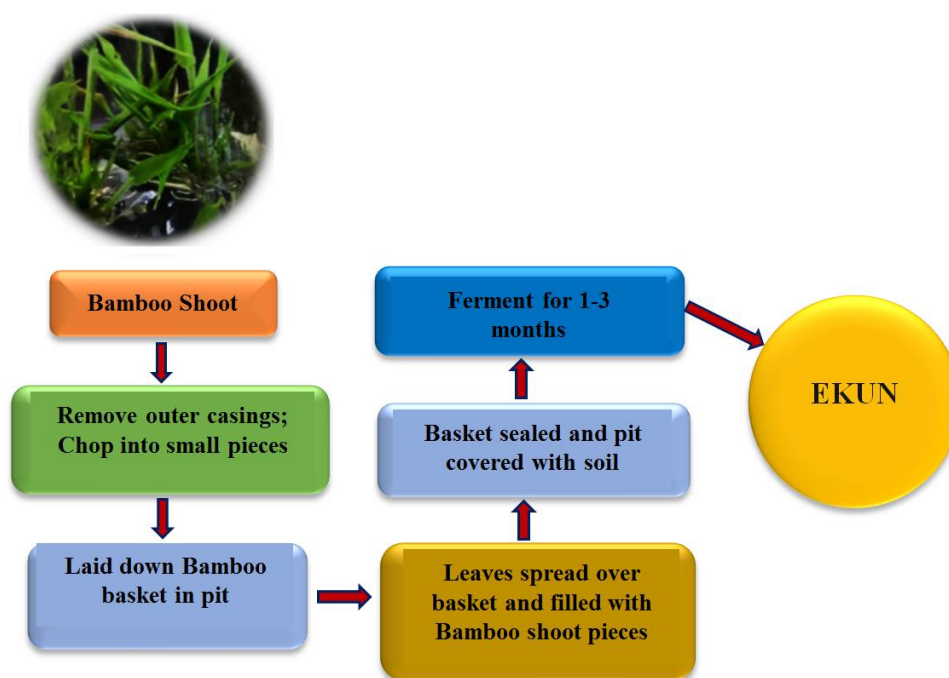
1.3. Fermented Bamboo Shoots Microflora

Fermented bamboo shoot products, such as bamboo shoot pickle samples, soidon, soibum, soijim, and lung-siej are fermented by *Lactobacillus* sp. [23]. *Lactobacillus* (LAB) species, a group of gram-positive bacteria are present in these foods [40]. These bacteria offer fermented foods its flavour, fragrance, and sour flavour. *Lactobacillus* spp., such as *Lactobacillus curvatus* and *Lactococcus lactis*, are the most common *Lactobacillus* species found in Soidon. The most common bacteria identified in Lung-siej are *Leuconostoc fallax*, *Leuconostoc mesenteroides*, *Lactobacillus brevis*, *Lactobacillus curvatus*, and *Lactococcus lactis* [38]. Table 2 shows a list of fermented bamboo shoot-based products and their associated microorganisms. Below are a few samples of fermented bamboo shoots from northeast India.

Table 2. Fermented Bamboo Shoots Microflora.

Fermented Bamboo Shoot Product	Microorganisms	Country	References
Ekung	<i>Lactobacillus plantarum</i> , <i>L. brevis</i> , <i>L. casei</i> , <i>Tetragenococcus halophilus</i>	India	[23]
Eup	<i>Lactobacillus plantarum</i> , <i>L. fermentum</i>	India	[23]
Hirring	<i>Lactobacillus plantarum</i> , <i>Lactococcus lactis</i>	India	[23]
Lung-seij	<i>Lactobacillus brevis</i> , <i>L. curvatus</i> , <i>Leuconostoc mesenteroides</i> , <i>L. fallax</i> , <i>Lactococcus lactis</i>	India	[13]
Mesu	<i>Enterococcus faecium</i> , <i>Lactobacillus plantarum</i> , <i>Lactococcus lactis</i>	India	[23, 8]
Soibum	<i>Lactobacillus brevis</i> , <i>L. plantarum</i> , <i>Leuconostoc fallax</i> , <i>L. mesenteroides</i>	India	[23, 40, 13]
Soidon	<i>Lactobacillus brevis</i> , <i>L. curvatus</i> , <i>L. Plantarum</i> , <i>Leuconostoc fallax</i>	India	[23, 40, 13]
Soijim	<i>Lactobacillus brevis</i> , <i>Leuconostoc fallax</i> , <i>L. mesenteroides</i> , <i>L. lactis</i>	India	[13]
Tabah bam Shoot pickel	<i>Lactobacillus plantarum</i> , <i>L. brevis</i>	Indonesia	[1]
Naw-maidong	<i>Lactobacillus buchneri</i> , <i>L. plantarum</i> , <i>L. brevis</i> , <i>L. fermentum</i>	Thailand	[7, 35]
Jiang-sun	<i>Lactobacillus plantarum</i> , <i>Lactococcus lactis</i> , <i>Enterococcus faecium</i>	Taiwan	[42]

1.4. Ekung

**Figure 1.** Preparation of Ekung (Tamang et al. 2012).

Nishi produces Ekung which is a fermented bamboo shoot food product indigenous to Arunachal Pradesh. Various dialects have different names for it such as Adi's iku and Apatani's hikku. Locally cultivated bamboo shoots (*Bambusa balcooa* Roxb., *Dendrocalamus hamiltonii* Nees. et Arn. Ex Munro, *Dendrocalamus giganteus* Munro, *Bam-*

busa tulda Roxb., *Phyllostachys assamica* Gamble ex Brandis) are harvested with the leaves removed and the bamboo shoots are cut into pieces [6]. The bamboo shoot parts are washed in a trench excavated in the forest near a water source. The chopped bamboo is placed in the pit in a bamboo basket which is then covered with leaves and

sealed. The bamboo shoots are fermented for 1–3 months using heavy stones to remove the water. In an airtight container this can be kept for a year. Ekung is sold in local markets and can be cooked with meat, vegetables, or fish [40]. Most common bacteria identified in ekung include *Lactobacillus plantarum*, *Lactobacillus Brevis*, *Lactobacillus casei*, and *Tetragenococcus halophilus*. Moisture are 94.7 percent, acidity 0.94 percent, pH 3.9, ash 14.0 percent DM, food value 363.0 kcal/100 g DM, protein 30.1 percent DM, carbohydrate 52.1 percent DM, fat 3.8 percent DM, calcium 35.4 mg/100 g, K 168.6 mg/100 g, and sodium 10.9 mg/100 g make up the nutritional value of ekung [38]. The preparation of ekung is displayed in Figure 1. *Lactobacillus plantarum* in ekung demonstrates mode of action by providing antifungal and antibacterial activities as well as extending the shelf life [46].

1.5. Eup

Arunachal Pradesh are known as nogom by Khampti, ipe by Adi, and hi by Apatani. Bamboo shoots are cut into small pieces and fermented in the same way as ekung for 1–3 months in the case of eup. Adesh's Eup is a dry fermented bamboo shoot. The word derives from the Nishi language. Bamboo shoots are sliced into little pieces and dried in the sun for 5–10 days, until the colour changes from white to chocolate brown [40]. *Lactobacillus fermentum* and *Lactobacillus plantarum* are the most common microbes discovered in eup. Moisture: 36.8%, acidity: 0.80%, pH: 4.1, ash: 18.2 percent DM, fat: 3.1 percent DM, protein: 33.6 percent DM, carbohydrate: 45.1 percent DM, food value: 342.7 kcal/100 g DM, Na: 3.4 mg/100 g, Ca: 76.9 mg/100 g, and K: 181.5 mg/100 g make up the nutritional content of eup [40]. The preparation of eup is depicted in Figure 2.

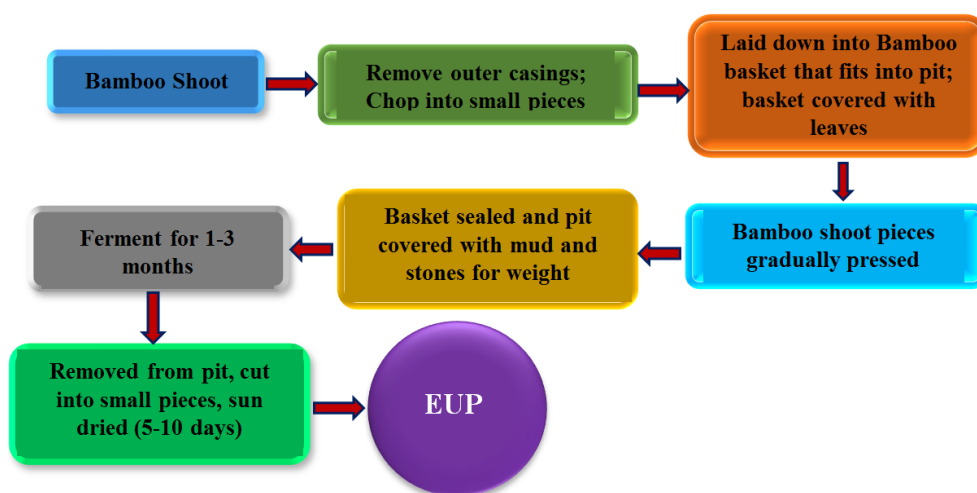


Figure 2. Preparation of Eup in Arunachal Pradesh (Tamang et al. 2012).

1.6. Hurring

Hurring is a fermented bamboo stalk product produced by the Apatani people in Arunachal Pradesh. The Nishi refer to them as hitak or hitch. Bamboo shoots are sliced lengthwise into 2–3 pieces or flattened by crushing and placed in bamboo baskets with leaves in the creation of hurring. The baskets are placed in a pit and fermented for 1–3 months covered with leaves and sealed. Hurring is typically offered in local markets as a curry ingredient. *Lactobacillus plantarum* and *Lactococcus lactis* are two bacteria typically found in hurring [40]. Moisture: 88.8%, pH: 4.0, acidity: 0.81 percent, protein: 33.0% DM, carbohydrate: 49.3% DM, fat: 2.7 percent DM, food value: 353.5 kcal/100 g DM, Ca: 19.3 mg/100 g, K: 272.4 mg/100 g, and Na: 3.4 mg/100 g are among the nutritional values of hurring [38]. The process of hurring preparation is depicted in Figure 3.



Figure 3. Hurring preparation (Tamang et al. 2012).

1.7. Lung-siej

Lung-siej is a Meghalayan traditional fermented bamboo shoot food made from *Dendrocalamus hamiltonii* bamboo found in the Meghalayan highlands [38]. Young bamboo shoots are chosen where the leaves are removed and the shoots are chopped in tiny pieces before being placed in a bamboo barrel or a glass bottle [29]. Bamboo cylinders are formed from slicing bamboo nodes with one side open and another closed. Bamboo shoot pieces are placed inside bamboo cylinders, which are then sealed by binding the rim with grass or thread [21]. The ends of the cylinder are sealed to prevent water from seeping into the cylinder that would turn the shoots dark and render them unsafe to eat. For fermentation the bamboo barrels are placed inverted near the water body during 1–2 months. Glass bottles can be used as fermentation containers instead of bamboo cylinders. Sliced bamboo shoots are squeezed into glass bottles and water is added until they are completely submerged [17]. The bottle is again sealed with a cap and maintained for one month near the kitchen oven. This is because lung-siej made in glass containers has a longer shelf-life up to 10–12 months while lung-siej made in bamboo cylinders only has a 1–2 month shelf-life. In general urban residents favour glass container lung-siej but village people prefer bamboo containers. The manufacture of lung-siej is mostly done by Khasi women [38]. The preparation of lung-siej is depicted. Lung-siej is prepared as a dish with meat and fish [20]. In most lung-siej samples lactic acid bacteria (LAB) can be identified [37].

1.8. Mesu

The Gorkha tribe of Sikkim prepare Mesu as meal, which is a fermented bamboo shoot. *Bambusa tulda* (Karati bans), *Dendrocalamus hamiltonii* (choya bans), and *Dendrocalamus sikkimensis* (bhalu bans) are edible bamboo shoots that are used to prepare this dish. Defoliated shoots are sliced and tightly packed into such a cylindrical rattan stem. The tip of container is tightly covered with leaves and let to ferment naturally for 7–15 days under anaerobic conditions. Mesu is taken in the form of a pickle. *Lactobacillus brevis*, *Lactobacillus plantarum*, *Lactobacillus curvatus*, *Leuconostoc citreum*, and *Pediococcus pentosaceus* are the most common bacteria discovered in Mesu [40]. Mesu has a distinct flavour and aroma. Nepalese Limboo women primarily prepare it. Local women sell Mesu in green bamboo containers at markets in the Sikkim and Darjeeling highlands during the rainy season [39]. Moisture: 89.9%, acidity: 0.8%, pH: 3.9, ash: 15.0 percent DM, protein: 27.0 percent DM, fat: 2.6 percent DM, carbohydrate: 55.6 percent DM, Ca: 7.9 mg/100 g, K: 282.6 mg/100 g, Na: 2.8 mg/100 g, food value: 352.4 kcal/100 g DM, Ca: 7.9 mg/100 g [3]. The process of making mesu is depicted. At the stage where the chopped bamboo shoots are maintained in air-tight bamboo vessels for fermentation for 7–12 days the mechanism of activity of different

microorganisms happens giving the texture and colour to the mesu food product [34].

1.9. Soibum

Manipur is known for its fermented culinary dishes, which are particularly created by the Meiteis, Manipur's indigenous people [34]. Manipur's traditional food bamboo shoot is known as soibum [35]. The soibum is pale in colour and has a sour taste. It is made from delicate bamboo shoots such as *Bambusa tulda* (Utang), *Bambusa balcona* (Ching saniebi), *Wanap*, *Unap*, *Dendrocalamus hamiltonii*, *Pecha*, *Melacona bambusoide* (Moubi/Muli), *Bambusa tulda* (Utang) and *B. balcona* (Ching saniebi), by natural fermentation. Young shoots are stripped of their outer casings and their interior parts are cut into pieces, washed, and fermented for 3–12 months. This is made in Manipur by Meitei women. The Meitei tribe serve it with steam rice as a common meal. In Manipur Meitei women regularly sell soibum as a vegetable in the market. *Lactobacillus plantatum*, *Lactobacillus brevis*, *Lactobacillus coryniformis*, *Lactobacillus delbrueckii*, *Lactococcus lactis*, *Streptococcus lactis*, *Enterococcus durans*, *Bacillus subtilis*, and yeasts such as *Candida* and *Saccharomyces*, to mention a few, are prevalent [38, 40]. Moisture: 92 percent, acidity: 0.98 percent, pH: 3.9, fat: 3.2 percent DM, carbohydrate: 47.2 percent DM, protein: 36.3 percent DM, food value: 362.8 kcal/100 g DM, Ca: 16.0 mg/100 g, K: 212.1 mg/100 g, and Na: 2.9 mg/100 g are among the nutritional values of soibum. The preparation of soibum is depicted. The method of action of various microorganisms such as *Lactobacillus plantarum* gives antibacterial function and extends the shelf life of soibum [3].

1.10. Soidon

Soidon refers to fermented bamboo shoot tips supplied by Manipuri women which are a staple in Manipur's diet (Prem-lata et al., 2020). The tip of a developed bamboo shoot (*Bambusa tulda* Roxb., *Dendrocalamus giganteus* Munro, and *Melocana bambusoides* Trin, *Teinostachya wightii*) is used for preparation of this diet [23]. In other terms, bamboo shoots are harvested from the apical meristem of *Teinostachya wightii* (Nath). The bottom parts of the casings as well as the exterior casings are taken away. The entire tips are buried in such an earthenware pot of water. The previous batch's soijim or sour liquid is introduced like a starter in a 1:1 dilution and fermented at ambient temperature for 3–7 days [9]. Leaves of *Garcinia pedunculata* Roxb., also known as *heibung* locally, can be placed in fermenting container to enhance the taste of soidon. Soidon can be kept at room temperature for year in a sealed jar. It can be used to prepare curry or a pickle [40]. Manipur's Bishnupur village produces some of the best soidon [34]. Vendors sell this on the street. Figure 4 shows the process of making soidon [15, 41].

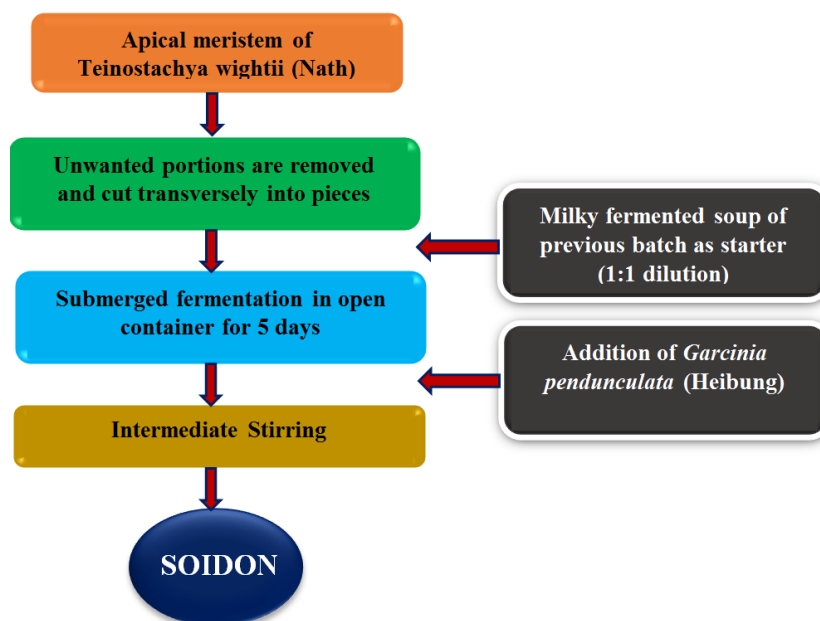


Figure 4. Soidon preparation (Soibam and Ayam, 2018).

2. Merits of Fermented Bamboo Shoots

2.1. Health Benefits

Fermented Bamboo shoots are consumed as part of the daily diet of tribal people in north-east India [2]. They are nutrient-dense and have a variety of health benefits including anti-free radicals, cholesterol reduction, anti-cancer, antioxidant, immune booster, anti-aging, cardiovascular disease prevention by protecting the heart, improved digestion, weight loss, blood pressure reduction, rich in flavones, glycosides, and antimicrobial properties, and probiotics [43]. Ayurveda recommends fermented bamboo shoots together with honey for people having piles and burning sensations during urination. Fermented bamboo shoots are low in fat, high in edible fibre, and vitamin C and E rich [43]. Bamboo leaves are also used to treat spasmodic diseases and stomach issues such as threadworms [33]. Soibum is made up of bamboo leaves and is high in antioxidants [43].

2.2. Medicinal Importance

Bamboo manna prepared from *Bambusa arundinacea* species is believed to be a good tonic for respiratory disorders in the Indo-Persian and Tibetan medicinal systems [5]. When mixed with palm-jaggery the juice of crushed bamboo shoots has protease activity which aids in protein digestion, cleansing wounds, maggot-infested sores, ulcers, and so on [27, 11, 36]. In Java, the sap from *Bambusa vulgaris* shoots is used to treat jaundice [44]. Bamboo salt tablets which are prevalent in Korea are shown to assist in the absorption of highly

therapeutic trace elements such as Cu, Zn, and Fe, and the removal of impurities and heavy metals [48]. It acts as an appetiser, a natural detoxifier, and a source of energy and nutrients for the body [16]. Apart from its nutritional value bamboo shoots are used in the cosmetics sector. Korea in particular has promoted delicious bamboo sea salt, which may be used in place of table salt in cooking and as a cleansing agent [16, 44].

2.3. Bamboo Shoots in Foreign Land

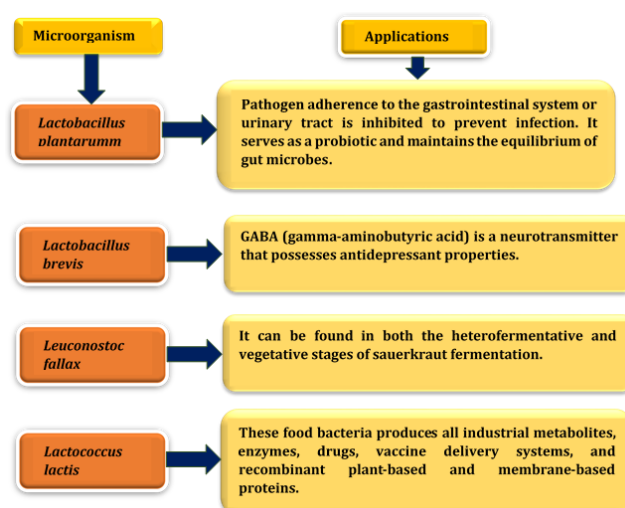


Figure 5. Benefits of Microorganisms in fermented bamboo shoots.

Bamboo shoots are utilized in India, Philippines, Korea, and Tibet, and other places (Figure 5). The anti-fatigue prop-

erty of *Bambusa blumeana* (Kawayangtinik) has been documented in Philippines [27]. Bamboo manna from the *Bambusa arundinacea* species is regarded as useful restorative for respiratory ailments in the Tibetan and Indo-Persian medical systems. In addition to food and medicine bamboo shoots are utilised in cosmetics. In Korea bamboo bath salts a cleansing product made from bamboo sea salt were introduced [41].

2.4. Industrial Consequence

Bamboo shoots are significant in the manufacturing industry. Bioethanol from bamboo is made with them [18, 33]. Besides, it obtains potassium, dietary fibres, carbohydrates, and vitamins. Bamboo shoots can be utilised to make useful xylooligosaccharides that are used in food, biodegradable polymers, nanoparticles, and pharmaceuticals [41].

2.5. Probiotics

Probiotic microorganisms are prevalent in fermented bamboo shoots such soibum, mesu, ekung, lung-siej, and soidon. *Lactobacillus plantarum*, a kind of LAB commonly found in fermented bamboo shoots, has potential probiotic properties and also cholesterol-lowering properties [43]. They have high hydrophobicity with *L. brevis*, which indicates that the bacterial culture can attach to the epithelial cell layer of the digestive system for successful colonisation [14, 2].

2.6. Fermented Bamboo Shoots Demerits

For the production and fermentation of bamboo-based fermented meals, a vast amount of water is required. Fermentation takes a long time process on whole. In the forest, a large quantity of bamboo shoots is chopped and sliced. Deforestation occurs as a result [30]. Consumption of fermented bamboo shoots can cause poisoning in some people. Bamboo stalks contain cyanogenic glycosides known as taxiphyllin, which can cause cyanide poisoning. This was described as a result of inhaling hydrogen cyanide gas (HCN) created by pickled bamboo shoots [43]. However when the advantages of fermented bamboo shoots are weighed against the negatives, the former outweighs the latter, making it a valuable source of food, functional food, and medicinal benefits.

2.7. Future Scope

Fermented bamboo shoots offer a number of benefits which can be applied in the future. Besides of several medical benefits they are also used in variety of other fields which are cost effective in the future. Thus, fermented bamboo shoots are potential in the future. It is possible in the regions listed below.

- 1) Industrial Application
- 2) Economic Value

2.8. Industrial Application

Fermented bamboo shoots can be employed in a variety of industrial applications such as food, pharmaceuticals, and biofuels. It is progressive in food industries. This can be employed like a source of bioactive substances, and also functional and healthy foods. It serves as a home for lactic acid bacteria that act as probiotics [47]. Although tribes of Northeast India produce fermented bamboo shoots locally. They have a wide range of applications and are considered as a plant-based source of food in Asian countries. This can be nothing more than “supporting sticks” for the destitute as well as a delectable meal. Due to probiotic bacteria fermented bamboo shoots are an essential feature in terms of diet, health, and therapeutic value in the international market [43]. It can be used to make ethanol or methane in the biofuel Industries. Bioethanol, a source of sugars, potassium, vitamins, and dietary fibres, are being produced from it [18]. Bio-methane can be made from bio-ethanol, which has a large amount of holocellulose and yields a lot of biomass [43].

2.9. Economic Importance

Fermented bamboo shoots have a great economic value. The tribal people in Northeast India usually produce these fermented bamboo shoots. Indigenous women such as the Meiteis only sell this in the local farmers market. However, due to its numerous dietary and health benefits as well as the medicinal values it can be imported to other countries [27, 31, 13]. Therefore, fermented bamboo shoots are valuable and hence will be continued in the future. Our suggestions for Fermented bamboo shoots, are extremely healthy and have a bright future in the food, pharmaceutical and other industries, thanks to their wide range of health advantages, medicinal characteristics, and probiotic nature. This should be advertised in national and international markets, rather than being kept buried in tribal marketplaces. More attention should be paid to the preservation of fermented bamboo shoots for a sustainability in order to prolong their shelf life.

3. Conclusion

Fermented bamboo shoots are rich in microorganisms, many of which are probiotics. They have anti-oxidant, anti-cancer, blood pressure-lowering, cardiovascular disease prevention and weight-loss properties to name a few. Apart from that, they can be used in a number of industries, including food, pharmaceuticals, and biofuels. They are monetary worth and the benefits are worth then drawbacks as they are referred as India's "green gold." They can be employed in variety of industries, such as food, pharmaceuticals, and biofuels.

Abbreviations

DM: Dry Matter

LAB: Lactic Acid Bacteria

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Author Contributions

Dr. M. Balasubramanian wrote the review article. Mr. S. Ramasubramanian, Dr. C. Ravinder Singh assisted in the evaluation and Mr. R. Muralikrishna editing of the article prior to its submission. The final manuscript was read and approved by all authors.

Conflicts of Interest

The authors declare no conflicts of interest.

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