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Bamboo shoots: an exploration into its culinary heritage in India and its nutraceutical potential

Biswajeet Acharya¹, Amulyaratna Behera^{1*} , Prafulla Kumar Sahu^{1*} , Fahima Dilnawaz^{1,4},
Suchismeeta Behera², Bimalendu Chowdhury³ and Durga Prasad Mishra¹

Abstract

Bamboo shoots are a unique and versatile ingredient that has been a part of traditional cuisine and medicine in India for centuries. This review article provides an overview of the culinary heritage of bamboo shoots in India, with a particular focus on the Northeast region. The article discusses the traditional methods of consumption and processing of bamboo shoots, along with the various traditional recipes that use bamboo shoots. The article also explores the nutraceutical potential of bamboo shoots and its bioactive components, along with the role of hydrogen cyanide in bamboo shoots. Furthermore, the impact of bamboo shoots on human health is analyzed. The review concludes with future prospects and the need for further research to fully understand the potential of bamboo shoots as a source of food and medicine.

Keywords Bamboo shoots, Bioactive substances, Hydrogen cyanide, Nutritional composition, Northeast India, Therapeutic use, Traditional cuisine, Sustainable Development Goals 9SDG, Goal-3 (Good health and well-being), Goal-15 (life on land)

Introduction

Bamboo, a member of the Poaceae family, is a tall, arborescent grass that is highly valued globally due to its ecological significance, versatility, and various human uses [1]. According to the Food and Agricultural Organisation of the United Nations (FAO), 800 million people are currently food and nutrition insecure [2]. To fulfill rising

global demand, FAO estimates that worldwide food production must be raised by 60% by 2050. However, due to water constraints, agricultural land cannot be increased [3]. The circumstances sparked interest in searching for alternative food supplies that may be cultivated in underutilized areas and are resistant to stressful environmental conditions [4]. Bamboo is one such underutilized plant with enormous potential to battle hunger and enhance health due to its nutritional and health-promoting characteristics [5, 6]. Bamboo can grow on degraded and marginal lands or in combination with other crops in agro-forestry systems [7, 8]. Bamboos assist to maintain and improve soil's physical, chemical, and biological qualities due to their high biomass build-up and plentiful litterfall [9]. The local ethnic people rely extensively on bamboo bioresources for a variety of reasons; further, many ethnobotanical applications of bamboo are unknown. The versatile applications of bamboo have led

*Correspondence:

Amulyaratna Behera
dr.amulyaratnabehera@gmail.com

Prafulla Kumar Sahu
kunasahu1@gmail.com

¹ School of Pharmacy, Centurion University of Technology and Management, Bhubaneswar, Odisha, India

² State Forensic Science Laboratory Rasulgarh, Bhubaneswar, Odisha, India

³ Roland Institute of Pharmaceutical Sciences, Berhampur, Odisha, India

⁴ Department of Biotechnology, Centurion University of Technology and Management, Jatni, Bhubaneswar, Odisha, India



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to the creation of monikers such as "Green Gold" and "Poor Man's Timber" [10]. In particular, it is a renewable, low-cost resource that is highly beneficial in remote areas of the developing world, where it helps to meet the basic needs of over two billion people. Bamboo shoots, which are considered a delicacy, can be consumed fresh, fermented, or roasted, and are a common vegetable in Asia, where they are prepared in various ways [11, 12]. Aside from being a dietary staple, and environmental protection, bamboo shoots have significant therapeutic potential due to their high nutritional value. They contain vitamins, amino acids, beta-carotene, phenolics, and phytosterols, which have numerous health benefits, including cholesterol-lowering, anticarcinogenic, neuroprotective, and antioxidant properties [13, 14]. Bamboo shoots are also an excellent source of fiber, which can prevent colon cancer and regulate blood cholesterol levels while being low in calories [15]. Despite the benefits of bamboo and its products, there is a lack of comprehensive scientific information on bamboo shoot cuisine in India, particularly in the Northeast region. Therefore, this review aims to provide an overview of traditional bamboo shoot preparation methods and their nutritional and therapeutic values. This study collected data from various high-citation publications and recent works in the field. Understanding the importance of bamboo and its culinary practices in India can contribute to the preservation of traditional knowledge and practices and promote the sustainable use of this valuable resource.

Methodology

The review was conducted by searching various databases, including Scopus, PubMed, Science Direct, Biorender, and Google Scholar, for high-citation publications and recent works on bamboo shoots. The search was focused on traditional methods of preparing bamboo shoot cuisine in India, particularly in the northeast, as well as scientific data regarding their nutritional status, therapeutic effects, and preference for bamboo shoots over other vegetables. The selection process involved screening titles, abstracts, and full texts of articles for relevance and quality, followed by data extraction and synthesis. The review followed a systematic and rigorous approach to ensure the accuracy and validity of the findings.

Bamboo shoots in India: a brief overview

Bamboo is widely distributed throughout India, with over 100 species available in the country. Bamboo shoots have been a part of the Indian diet for centuries, particularly in the northeastern states of the country, including Assam, Arunachal Pradesh, Manipur, Mizoram, Nagaland, and Tripura [16]. Additionally, efforts are being

made to promote bamboo cultivation and processing as a sustainable source of income for local communities. Locals in Odisha collect young bamboo culm sprouts (Karadis) from the woods to use in pickles and other food and drink preparations [17]. Additionally, it is flavor-added to various tomato- and lady's finger-based meals. Since young shoots are only accessible during the rainy season, the locals cut them into little pieces similar to noodles, dry them, and store them for the remainder of the year and called them "Hendua". It is the name for the dried shoots [18]. In Sambalpur, Orissa, India, the delicate bamboo shoots are shredded into juliennes and fermented to make kardi. It is a typical element in the Indian regions of Western Orissa and Kosal [19]. This fermented bamboo stalk is incorporated into several dishes, most notably the "amil", a sour vegetable soup [20]. Additionally, rice flour is used as a binder to create pancakes from it. To create a wonderful "saag" green leafy meal, the fragile shoots are cooked together with tender pumpkin leaves [21]. In southern India, rice is cooked over an open flame while soups are boiled in the hollows of young bamboo stalks. A variety of hot meat curries are placed in the bigger bamboo hollow and cooked over the fire. Food that has been cooked in bamboo has a flavor that is faint yet unique [22]. In Goa, bamboo shoots, often referred to as kill, are frequently consumed during the monsoon season [23]. In the Indian state of Jharkhand, curries and pickles are made using bamboo shoots. The "ginataanglabong" (labong with coconut milk and chiles) and "dinengdengnalabong" are the two most popular dishes for this (labong in fish bagoong with string beans, saluyot, and tinapa). They may be added to soups, salads, fried rice, curries, stir-fries, and snacks. Bamboo shoots are harvested in South Karnataka during their preferred season and preserved and salted in large quantities to be used out of season [24]. Figure 1 depicts a few newly gathered raw bamboo shoots from various sources in India.

Peoples of Northeast India and their culture

The Northeast region of India includes Arunachal Pradesh, Manipur, Assam, Mizoram, Meghalaya, Tripura, Nagaland, and Sikkim. [25]. Northeast India is divided into three geographical regions: the Eastern Himalayas, the North-Eastern Highlands, and the Brahmaputra and Barak valleys and plains [26]. Assam, Manipur, and Tripura all have hilly and plain regions. Bhutan, Burma/Myanmar, Bangladesh, Tibet (the People's Republic of China), and Nepal shared international boundaries. Ethno-history implies that individuals from Southeast Asia immigrated to Northeast India as Mongoloid tribes, forming significant ethnic-linguistic linkages [27]. Colonial control prevented Northeast Mongoloid ethnic



Physical appearance of Bamboo shoots before processing as food

Fig. 1 Bamboo shoots that have been collected from a variety of sources for the purpose of food processing in various bamboo species such as *Dendrocalamus hamiltonii*, *Dendrocalamus longispathus*, *Bambusa pallida*, *Bambusa vulgaris*, and *Bambusa jaintiana* in the Northeast India region. (Created with Biorender.com)

groups from connecting with other regions of Southeast Asia. Mongoloid people are divided into four primary groups: the Nagas, Kuki-Chin-Mizos, Khasi-Jintia-Garos, and Arunachal Pradesh tribes. Figure 2 depicts the location and visual depiction of Northeast India [28].

Culinary heritage of bamboo shoots in Northeast India

The culinary heritage of bamboo shoots has been a part of the Northeast region's food culture for centuries [29]. The use of bamboo shoots in various dishes is a testament to the rich and diverse culture of the area. Earlier, it served as a solution for food security during times of famine in distant and densely forested places [30]. Nearly all of the tribes in the area like eating bamboo shoots, and they each have their unique recipes and techniques for cooking with or flavoring bamboo shoots. According to the species or variation present in their localities, people have created culinary arts and processing techniques for using shoots as food [31]. Bamboo shoots may be eaten fermented, dried, or fresh depending on the species or variation. Species or varieties of bamboo with bitter-tasting shoots are often fermented or dried, whereas those with sweet tastes are typically flavored fresh [32, 33]. Figure 3 depicts the many traditional cuisines of Northeast India, particularly the states of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, and Tripura.

Fresh shoots as food

People in the area have classified various types of bamboo shoots into distinct dietary groups according to their extensive knowledge. There are many varieties of bamboo in the area that people love to use as fresh food, including *Phyllostachys mannii*, *Melocannabaccifera*, *Bambusa nutans*, *B. tulda*, *Dendroclamussikkimensis*, *D. giganteus*, and *Chimonobambusacallosa* (apical shoots) [34]. During the monsoon season, young shoots are collected, and the culm sheaths are removed to reveal the soft edible section. After being rinsed in water and sometimes immersed in water for a short while, the shoots are then cooked or fried in oil and eaten as vegetables or combined with pork and other vegetables [35]. Fresh bamboo shoots from these species are often made into pickles by other people. Some of the notable dishes made from fresh bamboo shoots are the Manipuri dish Usoi-Ooti, the Mizoram dish Rawtui-bai, and the Tripura dish Mia-gudhog [36].

Shoots dried and fermented for food

Another extremely typical activity in the area is drying bamboo shoots for sustenance. Due to the bamboo shoots' rapid development and short shelf life (two to three days), it takes relatively little time for the shoots to reach the proper eating stage (just one to two days after the shoots emerge out of the soil) [37]. People in the

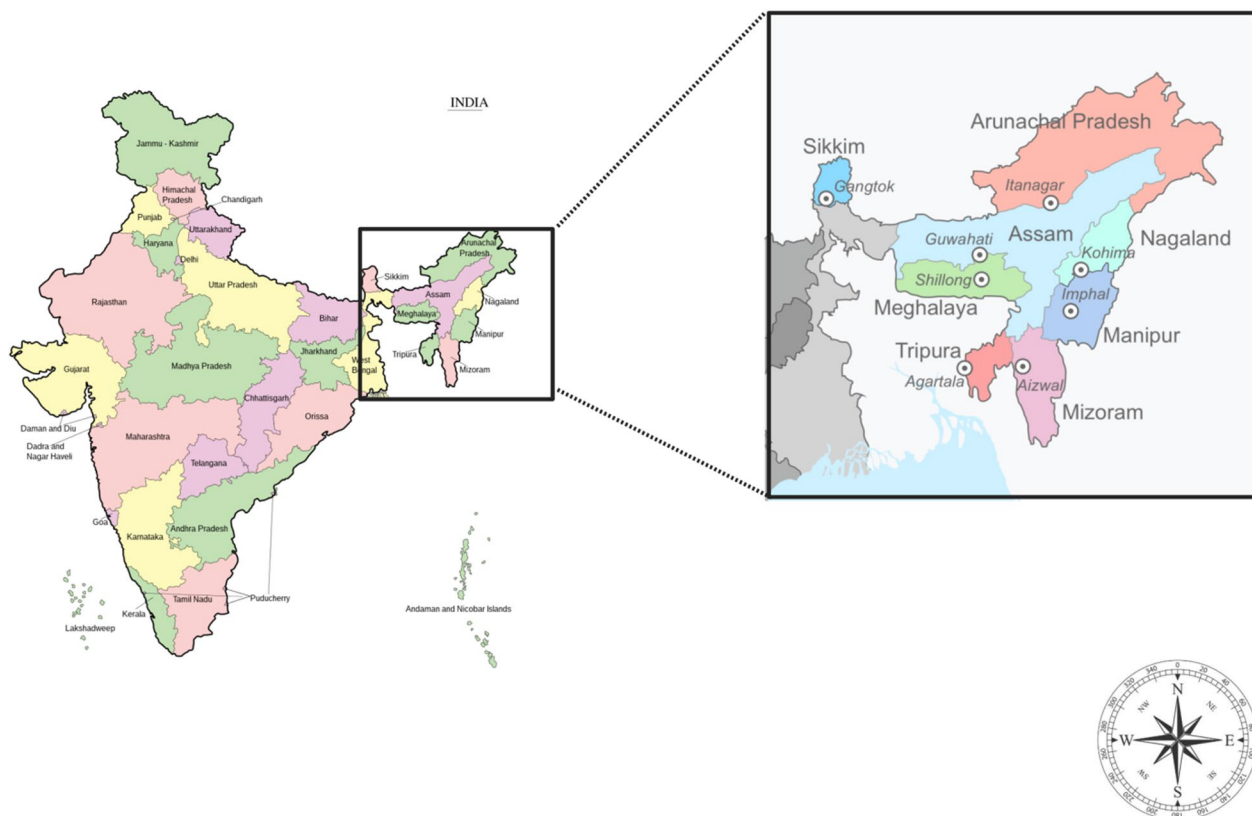


Fig. 2 An image depicting the numerous states in the region of Northeast India where bamboo shoots are the primary ingredient in the preparation of a variety of traditional fermented, dried foods and dishes (Created with Biorender.com)

area began drying bamboo shoots in the sun or over the fire to get around these issues by using bamboo shoots as food. These dried shoots may be used as a seasoning for a variety of meat and vegetable dishes throughout the year. In the Northeast area, notably in states like Manipur, Tripura, Arunachal Pradesh, and Meghalaya, young bamboo shoots are often fermented [38]. Several fermenting techniques are unique to a tribe, location, or species, or type of bamboo. The fermentation process was created locally, utilizing local resources, and verbally transmitted from one generation to the next [39]. Some Meghalayan tribes, including the Khasi, Garo, and Jaintia, primarily ferment the cut bamboo shoots in a water-filled container. The fermented shoots retain their crunchiness while acquiring a sour flavor that the locals like [40]. For fermenting using this water technique, the inhabitants of Meghalaya mostly favor the shoots of *Dendrocalamus hamiltonii*. The bamboo shoots are fermented by the Adi tribe in Arunachal Pradesh in a bamboo basket covered with ekkam (*Phrynium puberula*) leaves [41]. The Meetei people of Manipur ferment bamboo shoots either in an earthen pot or a bamboo basket. These fermented bamboo shoot products are known to the Meetei as soibum

or soijin [42]. To collect the exudates from fermented bamboo shoots, certain Naga tribes in the state of Nagaland ferment bamboo shoots in a conical bamboo basket with a hole at the bottom. The exudates are utilized all year round to flavor a variety of foods [43]. Bamboo shoots are also fermented by many tribes (Debbarma, Uchoi, and Chakma) in the state of Tripura, mostly in clay pots. According to the Debbarma and Uchoi tribes, fermented foods are known as Moiyakoshak, Medukeye, or Melyeamiley (Chakma tribe) [44]. The nutritional content of bamboo shoots is increased by the fermentation of the shoots using various techniques, which is also linked to a special group of bacteria. The proteins, vitamins, vital amino acids, and different beneficial substances are all increased throughout the fermentation process [45]. Table 1 displays several fermented and dried products of bamboo shoots prepared by different tribe communities of Northeast India.

Traditional other recipes for bamboo shoots

Shoots are eaten virtually all year long in Northeast India, either fresh (for around 6–7 months) or dried and fermented. Different areas' residents consume



Fig. 3 Traditional cuisine made from Bamboo shoots by the Northeast India people, **A** Usoi ooti, which is made by combining many vegetables like as maize, cucumber, and milk, is typically served with chapathi or paratha, **B** Soibam, which is made by combining other common spices like as coriander, is typically used as a diet meal, **C** Rawtui-bai, which is made by combining chillies and other spices, is typically eaten as salad, **D** Eromba, which is made by properly combining various types of vegetables such as potatoes, beans, and tomatoes with aromatic spices, **E** Singju, which is made by finely chopping bamboo shoots, is eaten as a salad, **F** Mia-Mosho is a mixed juice that is typically made by combining curd, chillies, coriander leaves, and other ingredients and then consumed (Created with Biorender.com)

bamboo shoots in various ways. Some populations enjoy fresh foods, such as the Mizo, while others choose both fresh and fermented foods, such as the Meetei people of Manipur and the Debbarma, Uchoi, and Chakma tribes of Tripura [50]. Manipur’s Meetei people produce delectable usoi-kangsu and Usoi-Ooti from young bamboo shoots. For Usoi-Kangsu or Usoi-Ooti, the fresh shoots are either cooked with pre-soaked peas and a little sodium bicarbonate after being cut into slices and soaked in water overnight to eliminate cyanogenic glycosides [51]. Fresh *Melocannabaccifera* and *Phyllostachys mannii* bamboo shoots are a favorite among Mizo people in the state of Mizoram [52]. Fresh *P. mannii* or *M.*

baccifera shoots are cooked and combined with green chillies, either with fermented pork or with native bean leaves. The dish is known as rawtui-bai. Additionally, fermented bamboo shoots are used in several cuisines, notably in Manipur, Nagaland, and Arunachal Pradesh [53]. The fermented shoots are used to prepare a variety of foods, either by themselves or with other ingredients, including pork, fresh or fermented fish, various vegetables, and spices [54]. Manipur’s Meetei people make Soijin-Eromba from bamboo shoots that have partly fermented. The fermented bamboo shoots are combined with fermented fish, chillies, and potatoes after being cooked. Catfish is also used to prepare soijin, along with

Table 1 Traditional fermentation and drying of bamboo shoots in Northeast India by their native tribals

Sl. No.	Name of the tribal communities	Native states	The local name of fermented and dried dishes	Types	Major apparatus used to ferment	Refs.
1	Khasi	Meghalaya	Pdam	Fermented	Plastic bottle	[38]
			Bastenga	Fermented	Bamboo basket while encased in banana leaves	[46]
2	Meetei	Manipur	Soibum	Fermented	Bamboo basket	[39]
			Soidon	Fermented	Earthenware containers	[39]
			Soijin	Fermented	Bamboo basket	[39]
3	Apatani	Arunachal Pradesh	Hikhu	Fermented	Banana leaves	[39]
			Hiring	Fermented	Bamboo cylinders	[47]
			Hithyi	Fermented	Bamboo basket	[40]
4	Adi	Arunachal Pradesh	Ekung	Fermented	Leaves of Bamboo	[40]
			Edung	Fermented	Bamboo cylinders	[40]
			Ikung	Fermented	Plastic bottle	[48]
			Ib	Dried	Earthen pot	[41]
5	Nyishing	Arunachal Pradesh	Eup	Fermented	Leaves of Bamboo	[41]
6	Limboo	Darjeeling and Sikkim	Mesu	Fermented	Bamboo stem	[41]
7	Mizo	Mizoram	Rawtuai rep	Dried	Earthen pot	[41]
8	Debbarma and Tripura Uchoi	Tripura	Moiya-Koshak	Fermented	Banana leaves	[49]
9	Chakma	Tripura	Midukye	Fermented	Banana leaves	[42]
			Melye-Amiley	Fermented	Earthen pot	[42]
10	Uchoi	Tripura	Moiya-Pangsung	Fermented	Mud pot	[42]

a healthy dose of oil and seasonings. The fermented bamboo shoots are used by the Khasi-Jaintia people to make pickles or to prepare pork. Different tribes in the state of Tripura, such as the Debbarma, Uchoi, Chakma, and Jamatia, employ fermented bamboo shoots to make chutney and other foods that are blended with fermented fish or other vegetables [55, 56]. Table 2 shows some noble dishes and cuisines prepared from bamboo shoots by the same communities in Northeast India.

Food items with bamboo shoot chunks and shreds

Bamboo shoots are a great ingredient for a variety of dishes, including stir-fries with noodles and other vegetables, cooking with rice, and preparing omelets and egg curries [60]. Along with beans, sambar, and other vegetables like *Carica papaya* and *Sechium edule*, bamboo shoots that have been chopped up taste great [61]. The crunchiness of papaya and *S. edule*, which cook into a paste, is preserved by little bits of bamboo shoots. Fried rice, ground nuts (like peanuts), and fresh or frozen peas go extremely well with bamboo shreds and little bits. Additionally, bamboo pieces are excellent for use in the preparation of besan-based foods like pakora and finger chips (gram flour) [62]. For creating these foods, fresh shoots of bamboo species like *P. mannii* and *B. tulda* are ideal since they have a pleasant flavor. Due to their hardness, the *D. hamiltonii* shoots' shreds and tiny bits may

also be used to make these foods, but they must first be boiled for at least 30 min [63].

Food items with bamboo shoot paste

One of the most practical and simple methods of long-term preservation is to turn bamboo shoots into a paste, which is also easier to pack and transport from one location to another [64]. The paste made from bamboo shoots may be kept in plastic bags or bottles made of glass. This paste may be used to make chapati and paratha, as well as bakery goods including cookies, bread, and biscuits. Additionally, the paste is used to season and thicken mutton or egg curries. The bamboo paste complements paneer (cottage cheese) quite nicely. Chapatti and paratha may be quite well-made using bamboo shoot paneer [65]. Table 3 provides an in-depth look at both the conventional and innovative meals that are made using different forms of bamboo shoots and other food substances that contribute to the dishes' enhanced deliciousness.

Nutraceutical potential of bamboo shoots

Bamboo shoots contain bioactive substances that can promote health and protect against chronic and degenerative diseases [66]. They are rich in fiber, which can prevent colon cancer and help manage blood cholesterol levels, and they are low in calories. Bamboo shoots are also an excellent source of vitamins, proteins, amino

Table 2 Northeast India’s traditional bamboo shoot recipes

Sl. no.	Tribe and state	Native states	Bamboo shoot recipe name	Types	Key ingredients	Refs.
1	Mizo	Mizoram	Rawtuai -Bawl (non veg)	Curry	Fermented porks, various spices like cardamom, clove, nutmeg etc	[57]
			Rawtuai -Bawl (veg)	Curry	Leaves of small beans, various spices like cardamom, clove, nutmeg etc	[50]
			Rawtuai-Kan	Fry	Fermented pork, green chilies and the leaves of tiny beans	[50]
			Rawtui-bai	Soup	Various spices like caraway, cumin seeds, mustards, cloves, ginger, garlic and onions	[50]
2	Meetei	Manipur	Usoi-Ooti	Curry	Dried pea	[58]
			Usoi-kangsu	Fry	Potatoes, fermented fishes and dried chilies	[51]
			Soijin-eromba	Curry	Potatoes, fermented fishes, lentils and dried chilies	[51]
			Ngakra-SoijinThongba	Curry	Cat fish, broccoli and various spices	[51]
3	Jamatia	Tripura	Mia-Gudhog	Fry	Fermented fish, chilli peppers, onions, and garlic	[50]
			Mia-Mosho	Fry	fermented fish, coriander leaves and chilies	[51]
			Mia –Chachiew	Stir fry	Rice flour, dried peas, or dal (also known as pulses)	[51]
			Mia-Mweiborog	Curry	Vegetables, fish, chiles, and onions	[50]
4	Adi	Arunachal Pradesh	Perok-Ikung	Curry	Chicken and spices	[50]
			Yekdin-Ikung	Curry	Pork and spices	[50]
			Engo-Ikung	Curry	Fishes and spices	[51]
			Itting-Oying	Curry	Vegetables and chicken/pork	[51]
5	Debbarma and Uchoi	Tripura	MoiyaKoshak-Shidal	Curry	Fermented fish	[59]
			Chakkhoi	Soup	Fermented vegetables	[52]
			Moya-Chakhoi	Curry	Vegetables and other spices	[52]

Table 3 The use of bamboo shoots as a food source in India in modern times

Food items with bamboo shoot	Key ingredients	Refs.
<i>Food items prepared with paste of bamboo shoots</i>		
Chapatti	Wheat flour, black cumin	[58]
Paratha	Wheat flour, black cumin and ghee	[58]
Bamboo Shoot Paste-Egg Curry	Onion, garlic, ginger, coriander, cumin, mustard, tomatoes and egg	[57]
Bamboo shoot paste-Mutton	Onion, garlic, ginger, coriander, cumin, mustard and goat meat	[58]
Bhujia	Coriander, cumin, mustard, potatoes and egg	[58]
Cookies	wheat flour, butter and oil, sugar, coconut powder, baking powder	[57]
Bread	Wheat flour, yeast and baking powder	[58]
Paneer	Coagulated milk, butter, peas	[58]
<i>Food items prepare with chunks and shreds of bamboo shoots</i>		
Pickles	Dried chilies, mustard oils, garlic, asafoetida	[58]
Bamboo shoot rice	Long grain rice, cumin seeds	[57]
Bamboo shoot fried Rice	Long grain rice, ground nuts, curry leaves, peas, cashew nuts	[58]
Bamboo shoot- Omelet	Egg, tomatoes, onions, coriander powders	[58]
Bamboo shoot- Noodles	Noodles, peas, carrots, beans, soya sauces and chili sauces	[57]
Pakora	Gram flour, onions, curry leaves	[58]
Finger chips	Potatoes, gram flours, chili powder	[57]

acids, beta-carotene, and various phenolics. Additionally, they contain phytosterols, which have cholesterol-lowering and anticarcinogenic properties, neuroprotective actions, and antioxidant actions [67, 68].

Table 4 A comparison of essential nutrition content in different species of bamboo shoots with normal diet

	Nature of shoots	Bamboo species	Fats (g/100 g)	Protein (g/100 g)	Carbohydrate (g/100 g)	Fibers (g/100 g)	Vitamin C (mg/100 g)	Vitamin E (mg/100 g)	Refs.
1	–	Normal requirement of nutrients in daily life	70	50	310	30	90	15	[69]
2	Raw shoots	<i>Dendrocalamus asper</i>	3.59	25.80	8.85	0.70	–	3.30	[70]
		<i>D. giganteus</i>	0.39	–	2.90	–	–	3.28	[70]
		<i>Bambusavulagaris</i>	0.20	25.70	5.10	0.70	0.69	3.28	[70]
		<i>Bambusa nutans</i>	1.00	21.10	3.40	0.76	0.91	5.30	[70]
3	Fermented shoot	<i>Dendrocalamus asper</i>	–	–	–	–	–	–	[71]
		<i>D. giganteus</i>	–	–	–	0.70	–	–	[71]
		<i>Bambusavulagaris</i>	–	–	–	0.96	–	–	[69]
		<i>Bambusa nutans</i>	–	–	–	0.75	–	–	[71]
4	Boiled shoots	<i>Dendrocalamus asper</i>	–	17.10	3.10	–	–	–	[71]
		<i>D. giganteus</i>	–	11.66	–	0.21	0.32	1.09	[71]
		<i>Bambusavulagaris</i>	–	13.50	5.00	–	–	–	[70]
		<i>Bambusa nutans</i>	–	17.30	5.10	–	–	–	[71]

Incorporating bamboo shoots into one’s diet can be a great way to improve overall health and well-being. However, it is important to note that not all bamboo shoots have the same nutritional composition, and some may contain harmful toxins if not prepared properly [69]. It is best to seek advice from a healthcare professional or a reliable source before consuming bamboo shoots. Table 4 includes a list of the necessary nutrient content in different species of bamboo shoots in three forms: fermented, raw, and cooked bamboo shoots.

A study on five bamboo species found in Northeast India showed that they contain important bioactive components that support various pharmacological and nutraceutical actions. These species include

Dendrocalamushamiltonii, *Dendrocalamuslongispathus*, *Bambusa pallida*, *Bambusa vulgaris*, and *Bambusajaintiana* [72]. Bamboo shoots contain various bioactive substances, such as phenolic acids, catechin, caffeic acid, protocatechuic acid, p-coumaric acid, p-hydroxybenzoic acid, ferulic acid, syringic acid, chlorogenic acid, gallic acid, vanillic acid, and several flavonoids, including isovitexin, isoorientin, tricetin, orientin, and vitexin [73]. Many of these substances have anti-inflammatory and antioxidant properties, which make bamboo shoots a potentially beneficial addition to one’s diet. For example, isovitexin has been shown to help protect against liver damage, and orientin has been linked to a decreased risk of cardiovascular disease [74]. Several bioactive components

(See figure on next page.)

Fig. 4 Chemical structures of bioactive compounds of Bamboo species (*Dendrocalamus hamiltonii*, *Dendrocalamus longispathus*, *Bambusa pallida*, *Bambusa vulgaris*, and *Bambusa jaintiana*) in the Northeast India region. The chemical name and IUPAC names are as follows: **Cholesterol**- (3S,8S,9S,10R,13R,14S,17R)-10,13-dimethyl-17-[(2R)-6-methylheptan-2-yl]-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol); **Stigmasterol**- (butanedioate;(3S,8S,9S,10R,13R,14S,17R)-17-[(E,2R,5S)-5-ethyl-6-methylhept-3-en-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol); **Campesterol**- (3S,8S,9S,10R,13R,14S,17R)-17-[(2R,5R)-5,6-dimethylheptan-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol); **Stigmastanol**- (3S,5S,8R,9S,10S,13R,14S,17R)-17-[(2R,5R)-5-ethyl-6-methylheptan-2-yl]-10,13-dimethyl-2,3,4,5,6,7,8,9,11,12,14,15,16,17-tetradecahydro-1H-cyclopenta[a]phenanthren-3-ol); **Beta-sitosterol**- (3S,8S,9S,10R,13R,14S,17R)-17-[(2R,5R)-5-ethyl-6-methylheptan-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol); **Ergosterol**- (3S,9S,10R,13R,14R,17R)-17-[(E,2R,5R)-5,6-dimethylhept-3-en-2-yl]-10,13-dimethyl-2,3,4,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol); **Phenolic acid**- (O-hydroxybenzoic acid); **Protocatechuic acid**- (3,4-dihydroxybenzoic acid); **P-hydroxybenzoic acid**- (4-Hydroxybenzoic acid); **Catechin**- (2R,3S)-2-(3,4-dihydroxyphenyl)-3,4-dihydro-2H-chromene-3,5,7-triol); **Caffeic acid**- (E)-3-(3,4-dihydroxy phenyl) prop-2-enoic acid); **Syringic acid**- (4-hydroxy-3,5-dimethoxy benzoic acid); **Ferulic acid**- (E)-3-(4-hydroxy-3-methoxyphenyl)prop-2-enoic acid); **Vanillic acid**- (4-hydroxy-3-methoxy benzoic acid); **Gallic Acid**- (3,4,5-trihydroxy benzoic acid); **Chlorogenic acid**- (1S,3R,4R,5R)-3-[(E)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy-1,4,5-trihydroxycyclohexane-1-carboxylic acid); **Orientin**- (2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-8-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one); Iso-orientin- (2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-6-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one); **Vitexin**- (5,7-dihydroxy-2-(4-hydroxyphenyl)-8-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one); **Isovitexin**- (5,7-dihydroxy-2-(4-hydroxyphenyl)-6-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one); **Tricetin**- (5,7-dihydroxy-2-(4-hydroxy-3,5-dimethoxyphenyl)chromen-4-one)

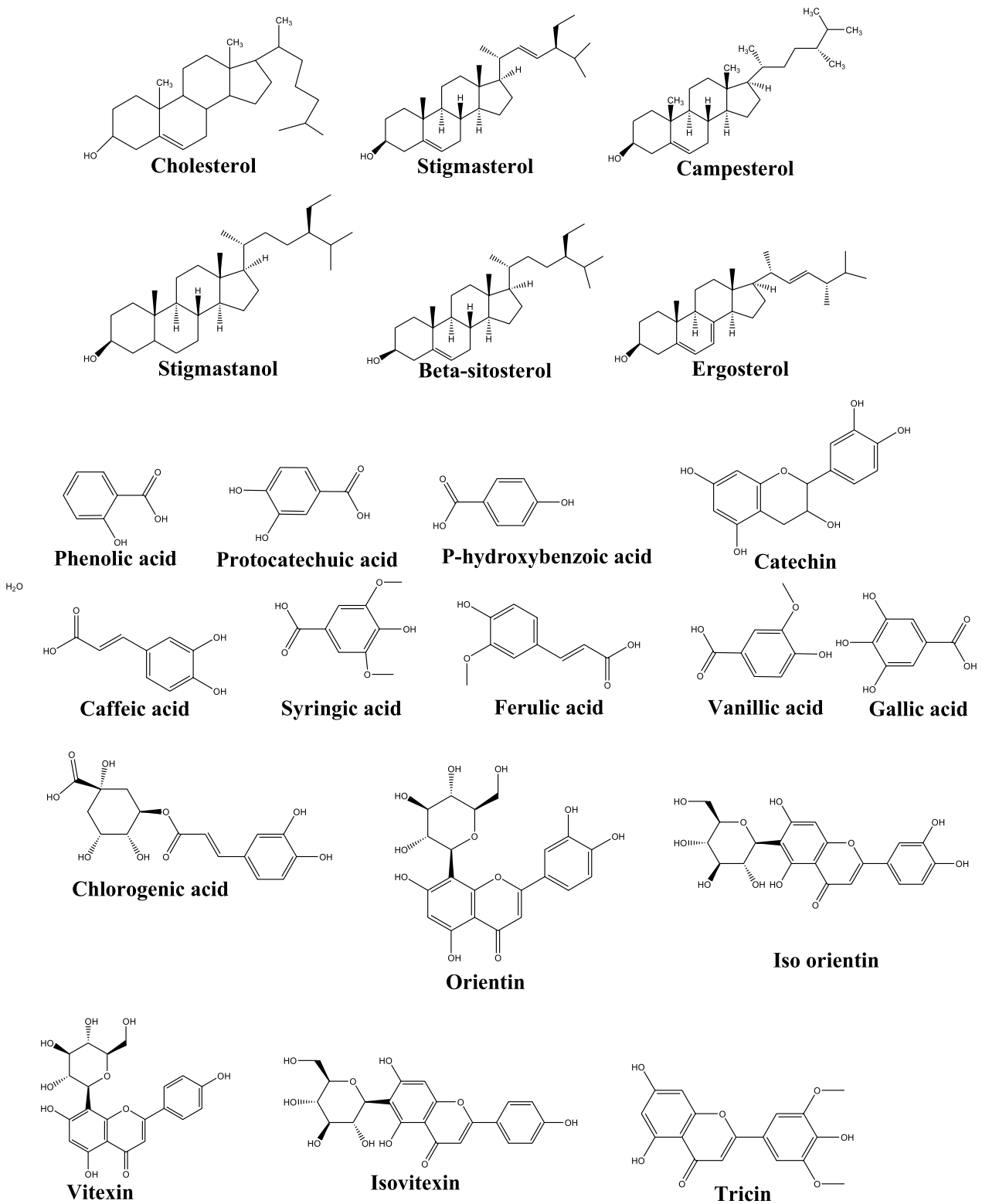


Fig. 4 (See legend on previous page.)

Table 5 Major phytochemicals in several bamboo species found in Northeast India

Phytochemical classification	Flavonoids			Phenolic acids			Lignans		Stilbenes		Terpenoids			Alkaloids		References
	Orientin, vitexin	Tricin, luteolin, apigenin	Tricin, luteolin, apigenin	Ferulic acid, p-coumaric acid	Chlorogenic acid, caffeic acid	Galic acid, caffeic acid, ellagic acid	Pinoresinol	Klason lignin, 1.5% acid-soluble lignin	Resveratrol	Chalcone, gramistilbenoids A, B, and C	β -sitosterol, lupeol, campesterol	Thymol, carvacrol	Bamboosides	Betaine, arecaidine, cordycepin, arecoline		
Abundance	High	High	High	High	High	High	Moderate	Moderate	Low	Low	Moderate	Moderate	Low	Low		
<i>Bambusa vulgaris</i>	Yes	No	Yes	Yes	No	No	Yes	No	Yes	No	Yes	No	Yes	No	[66,75]	
<i>Dendrocalamus hamiltonii</i>	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	[67]	
<i>Dendrocalamus longispatus</i>	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	[67,76]	
<i>Bambusa pallida</i>	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	[68]	
<i>Bambusa jaintiana</i>	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	No	No	No	[68]	

of *Bambusa vulgaris* are listed in Fig. 4 along with their IUPAC names. Table 5 provides a summary of various bioactive constituents from various categories, as well as their availability and pharmacological activity.

Role of cyanogenic glycosides in bamboo shoots

Cyanogenic glycosides are a class of nitrile-containing plant secondary metabolites that, upon enzymatic breakdown, produce cyanide (cyanogenesis) [77]. At least 2000 plant species, some of which are consumed as food, contain cyanogenic glycosides. They are components of plants generated from amino acids and created as secondary metabolites. The cyanogenic glycoside taxiphyllin, a p-hydroxylated mandelonitrile tiglochinin, is found in bamboo shoots. In the hydrolysis of taxiphyllin, glucose and hydroxybenzaldehyde cyanohydrin are produced. The further breakdown of benzoaldehyde cyanohydrin yields hydroxybenzaldehyde and hydrogen cyanide [78, 79]. The emission of hydrogen cyanide determines how dangerous cyanogenic glycosides and their derivatives are. Toxicity has been linked to the genesis of various chronic disorders and may cause acute cyanide poisoning. Animals, including humans, may become poisonous to cyanide at concentrations of 0.5–3.5 mg HCN per kilogram of body weight. Human cyanide poisoning has been associated with symptoms including vomiting, stomach pain, diarrhea, convulsions, and in extreme instances, death [80]. The capacity of cyanogenic glycosides to hydrolyze either spontaneously or in the presence of an enzyme to create cyanide as the end product of their hydrolysis is connected with their toxicity [81]. Thus, the amount of free cyanide produced during hydrolysis is used to assess the hazardous amounts of cyanogenic glycosides. The overall amount of cyanogenic glycosides in the diet is thus difficult to quantify.

Employing appropriate processing techniques can mitigate the risk of HCN toxicity in bamboo shoots. The traditional methods used by Adi women, as well as the techniques discovered by Bhatt et al. [82], offer promising solutions. Additionally, the optimal cooking parameters and pre-soaking methods may be effective in reducing cyanide levels [83]. Finally, It has been also reported that, the low-temperature superheated steam drying can eliminate HCN from bamboo shoots [84]. These findings provide valuable insights into the safe preparation of bamboo shoots, allowing individuals to enjoy their nutritional benefits without concern for toxicity.

Therapeutic use of bamboo shoots

Bamboo shoots' therapeutic characteristics may be used pharmacologically. Research on bamboo's traditional application has been conducted extensively. Various

plant products are assessed based on their traditional uses and medicinal benefits based on the efficacy of treatment, leading to the discovery of newer and more cost-efficient drugs for treating a variety of ailments [85]. Bamboo has been used in traditional medical practices in South Asian nations to treat hypertension, sweating, and paralysis [86].

According to recent studies, the presence of phytochemicals in bamboo shoots has a variety of health benefits, including the prevention of cancer, aiding in weight loss, lowering cholesterol levels, and enhancing appetite and digestion. People on sugar-restricted diets can use it because it is also low in sugar. The shoots also contain anticarcinogenic compounds and including them regularly in the diet significantly lowers the number of free radicals that can result in dangerous carcinogens [87]. It is thought that bamboo extract may have anti-inflammatory and antioxidant properties. Bamboo shoots are reported to have antiviral, antibacterial, and anticancer qualities due to the presence of lignans, a key component of fiber [88]. Additionally, they include other potential phytochemicals, which are strong antioxidants and may be anti-cancer, anti-bacterial, and anti-fungal [89]. *Bambusa vulgaris* also has pharmacological properties, including antipyretic [90], analgesic [91], anti-inflammatory [92], antidiabetic [93], antioxidant [94], antiviral [95], diuretic [96], abortifacient [97], hepatoprotective [98], anti-anxiety [99], and is effective in renal impairment [100]. Table 5 includes other major pharmacological actions with appropriate literature and citations. Figure 5 depicts another function of the bamboo plant, whose societal worth is growing by the day and should be investigated further.

Conclusion with prospects

The increasing interest among scientists, consumers, and the food industry in foods that promote health and well-being is due to our society's economic, cultural, and scientific growth, resulting in a significant shift in our eating habits and way of life. As a result, there is a growing demand for functional and nutraceutical foods that contain bioactive chemicals that have health-promoting properties. Bamboo shoots have been widely consumed in India and have a lot of potential to be used in various meals worldwide. There are several edible species of bamboo found across the globe that are consumed in various ways and have local names.

Bamboo plays an essential role in the daily lives of indigenous people in Northeast India because of its vast usefulness as a source of traditional food, building

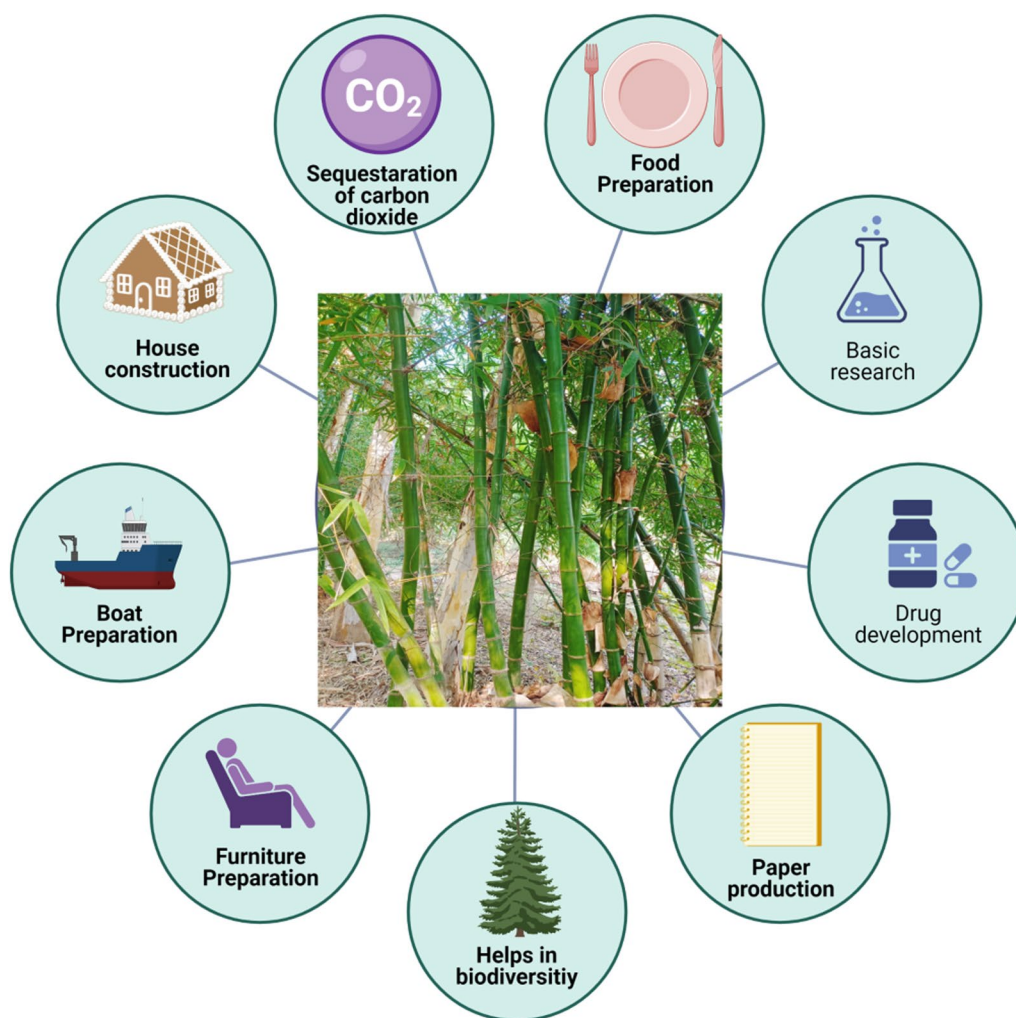


Fig. 5 Application of bamboo in multi-sector like food and drug preparation, several wooden stuff preparations, managing bio-diversities, etc. (Created with Biorender.com)

materials for homes, and raw materials for the creation of practical household goods and handicraft products. Bamboo shoots are not only tasty and healthy, but they also contain bioactive chemicals that are good for health and possess many pharmacological actions that need to be discovered. Although the presence of cyanogen glycosides in bamboo shoots is a risk, boiling them in water or brine is an effective technique to remove them. The distinct aroma of bamboo shoots encourages people to adopt them as a part of food by processing traditional cuisine with different components.

Despite the numerous health benefits of bamboo shoots, limitations still exist, and future studies are needed to discover more potential uses. For instance, while the presence of phytosterols in bamboo shoots has many health benefits, including the prevention of cancer, aiding in

weight loss, and lowering cholesterol levels, additional studies are needed to determine the exact mechanisms and effects. Additionally, more research is needed to investigate the pharmacological properties of specific bamboo species, including *Bambusa vulgaris*, which has shown to have antipyretic, analgesic, anti-inflammatory, antioxidant, antiviral, diuretic, hepatoprotective, anti-anxiety, and renoprotective properties. Innovative techniques of preparation should also be widely publicized to increase the demand for bamboo shoots.

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Author contributions

BA and PKS did conceptualization and idea for the article. AB and BA done literature search and design of the work. BC and PKS performed data analysis

and interpretation. BA and DPM done writing—original draft preparation. FD and SB contributed to writing—review and editing. All authors have read and approved the final manuscript.

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