Chapter 17
Application of Bamboo in the Food and Pharmaceutical Industry

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Abstract Bamboo is an enduring plant blessed with a plethora of functional components that make it incredibly useful for the development of functional foods. It has served as food and medicine since ancient times. Bamboo-based products commercially available in the markets of different countries are canned and fermented shoots, pickle, shoot powder, bamboo juice and water, beverages, and bamboo shoot fortified food products. The bioactive compounds such as phenols, flavonoids, and phytosterols in bamboo shoot and leaves provide youthful feeling, athletic energy, and longevity to regular consumers. Recent studies have also shown that bamboo shoot is a good source of acetylcholine, which has preventive effects against Alzheimer's disease. Bamboo salt, bamboo vinegar, bamboo extracts, and bamboo silica are some important bamboo-based pharmaceutical preparations that are now gaining importance. Although some chemical compounds in shoots are labeled as antinutrients, their role as potential healthy biochemical components for the prevention of several health problems has been scientifically elucidated. The importance of bamboo shoots linked to functional health-modulating functions are anti-oxidation, antidiabetic, anticancer, cardiovascular, anti-inflammatory, antimicrobial, antiviral, and antihypertensive. Bamboo being rich in nutrients, antioxidants, and bioactive compounds has attracted significant research and commercial interest and is gaining popularity worldwide. This chapter discusses the nutrients and bioactive compounds in bamboo and their potential role in developing novel food and pharmaceutical products to improve health globally.

Keywords Bamboo · Nutrients · Bioactive compounds · Antioxidants · Health food

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17.1 Introduction

Bamboo is one such precious resource that has played a significant role in human civilization since time immemorial for subsistence to entertainment and emotional support of people living in tropical and subtropical parts of the world, in particular regions like East and South Asia (Chongtham and Bisht 2021). Due to extensive use and application of bamboo for each and every aspect of life, these regions are in fact known as "Bamboo Civilization," and countries like China are called "Bamboo Civilized Country" (Jiayan 2014). It serves as construction material, in making of various agricultural and household items, and as fiber and fabrics for food and medicine (Chongtham and Bisht 2021). Bamboo is rightly called "plant with thousand faces due to its multiple uses." In the present time too, bamboo is ahead of steel in tensile strength, and at the same time, it is proving better than plastic in plasticity and multiple applications. For centuries bamboo has been a favorite food for many animals and for humans as well (Nirmala et al. 2011; Chongtham and Bisht 2021). Bamboo is a rare example that has become a staple food for animals like the giant panda, basically a carnivorous animal (Xue et al. 2015). In many societies and cultures also, bamboo is revered as high valued food. Like in Japan the young juvenile shoots of bamboo are called "king of forest vegetables," and in the Tang Dynasty of China, it was said, "there is no banquet without bamboo" (Nirmala et al. 2011).

Bamboo is also considered valued medicine and health rejuvenating tonic particularly in countries like China, Japan, Korea, and India, and every part of the plant like leaves, shoots, sap, nodes, internodes, and roots was used for treating various ailments and for various health benefits (Wróblewska et al. 2019). The use of "banslochan" (an amorphous substance collected from the culms of some bamboos) as an important ingredient in one of the earliest formulated health tonic called "Chyawanprash" in India is there for centuries (Nirmala et al. 2011). Similarly, the use of bamboo leaves, shavings, and sap in the Chinese traditional medicine is very old (Chongtham and Bisht 2021). Old works of literature like Compendium Materia Medica (a pharmaceutical text of Ming Dynasty, 1368–1644), Ayurveda, and Bhavprakash Nighantu (old medical compilations in India) have mentioned a number of medicinal uses of bamboo (Nirmala et al. 2011). However, for the last 100–200 years the use of bamboo for food and medicine has been pushed back due to industrialization, change in food habits, and the popularity of allopathic medicines. But now bamboo is being seen as a solution for various new-age diseases like diabetes, obesity, cancer, and various cardiovascular diseases and reported to be endowed with antioxidants, antibacterial, antifungal, anti-fatigue, cholesterol-lowering, and neuron protecting properties (Hu et al. 2000; Fujimura et al. 2005; Zhang et al. 2006). Bamboo is no more a neglected crop or poor man's food but a rich man's delicacy and superfood (Chongtham and Bisht 2021). Recent studies revealed the potential of bamboo, rich in nutrition, presence of various bioactive compounds, and several health benefits, that can prevent many chronic diseases that has led to increasing interests among researcher for its application in the food, beverages, and

pharmaceutical industries (Nirmala et al. 2011, 2018; Nirmala and Bisht 2017; Bajwa et al. 2015; Rawat et al. 2016; Saini et al. 2017; Chongtham and Bisht 2021). Bamboo leaves are being used for tea and alcoholic drinks, young and old culms, shavings, and the sap is being used for the formulation of various medicinal products, and young juvenile shoots of many species of bamboo have taken the status of health food and are being consumed as fresh, dried, paste, and fermented and in fortified forms (Chongtham and Bisht 2021).

In recent years, global attention has increased for a sustainable and long-term solution for micronutrient deficiency supporting the relation between nutrition and advancement in agriculture and food system (Black et al. 2013). There is also a need of integrated approaches in food sector regarding the rising situation for noncommunicable diseases due to the fast-changing lifestyle of the present century (Roos et al. 2019). According to the report of the World Health Organization (WHO 2010), the fast-changing lifestyle with poor choices of nutritious food and several other critical factors have increased the risk of noncommunicable diseases like cardiovascular diseases, obesity, diabetes, osteoporosis, cancer, gastrointestinal diseases, and respiratory diseases. Thus, there is a significant change in the food industries due to shifting of consumer's choice from healthy foods to food that prevents nutrition-related diseases and improves the physical and mental well-being of consumers leading to the development of modern functional foods. Recent studies revealed the potential of bamboo in food sector being rich in nutrition, presence of good quantity of bioactive compounds, and several health benefits that can prevent many chronic diseases that has led to increasing interest among researcher for its application in the food industry (Nirmala et al. 2011; Nirmala and Bisht 2017; Bajwa et al. 2015; Rawat et al. 2016; Saini et al. 2017). There have been recent reports in the food sectors for the uses of bamboo, such as shoots in bakery products (Santosh et al. 2018, 2019), leaf extract for treatment of ailments (Das 2019), source of natural bioactive compounds and antioxidants (Nirmala et al. 2018), dried bamboo culm for the physical characteristics and proximate composition of fortified products in relation to sugar and fat substitute formulation (Felisberto et al. 2019), and bamboo fiber for improving the sensory quality of food products (Silva et al. 2020). Phenol, phytosterol, and dietary fiber are extensively used in industrial purposes for their several health benefits; however, the enhancement of such bioactive compounds in fortified products is not studied in detail so far. Bamboo is rich in mineral (Chongtham et al. 2020), but the potential in improving the content in the product is still to be explored. This chapter discusses the importance of bamboo in the food sector and its application in the food and pharmaceutical industries.

17.2 Bamboo as Food

Young juvenile shoots, leaves, culms, and seeds of many bamboo species are food to many animals and birds and are, for some, exclusive food (giant panda and golden lemurs) and seasonal delicacy for animals like mountain gorilla (Xue et al. 2015).

For humans, young juvenile shoots of some 100–200 species and seeds of few species are food in parts of the world like in East and Southeast Asian countries. The consumption of bamboo seeds is known in few regions particularly in South India (Prasad et al. 1985). The seeds of *Bambusa arundinacea* and *Phyllostachys bambusoides* are called "bamboo rice" in some parts of South India and cooked and eaten as rice occasionally (Prasad et al. 1985). There are reports that during the famine of 1883, *B. arundinacea* produced seeds in abundance which were consumed at many places of South India for sustenance (Prasad et al. 1985).

Young juvenile shoots are consumed in many parts of East and Southeast Asia (Collins and Keilar 2005; Chongtham and Bisht 2021). China, Japan, Korea, and the northeastern regions of India are the main bamboo shoot producers as well as consumers. Fresh shoots have a crisp and crunchy taste and are used in making soups, stir-fries, snacks, salads, fried rice, spring rolls, and several other dishes (Nirmala et al. 2011). The most common species preferred as fresh or canned are *Phyllostachys pubescens*, *Dendrocalamus hamiltonii*, *D. giganteus*, *Bambusa balcooa*, *B. bambos*, *Thyrsostachys siamensis* (Chongtham and Bisht 2021). Shoots are also consumed as fermented dried, pickled, and processed/canned (Bashir 2010). In North-East India, bamboo shoots are mainly consumed as fermented and there are a number of fermentation processes that are developed according to bamboo species as well as the taste of the people (Giri and Janmejay 2000). Fermentation has two major roles in bamboo shoot processing, one is to increase the shelf life of shoots for more than 1 year, which is otherwise just 2–3 days, and secondly decrease the content of taxiphylin and other antinutrients in the shoots (Sarangthem and Singh 2013; Choudhury et al. 2012). Fermentation also increases the food value of shoots by producing additional bioactive compounds and increasing the content of proteins, amino acids, and mineral elements (Nirmala et al. 2011). Bamboo shoots being seasonal crops with very fast growth and very short shelf life after harvest need proper processing techniques for future use, easy transportation, and an increase of the shelf life. Some bamboo species have a very high amount of antinutrients and bitterness and need proper processing to make shoots fit for consumption. Simple washing, boiling, soaking, sun drying, and fermentation are the traditional methods of processing bamboo shoots particularly in India and many other South-East Asian countries (Chongtham and Bisht 2021). Now bamboo shoots are also being processed with various modern methods with high-tech machines and tools particularly in countries like China, Taiwan, Korea, and Thailand. Methods like freeze-drying, hot air drying, oven drying, solar drying, osmotic dehydration, and canning are the most common ones (Wongsakpairod 2000; Madamba 2003; Xu et al. 2005; Cheng 2006; Chongtham and Bisht 2021).

Bamboo shoots are consumed in different forms (fresh, dried, fermented, powder, paste) and in different ways, like just boiled in Japan, stir-fry and soups in China and Korea, heavily spiced in Thailand, Indonesia and India, or pickled in Myanmar, Nepal and in many other South-East Asian countries (Table 17.1). The juvenile bamboo shoots are delicious as well as rich in nutrient components mainly proteins, carbohydrates, minerals, vitamins, dietary fiber, and various bioactive compounds like phenols and phytosterols which exhibit a great potential of bamboo shoots as a

Table 17.1 Traditional bamboo shoot dishes of different countries

Country	Local name of bamboo dish	Reference
India	*Khorisa*, *Tuaithur*, *Byapu*, *Papu sududanjii*, *Usoi-Ooti*, *Usoi-kangsu*, *Soibum thongba*, *Soibum eronba*, *Tenga*, *Lung-seij*, *Jhur*, *Jingtah*, *Rawtui-bai*, *Rhuchak*, *Voyen*, *Handua*, *Pu-erh*, *Sabji*, *Mia-gudhog*	Tripathi (2011); Tamang et al. (2012); Bhatt et al. (2005); Singh et al. (2007); Jeyaram et al. (2009); Bisht et al. (2015); Kithan et al. (2015); Kumar et al. (2017); Thomas et al. (2014)
China	*Ulanzi*	Qing et al. (2008)
Japan	*Menma*, *Takenoko gohan*	Tripathi (2011)
Thailand	*Ma khua proh*, *Dom jud naomi*, *Naw-mai-dong*, *Kaeng kae*	Phithakpol et al. (1995); Tangkanakul et al. (2006); Kumar et al. (2017)
Philippines	*Ginataang labong*, *Diendeng na labong*	Phithakpol et al. (1995)
Indonesia	*Gulai rebung*, *Sayur ladeh*, *Lumpia*	Bhatt et al. (2003); Tripathi (2011)
Vietnam	*Sup mang cua*	Avieli (2005)
Korea	*Jooksun*	Kim et al. (2007)
Nepal and Bhutan	*Alu tama*, *Mesu*	Tamang (2005)

food resource (Bhargava et al. 1996; Chen et al. 1999; Kumbhare and Bhargava 2007; Nirmala et al. 2007, 2008, 2018; Satya et al. 2010; Choudhury et al. 2012). Bamboo shoots are quite rich in some dietary components like potassium, silica, selenium, manganese, dietary fiber, phenols, phytosterols, amino acids, and vitamin (Satya et al. 2010; Chongtham and Bisht 2021). This neglected vegetable is richer in many nutritional components compared to common vegetables we consume regularly (Nirmala et al. 2011). Moreover, bamboo shoot is low in calories and have fewer carbohydrates, nearly negligible fats, and cholesterols and have a high amount of phytosterols, which is quite good for the present-day sedentary lifestyle of the majority of people particularly in industrial and well-developed countries. The amount of phytosterols in bamboo shoots ranges from 91–265 mg/100 g dry weight which is quite a good amount compared to many other food items.

Recent studies revealed the potential of shoots being rich in nutrition, presence of a good quantity of bioactive compounds, and several health benefits that can prevent many chronic diseases that have led to increasing interest among researchers for its application in the food industry (Nirmala et al. 2011; Nirmala and Bisht 2017; Bajwa et al. 2015; Rawat et al. 2016; Saini et al. 2017). Bamboo shoot in fresh and fermented forms is an important ingredient in the cuisines across the Himalayas. For centuries, young edible bamboo shoots have remained one of the highly palatable dishes in delicacies (Satya et al. 2012) and an important forest vegetable in the traditional culinary preparation of China for more than 2500 years. In India, the use of bamboo shoots is still limited to the Northeast region and some other hilly parts in South and North-West India. Though, bamboo shoots remain a neglected crop, consumed usually by the local people, the delicacy of the vegetables is in high demand in up-scale markets and standard restaurant, which is why shoots are no longer considered as "poor man's timber" but are considered as "rich man's

delicacy" (Nirmala et al. 2011). Fresh shoots have a crisp and crunchy taste and are used as an ingredient in making soups, stir-fries, snacks, salads, fried rice, spring rolls, and several other fried dishes (Nirmala et al. 2011). In countries like China, Japan, and India, they are sold in various processed forms like dried, fermented, pickled, and canned (Bashir 2010). Popular fresh and fermented bamboo shoot products of Northeast India include *Usoi*, *Soibum*, and *Soidon* of Manipur; *Hirring*, *Ekung*, and *Eup* of Arunachal Pradesh, *Rep* of Mizoram; *Kardi* or *amil* of Assam, and *Lung-Siej* of Meghalaya. Some of the famous local dishes include *Usoi-Ooti*, *Soibum eromba* of Manipur, *Rawtui-bai* of Mizoram, and *Mia-gudhog* of Tripura (Thomas et al. 2014; Bisht et al. 2015). Young tender shoots are used for the preparation of fermented products *Soibum* and *Soijin*, whereas apical meristem is used for the preparation of *Soidon* in Manipur, India. Some of the local delicious dishes of bamboo shoots of other countries include *Gulai rebung*, *Sayur ladeh* of Indonesia, *Ulanzi* of China, *Mesu* of Nepal and Bhutan, *Takenoko gohan* of Japan, *Naw-mai-dong* of Thailand, *Ginatang labong* of the Philippines, *Sup mang cua* of Vietnam, and *Jooksun* of Korea (Table 17.1) (Phithakpol et al. 1995; Avieli 2005; Tamang 2005; Kim et al. 2007; Qing et al. 2008).

17.3 Nutritional Properties of Bamboo

Bamboo in food sectors is known mostly for young shoots and leaves which are used for feeding humans and animals (Halvorson et al. 2011). In many Asian and African countries, bamboo leaves are used as fodder for many animals like the giant panda, golden bamboo lemur, elephants, as well as cattle, sheep, and goat, and they are also considered of highly medicinal value in many Asian countries (Chongtham and Bisht 2021). Singhal et al. (2011) analyzed the nutritional content in the leaves of 27 bamboo species and reported rich crude protein and low crude fiber content with 70% silica of the total ash and other insoluble mineral matters. Andriarimalala et al. (2019) analyzed the chemical composition and nutritive values of the leaves of nine bamboo species, *Bambusa balcooa*, *Bambusa bambos*, *Bambusa vulgaris*, *Bambusa tulda*, *Dendrocalamus asper*, *Dendrocalamus giganteus*, *Dendrocalamus strictus*, *Phyllostachys aurea*, and *Gigantochloa pseudoarundinacea*, which are used as cattle fodder and did not affect the ruminant's diet and the milk production. Due to higher content of water, crude protein, phosphorus, and less tannin in the leaf of bamboo species *Bonia saxatilis*, the Assamese macaques (*Macaca assamensis*) predominantly consume bamboo leaf (Li et al. 2020). Bamboo leaves are also rich in antioxidant, and the polyphenols and the extract from the leaves of *Phyllostachys* Sieb. have been certified for use in edible oil, meat product, aquatic product, and various other food additive (Lu et al. 2006). The antioxidant extract from bamboo leaves is also used to improve the storage stability and extend the shelf life of seafood (Xie et al. 2020). Bamboo leaf extracts are used in traditional medicine due to content of phenolic acids and flavonoids such as cryptochlorogenic acid,

chlorogenic acid and neo-chlorogenic acid, caffeic acid, ferulic acid, luteolin and tricin, isoorientin, orientin, vitexin, and isovitexin (Ma et al. 2020).

The juvenile bamboo shoots are delicious as well as rich in nutrient components mainly proteins, carbohydrates, minerals, vitamins, and dietary fiber which exhibit great potential as a food resource (Table 17.2). Nutritional analysis of bamboo shoots has been conducted by many researchers which showed a high amount of dietary fiber, vitamins, minerals, protein, antioxidants, and polyphenols and low amount of fat (Bhargava et al. 1996; Chen et al. 1999; Bhatt et al. 2005; Kumbhare and Bhargava 2007; Nirmala et al. 2007, 2008, 2018; Satya et al. 2010; Choudhury et al. 2012). In 1953, the US Bureau of Human Nutrition and Home Economics reported the average food value of many species of bamboo shoot (Young 1954). Xia (1989) analyzed the nutritional profile of *Phyllostachys pubescens* locally known as Moso bamboo from Guangdong province, China, and reported the content of reducing sugar, protein, crude fat, fatty acids, vitamins, minerals, and amino acids. Tripathi (1998) analyzed the nutritional value of edible shoots of *Bambusa vulgaris*, *B. bambos*, and *Melocanna baccifera* and observed 88.8% moisture, 3.9% protein, 0.5% fat, 5.7% carbohydrate, and 1.1% minerals, particularly in *B. bambos*. Young shoots are a good source of dietary fiber due to which the calorie content of shoot is very low (Shi and Yang 1992; Nirmala et al. 2011). A high amount of dietary fiber in bamboo shoot is associated with several health benefits that include reducing the risk of cardiovascular diseases, hypertension, obesity, cancer, and certain gastrointestinal disorders (Anderson et al. 2009; Lattimer and Haub 2010; Brennan et al. 2012). It also controls or lowers the level of sugar in the blood, promotes regularity and prevents constipation, lowers blood cholesterol levels, and helps in weight control (Behall 1997). Shoots are also a good source of health-promoting bioactive compounds such as phytosterols, flavonoids, and phenolic acids which show effectiveness in decreasing blood pressure and cholesterol, increasing appetite, and having anticancerous and antidiabetic properties (Park and Jhon 2009; Hong et al. 2010; Nirmala et al. 2011; Singhal et al. 2013). Bamboo shoot has a good profile of minerals mainly potassium, calcium, manganese, zinc, chromium, copper, and iron, plus lower amounts of phosphorus and selenium (Shi and Yang 1992; Saini et al. 2017; Bajwa et al. 2019). Fresh bamboo shoots are also a good source of thiamine, niacin, vitamin A, vitamin B6, and vitamin E (Visuphaka 1985; Xia 1989; Shi and Yang 1992). Shoots contain 17 amino acids, 8 of which are essential for the human body (Qiu 1992; Ferreira et al. 1995). It is rich in amino acid tyrosine comprising about 57–67% of total amino acids (Kozukue et al. 1983). Fat content is comparatively low (0.26–0.94%), and the total sugar content, 2.5% on average, is lower than that of other vegetables, whereas the water content is 90% or more (Nirmala et al. 2011). Lignans in bamboo shoots have anticancer, antibacterial, and antiviral activities (Fujimura et al. 2005). High content of cellulose in bamboo shoot promotes digestion by increasing the peristaltic movement of the intestines (Fujimura et al. 2005; Shi and Yang 1992). Recent studies have also shown a good source of acetylcholine in the upper portion of *Phyllostachys bambusoides*, which is an important neurotransmitter in the cholinergic nervous systems of vertebrates and insects, which has preventive effects against Alzheimer's disease (Singhal et al.

Table 17.2 Nutritional content in fresh juvenile shoots of some edible bamboo species (macronutrients g/100 g fresh weight, vitamins mg/100 g fresh weight, and minerals mg/100 g dry weight) (Adapted from Chongtham and Bisht 2021)

Species	*B. balcooa*	*B. bambos*	*B. nutans*	*C. callosa*	*D. giganteus*	*D. hamiltonii*	*M. baccifera*	*P. mannii*
Carbohydrate	3.22 ± 0.13	1.72 ± 0.08	2.76 ± 0.10	1.26 ± 0.01	5.65 ± 0.06	3.33 ± 0.04	2.22 ± 0.01	2.73 ± 0.02
Amino acids	2.13 ± 0.03	2.31 ± 0.01	2.21 ± 0.02	4.61 ± 0.02	2.26 ± 0.04	2.33 ± 0.02	2.43 ± 0.05	2.36 ± 0.06
Starch	1.21 ± 0.02	1.24 ± 0.08	1.36 ± 0.08	0.71 ± 0.02	2.38 ± 0.04	1.74 ± 0.02	0.85 ± 0.02	1.09 ± 0.02
Protein	3.70 ± 0.09	5.87 ± 0.39	3.47 ± 0.23	4.57 ± 0.03	3.64 ± 0.05	3.37 ± 0.03	3.22 ± 0.02	3.24 ± 0.03
Fat	0.47 ± 0.01	0.53 ± 0.04	0.70 ± 0.05	0.43 ± 0.02	0.49 ± 0.02	0.42 ± 0.02	0.34 ± 0.02	0.44 ± 0.01
Vitamin C	2.63 ± 0.02	1.63 ± 0.03	1.52 ± 0.03	2.59 ± 0.03	2.21 ± 0.02	2.48 ± 0.07	1.44 ± 0.04	3.23 ± 0.05
Vitamin E	0.42 ± 0.03	0.60 ± 0.04	0.49 ± 0.02	0.81 ± 0.02	0.56 ± 0.03	0.68 ± 0.03	0.40 ± 0.07	0.53 ± 0.04
Potassium	4230 ± 60	5980 ± 60	5230 ± 60	6570 ± 60	4590 ± 50	5230 ± 60	6480 ± 60	6660 ± 70
Phosphorus	560 ± 30	750 ± 50	580 ± 30	750 ± 50	540 ± 30	560 ± 40	620 ± 40	930 ± 60
Magnesium	210 ± 10	230 ± 20	200 ± 10	220 ± 10	190 ± 10	200 ± 10	300 ± 20	230 ± 20
Calcium	180 ± 10	190 ± 10	180 ± 10	220 ± 20	210 ± 20	150 ± 10	210 ± 20	130 ± 10
Silicon	150 ± 2.8	130 ± 1.8	160 ± 2.8	100 ± 1.8	120 ± 1.6	190 ± 2.8	120 ± 2.4	70 ± 1.2
Iron	8.2 ± 0.8	8.0 ± 0.8	8.8 ± 0.8	6.5 ± 0.6	6.9 ± 0.6	7.4 ± 0.3	7.2 ± 0.8	9.1 ± 0.8
Zinc	6.8 ± 0.4	10 ± 0.6	9.5 ± 0.6	8.0 ± 0.8	6.1 ± 0.4	6.8 ± 0.4	10 ± 0.8	10 ± 0.8
Copper	2.6 ± 0.4	2.5 ± 0.4	1.9 ± 0.2	3.4 ± 0.6	5.1 ± 0.8	2.6 ± 0.4	2.8 ± 0.4	2.6 ± 0.4
Manganese	2.5 ± 0.2	3.6 ± 0.2	9.7 ± 0.8	3.5 ± 0.4	1.3 ± 0.1	1.2 ± 0.1	5.5 ± 0.6	9.0 ± 0.8
Nickel	0.9 ± 0.1	0.7 ± 0.1	0.8 ± 0.1	0.9 ± 0.1	0.8 ± 0.1	0.7 ± 0.1	1.0 ± 0.1	0.8 ± 0.1

Note: *B., Bambusa; C., Chimonobambusa; D., Dendrocalamus; M., Melocanna.* Data presented in mean values ± standard deviation ($n = 3$)

2013). Bamboo salt, bamboo vinegar, bamboo extracts, and bamboo silica are some important bamboo-based pharmaceutical preparations which are now gaining importance. Akakabe et al. (2006) mentioned that bamboo vinegar can act as an insecticide and bactericide and can be used as a deodorant. Bamboo salt is known to have many therapeutic effects on diseases such as inflammations, viral diseases, diabetes, circulation, organ disorders, and cancer (Hwang et al. 2008). In the traditional medicine of the Republic of Korea, it is used for treating cancer patients (Singhal et al. 2013). With major advancement in technology and reports of the nutritional profile, bamboo shoot is recommended as a healthy food.

17.4 Bamboo as Medicine

The medicinal properties of bamboo have been recognized for centuries particularly in Indian and Chinese traditional medicine systems. Leaves, seeds, bamboo shavings, sap, culms, rhizomes, and shoots are all reported to have medicinal properties (Nirmala et al. 2011; Wróblewska et al. 2019; Chongtham and Bisht 2021). In China, the medicinal properties of bamboo are compiled in the Compendium of Materia Medica (during the Ming Dynasty, 1368–1644). Similarly, in ancient India, bamboo is defined as, "Bamboo by nature is laxative, frigid, seminal, curative, palatable, bladder purifier and full of astringent juice. It splits cough, subsides bile and cures leprosy, bloody flux, wounds and swelling" (Tewari 1992). In India, the use of bamboo for medicinal and health benefits goes back to nearly 8000 to 10,000 years. Banslochan (also called Tabasheer), an amorphous substance collected from the culms of some species of bamboo, is being used in the health tonic called "Chyawanprash" since the time of Chyawanrishi (a sage named Chyawan) who lived nearly 10,000 years ago (Chongtham and Bisht 2021). Banslochan is used in various Ayurvedic prescriptions like for asthma, cough, etc. and considered as an astringent, stimulant, febrifuge, cooling tonic, antispasmodic, and aphrodisiac (Nirmala and Bisht 2017). Banslochan (Tabasheer) is also used in the preparation of various Chinese traditional medicines like Chenjin-wan, Quinghua-ditan-tang, and Xiaoer-qizhen-dan along with other bamboo parts like shaving, leaves, and other plant herbs (Chongtham and Bisht 2021). In Chinese medicines, bamboo sap is also extensively used which is considered to help to treat cold and fever and resolves phlegm or loss of consciousness associated with phlegm heat (Sangeetha et al. 2015). Bamboo shoots for the treatment of ailments such as chickenpox, skin diseases, infections, ulcers, etc. are also reported since ancient times (Sangtam et al. 2012).

The leaves of bamboo are also endowed with various medicinal properties and are a rich source of antioxidants and various bioactive compounds. The leaves of bamboo are given for the treatment of cough, fever, leprosy, and hematemesis in the Ayurvedic and Chinese traditional medicine systems (Das 2019). The leaves also have anti-inflammatory, antiulcer, antimicrobial, and hypoglycemic activities (Das 2019). The aqueous and ethanolic extract of bamboo leaves proved effective against

Staphylococcus aureus, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Bacillus* sp. (Das 2019). The BLE (bamboo leaf extract) is mainly composed of flavonoids, lactones, and phenolic acids which have preventive measures to the reactive oxygen species (ROS) in the body and protects DNA, proteins, and lipids from the highly reactive ROS (Wróblewska et al. 2019; Chongtham and Bisht 2021). In South India, the *Bambusa* leaf extract is reported to be administered for the strengthening of cartilage and for treating osteoarthritis and osteoporosis (Sangeetha et al. 2015). This leaf extract has a vital role in the integrity of the bones, arterial walls, skin, teeth, gums, hair, and nails and is used to alleviate eczema and psoriasis (Vanithakumari et al. 1989). In eastern Asia, particularly in Japan, the leaves of *Sasa senanensis* (Kumaizasa) are called "Sasa Health" for centuries due to various health benefits of the *S. senanensis* leaf extract (Sangeetha et al. 2015). The extract of Kumaizasa leaves is also reported to have antitumor activity and immune potentiating efficiency.

The seeds of bamboo are very nutritious and also reported to have medicinal and aphrodisiac properties. The Kani tribes of Tamil Nadu in South India believe that the seeds of *Bambusa arundinacea* enhance the fertility (Sangeetha et al. 2015) and the explosive increase of rodent population in the northeastern region of India is also considered due to the fertility-increasing property of the seeds of *Melocanna baccifera* on which they feed and then multiply (Biswas et al. 2016).

17.5 Pharmaceutical Properties of Bioactive Compounds in Bamboo Shoot

Pharmaceutical properties of the bamboo shoot were recorded dating back to the Ming Dynasty (1368 to 1644), with a statement as: "It's slightly cold, sweet, non-toxic, and it quenches thirst, benefits the liquid circulatory system and can be served as a daily dish" (Yuming et al. 1999). The medicinal benefits of bamboo shoot in human health were proclaimed for more than 2000 years in archaic Chinese medicinal books, such as "Ben Chao Qui Zheng," "Ben Jing Feng Yuan," "Yao Pin Hua Yi," and "Jing Yue". It mentioned promoting digestion through the peristalsis motion of the intestine and also to be effective in cardiovascular disease prevention (Nirmala et al. 2011). Bamboo leaves are also used as herbal medicines in different areas of the world due to major bioactive compounds such as phenolic acids including cryptochlorogenic acid, chlorogenic acid and neo-chlorogenic acid, caffeic acid, ferulic acid, luteolin, and tricin (Zhu et al. 2018). Leaves are also rich in flavonoids such as isoorientin, orientin, vitexin, and isovitexin (Yang et al. 2014). The phenolic extracts from bamboo leaves have the properties of treating inflammation, hypertension, cardiovascular disease, arteriosclerosis, and cancer (Ma et al. 2020). The extract from *Phyllostachys nigra* leaves which is rich in isoorientin, orientin, and isoitexin is reported to have increased coronary blood flow and prevent myocardial ischemia in rabbits (Fu et al. 2005). Leaves of *Sasa quelpaertensis* Nakai are used for tea as a therapeutic purpose with antidiabetic, diuretic, and anti-

Table 17.3 Health benefits of bamboo shoots

No.	Potential activities	Reference
1	Antioxidant and anti-inflammatory effects of bamboo shoot extracts	Hu et al. (2000); Lu et al. (2005); Bajwa et al. (2019)
2	Antimicrobial and antifungal activities of bamboo shoot	Fujimura et al. (2005)
3	Cholesterol and body weight lowering effects of bamboo leaves extract	Ryou et al. (2012)
4	Antioxidant and phenolic extract of bamboo leaves promotes digestion	Ma et al. (2020)
5	Anti-inflammatory and anti-obesity effects of bamboo leaf extract	Moon-Hee et al. (2017)
6	Anti-obesity activities of bamboo shoot	Li et al. (2016)
7	Antiapoptotic activities of bamboo shoot	Hong et al. (2010)
8	Anticancer, antibacterial, antiviral activity of bamboo shoot fiber	Shi and Yang (1992); Hiromichi (2007)
9	Antidiabetic properties of bamboo leaves	Yang et al. (2010)
10	Anti-fatigue activity of bamboo shavings	Zhang et al. (2006)
11	Cholesterol-lowering properties of bamboo shoot	Park and Jhon (2009)
12	Antihypertension effects of bamboo shoot extract	Liu et al. (2013)
13	Bamboo lignin protects neurons from oxidative stress	Akao et al. (2004)
14	Bamboo shoot extract enhances the antioxidant activities	Bajwa et al. (2019)

inflammatory effects (Ryou et al. 2012). The old-age practice of bamboo for numerous health benefits is now authenticated with modern research in terms of preventing cancer, weight control, maintaining cholesterol level, and improving appetite and digestion, and there are many bamboo-based nutraceutical products available in the market (Shi and Yang 1992; Fujimura et al. 2005; Park and Jhon 2009; Nirmala et al. 2011; Ryou et al. 2012; Bajwa et al. 2015, 2019; Yang et al. 2010; Ma et al. 2020) (Tables 17.3 and 17.4).

17.5.1 Phytosterol

Bioactive compounds are phytochemicals that are typically present in small quantities in foods that promote health benefits by modulating the metabolic process of the human body system such as antioxidant activity, enzyme activity, receptor activity, and also gene expression (Correia and Beirao-da-Costa 2012). Bamboo shoots are a rich source of bioactive compounds with various dietary fiber components, phytosterols which are a precursor of many pharmaceutical steroids and phenols that act as free radical terminators, metal chelators, and singlet oxygen quenchers (Srivastava 1990; Kris-Etherton et al. 2002; Nirmala et al. 2011). There are several health

Table 17.4 Nutraceutical products of bamboo

No.	Product name	Health benefits
1	Biotin bamboo extract	Promotes and maintains skin tissue
2	Swanson bamboo extract	Silica supplement for hair, skin, and nails
3	BioFinest bamboo extract	Weight control, improves digestion, boosts immune system
4	NutriStart bamboo silica	Skin, ligament, tendon, and bone supplement
5	Boo bamboo Suncare natural sunscreen	Protection from broad-spectrum UVA/UVB
6	Enerex bamboo silica	Antiaging; strengthens the arteries, joints, nail, hair, skin, and bones
7	Silicon mix bamboo extract	Hair and skin supplement
8	Shudhanta herbal bamboo capsule	Aids digestion, immune booster, antibiotic and anti-inflammatory
9	Herbal papaya bamboo leaf extract liquid	Improving blood circulation
10	Bamboo Nutra	Antiaging, anti-obesity
11	Bamboo flex	Anti-inflammatory, remineralization, and development of bone structure
12	Bonusan forte	Anti-fatigue, supports energy metabolism, good for nervous system
13	Guozen bamboo leaf essence	Purifies blood and strengthens bones
14	Hawlik Cappillary capsules	Improves hair health
15	Lambert silica capsules	Contributes to structure and resilience of connective tissue, synthesis of bone collagen and cartilage
16	Sanacel	Improves digestion
17	Silice de Bambou	Prevents premature aging, preserves skin youthfulness, and promotes strong hair and healthy bones and teeth
18	Solaray bamboo capsules	Stimulates collagen synthesis in bone and connective tissue

benefits of phytosterols such as anticancer, cholesterol-lowering, anti-inflammatory, and anti-atherogenicity properties (Shi and Yang 1992; Hu et al. 2000; Lu et al. 2005; Hiromichi 2007; Park and Jhon 2009) (Table 17.3). In the pharmaceutical and nutraceutical industry, bamboo shoot can be a good source of phytosterol which is used for manufacturing steroids (Nirmala et al. 2011). The concentration of phytosterol in edible bamboo species, *Bambusa tulda* and *Dendrocalamus giganteus*, was estimated in fresh and fermented shoots (Srivastava 1990). The study reported higher phytosterol content in fermented shoots (1.6–2.8%) which was higher than the fresh shoot (0.21–0.39%). Lachance and He (1998) studied the phytosterol composition from the crude extract of various bamboo species, *Bambusa oldhami*, *B. edulis*, *Pseudosasa usawai*, *Dendrocalamus latiflorus*, *Phyllostachys edulis*, *P. pubescens*, and *P. makinoi*. The crude extract of bamboo shoots was analyzed using gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS), and several mixtures of phytosterol were reported

including sitosterol, sitastanol, stigmasterol, beta-sitosterol, stigmasta-3,5-dien-7-one, stigmast-4-en-3-on, stigmasta-5,22-dien-3-ol, campesterol, and derivatives. The study also reports the lowering of cholesterol levels in mammals that include LDL (low-density lipoprotein) cholesterol, serum cholesterol, and total liver lipids with the administration of crude extract of bamboo shoot containing phytosterol. Analysis of phytosterol composition in the bamboo shoot extract from *Phyllostachys pubescens* using gas chromatography-mass spectrometry (GC/MS) led to the identification of 17 compounds with main components of 26% β-sitosterol, 10.5% of 9,12-octadecadienoic acid, and 9.83% of 9,12,15-octadecatrienoic acid (Lu et al. 2009a). The total phytosterol content in shoots of *Bambusa balcooa* and *Dendrocalamus strictus* was also studied in fresh and fermented shoots (Sarangthem and Singh 2003). Phytosterol concentration was higher in fermented bamboo shoots of *B. balcooa* (0.61%) and *D. strictus* (0.42%) as compared to the fresh shoot which ranges from 0.14 to 0.18%. Lu et al. (2009b) analyzed the phytosterol composition of bamboo species *Pleioblastus amarus*, *Dendrocalamus latiflorus*, *Phyllostachys pubescens*, and *P. praecox* using a UPLC-APCI-MS method and identified the presence of phytosterol compounds, 6-ketocholestanol, desmosterol, ergosterol, cholesterol, lanosterol, cholestanol, stigmasterol, campesterol, β-sitosterol, and stigmastanol (Fig. 17.1.).

Nirmala et al. (2014) reported the total phytosterol content of fresh juvenile shoots of *Bambusa balcooa*, *B. tulda*, *B. nutans*, *Dendrocalamus giganteus*, *D. hamiltonii*, *D. membranaceus*, and *D. strictus* which ranges from 0.19 g/100 g to 0.13 g/100 g with maximum content in *B. balcooa* and *D. hamiltonii*. Similarly, Ingudam and Sarangthem (2016) also reported maximum content of phytosterol with 0.29 g/100 g dry weight in *D. hamiltonii* during analysis in four different portions of shoots, i.e., apex, middle, the base, and the culm sheath covering the soft shoots of twelve bamboo species *Dendrocalamus brandisii*, *D. strictus*, *D. giganteus*, *D. flagellifer*, *D. hamiltonii*, *D. sericeus*, *Bambusa tulda*, *B. balcooa*, *B. nutans*, *B. kingiana*, *B. khasiana*, and *Cephalostachyum pergracile*. Apex portion of the shoot was observed with maximum content of phytosterol in *D. hamiltonii*, whereas minimum content was observed in culm sheath with 0.03 g/100 g dry weight in *D. strictus*. The total phytosterol content in *Dendrocalamus latiflorus* was reported as 0.16 g/100 g dry weight in the fresh shoot (Thounaojam et al. 2017). Santosh et al. (2019) evaluated the total phytosterol content in *D. hamiltonii* shoot paste used for fortification and reported a maximum content of 0.47 g/100 g dry weight which was higher than previously reported 0.19 g/100 g dry weight (Nirmala et al. 2014) and 0.29 g/100 g dry weight (Ingudam and Sarangthem 2016) (Table 17.5).

Fig. 17.1 Phytosterols isolated from bamboo shoot

Table 17.5 Phenol and phytosterol (mg/100 g) content in some species of fresh bamboo shoot

No.	Species	Phenol (mg/100 g)	Phytosterol (mg/100 g)	Reference
1	*Bambusa balcooa*	191.37 ± 2.62	190.00 ± 0.01	Nirmala et al. (2014)
		–	190.0 ± 10.5	Ingudam and Sarangthem (2016)
		101.65 ± 2.75	–	Badwaik et al. (2015)
2	*B. bambos*	360.00 ± 0.05	–	Pandey and Ojha (2014)
		760.00 ± 0.47		Pandey et al. (2012)
3	*B. kingiana*	–	222.00 ± 10.8	Ingudam and Sarangthem (2016)
4	*B. khasiana*	–	289.00 ± 5.8	Ingudam and Sarangthem (2016)
5	*B. nutans*	275.36 ± 2.04	–	Nirmala et al. (2014)
		–	94.00 ± 7.4	Ingudam and Sarangthem (2016)
		489.83 ± 5.08	164.20 ± 0.30	Bajwa et al. (2015)
6	*B. pallida*	79.85 ± 3.98	–	Badwaik et al. (2015)
7	*B. tulda*	443.97 ± 6.09	130.00 ± 0.01	Nirmala et al. (2014)
		390.00 ± 0.07	–	Pandey and Ojha (2014)
		960.00 ± 0.56		Pandey et al. (2012)
		–	190.00 ± 15.7	Ingudam and Sarangthem (2016)
		80.54 ± 3.21	–	Badwaik et al. (2015)
8	*Cephalostachyum pergracile*	–	215.00 ± 31.8	Ingudam and Sarangthem (2016)
9	*Dendrocalamus asper*	580.00 ± 0.07	–	Pandey and Ojha (2014)
		840.00 ± 0.25		Pandey et al. (2012)
10	*D. brandisii*	–	276.60 ± 1.60	Ingudam and Sarangthem (2016)
11	*D. flagellifer*	–	144.30 ± 15.8	Ingudam and Sarangthem (2016)
12	*D. giganteus*	222.40 ± 6.26	150.00 ± 0.08	Nirmala et al. (2014)
		336.56 ± 9.3	136.23 ± 2.40	Bajwa et al. (2015)
		–	198.70 ± 1.3	Ingudam and Sarangthem (2016)
13	*D. hamiltonii*	264.83 ± 6.75	190.00 ± 0.04	Nirmala et al. (2014)
		–	293.80 ± 16.1	Ingudam and Sarangthem (2016)
		586.36 ± 4.3	198.27 ± 2.30	Bajwa et al. (2015)
		88.23 ± 4.38	–	Badwaik et al. (2015)
		610.00 ± 0.01	470.00 ± 0.02	Santosh et al. (2019)
14	*D. latiflorus*	414.43 ± 6.26	160.76 ± 0.08	Thounaojam et al. (2017)
		612.24 ± 1.8	146.33 ± 3.10	Bajwa et al. (2015)
15	*D. membranaceus*	302.73 ± 8.53	–	Nirmala et al. (2014)

(continued)

Table 17.5 (continued)

No.	Species	Phenol (mg/100 g)	Phytosterol (mg/100 g)	Reference
16	*D. sericeus*	–	266.00 ± 14.5	Ingudam and Sarangthem (2016)
17	*D. strictus*	271.23 ± 5.64	140.00 ± 0.03	Nirmala et al. (2014)
		0.63 ± 0.08	–	Pandey and Ojha (2014)
		1250 ± 0.68		Pandey et al. (2012)
		–	212.40 ± 12.1	Ingudam and Sarangthem (2016)

Data presented in mean values ± standard deviation ($n = 3$)

17.5.2 Phenol

Plant phenols or polyphenols are secondary metabolites of plants that act as free radical terminator, metal chelators, and singlet oxygen quenchers (Kris-Etherton et al. 2002). There are several health-promoting properties of phenol such as antioxidant and antimicrobial activity, due to which bamboo shoot, rich in phenol, is gaining importance in the food industry (Park and Jhon, 2010). Satya et al. (2009) reported the total phenolic content of bamboo shoots ranging from 153.91 to 222.81 GAE (gallic acid equivalents)/100 g dry weight in four species, *Bambusa balcooa*, *B. tulda*, *B. vulgaris*, and *Dendrocalamus hamiltonii*. Park and Jhon (2010) identified eight phenolic compounds from the shoot extracts of *P. pubescens* and *P. nigra* which include protocatechuic acid, p-hydroxybenzoic acid, catechin, caffeic acid, chlorogenic acid, syringic acid, p-coumaric acid, and ferulic acid (Fig. 17.2).

Nirmala et al. (2014) investigated the bioactive compounds in bamboo species *Bambusa balcooa*, *B. tulda*, *B. nutans*, *Dendrocalamus giganteus*, *D. hamiltonii*, *D. membranaceus*, and *D. strictus* (Table 17.5). Phenol content in the fresh shoots of all the seven selected species ranged from 191.37 mg/100 g to 443.97 mg/100 g fresh weight which was highest in *B. tulda* and minimum in *B. balcooa*. Pandey and Ojha (2013) studied total phenol content in the shoots of *Bambusa tulda*, *Dendrocalamus asper*, and *D. strictus* at different optimum harvesting ages of fresh shoots which ranged from 0.57 to 2.97 g/100 g with maximum content in *D. strictus*, whereas total phenol content in fresh shoots of *B. bambos*, *B. tulda*, *D. asper*, and *D. strictus* was reported with the range from 0.36 to 0.63 g/100 g (Pandey and Ojha, 2014).

Total phenol content in the fresh bamboo shoot of *Dendrocalamus latiflorus* was reported as 414.43 mg/100 g fresh weight (Thounaojam et al. 2017). Bajwa et al. (2015) analyzed the physicochemical and nutritional qualities of *Dendrocalamus hamiltonii* shoots in which the phenol content was reported to be 0.59 g/100 g fresh weight, whereas Santosh et al. (2019) also reported the total phenol content of the same species with 0.61 g/100 g fresh weight.

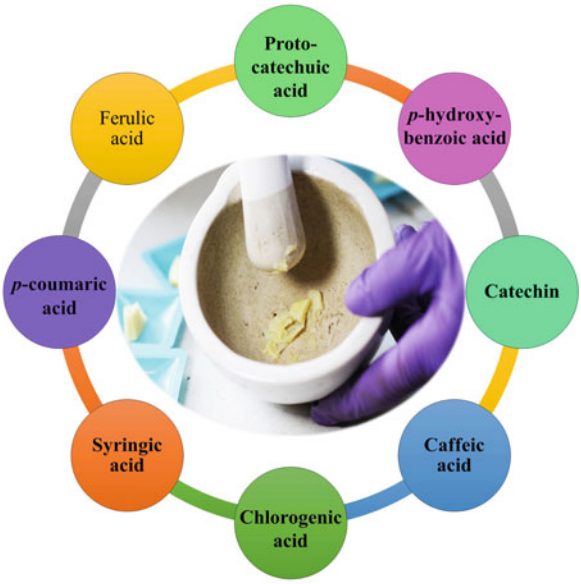

Fig. 17.2 Phenolic compounds isolated from bamboo shoot

17.5.3 Dietary Fiber

Dietary fiber comprises a unique blend of bioactive components that are indigestible parts of plant food that cannot be digested by the human digestive enzyme. They are composed of straight chains of carbohydrate molecules that have the potential to bind and remove harmful toxins and carcinogens in the digestive tract (Lattimer and Haub, 2010). There are two types of dietary fiber: soluble and insoluble. Soluble fiber can dissolve in or absorb water in the large intestine passing undigested from the small intestine to produce short-chain fatty acids that are effective in binding toxins and cholesterol in the intestinal tract (Young et al. 2005). On the other hand, insoluble fiber cannot dissolve in water, therefore increasing the fecal bulk and viscosity which remove potential toxins and carcinogens from the intestinal tract in less contact time by speeding out from the body (Adlercreutz et al. 1987). Bamboo shoots are a rich source of dietary fiber which has been investigated by several researchers (Rajyalakshmi and Geervani 1994; Bhatt et al. 2005; Kumbhare and Bhargava 2007; Nirmala et al. 2008, 2011, 2014; Bajwa et al. 2015; Rawat et al. 2016; Thounaojam et al. 2017; Santosh et al. 2019). Several health benefits of dietary fiber of bamboo shoot have been reported including treatment and prevention of obesity and diabetes, reduced cardiovascular diseases, and decreased incidence of certain types of cancer (Nirmala et al. 2009; Tucker and Thomas 2009). Park and Jhon (2009) investigated the health benefits of bamboo shoot dietary fiber on humans by the administration of a fiber-free diet and a diet with bamboo shoot fiber which confirmed the beneficial effects of bamboo shoot dietary fiber in lowering blood cholesterol levels and improving bowel functions. Lignans are an

important component of fiber present in bamboo shoots which are reported to have anticancer, antibacterial, and antiviral activity (Shi and Yang 1992; Akao et al. 2004). Nirmala et al. (2009) reported a comparative account on the dietary fiber components of *Dendrocalamus giganteus* in fresh, canned, and boiled shoots. Shoots have a high amount of neutral detergent fiber (NDF), ranging from 2.23 g/100 g to 4.18 g/100 g which also showed an increase in other fiber components including acid detergent fiber (ADF), lignin, hemicellulose, and cellulose after fermentation. A high content of dietary fiber was also reported from fresh bamboo shoots of *Bambusa bambos*, *B. kingiana*, *B. nutans*, *B. polymorpha*, *B. tulda*, *B. vulgaris*, *Dendrocalamus asper*, *D. brandisii*, *D. giganteus*, *D. hamiltonii*, *D. membranaceus*, *D. strictus*, *Gigantochloa albociliata*, and *G. rostrate*, ranging from 2.26 to 4.49 g/100 g fresh weight with maximum in the shoots of *B. kingiana* (Nirmala et al. 2011). Bhatt et al. (2005) determined crude fiber for 11 bamboo species, *Bambusa balcooa*, *B. nutans*, *B. tulda*, *Dendrocalamus giganteus*, *D. hamiltonii*, *D. hookerii*, *D. longispathus*, *D. sikkimensis*, *Melocanna baccifera*, *Phyllostachys bambusoides*, and *Teinostachyum wightii*. The estimation was carried out using acid and alkaline digestion methods (Maynard 1970) in a dry matter which ranged from minimum of 23.1 g/100 g dry weight in *P. bambusoides* to maximum35.5 g/100 g dry weight in *M. baccifera*. Dietary fiber in the shoots of *Bambusa arundinacea*, *D. hamiltonii*, *D. latiflorus*, *B. nutans*, and *D. strictus* has also been reported (Rajyalakshmi and Geervani 1994; Kumbhare and Bhargava 2007; Bajwa et al. 2015; Rawat et al. 2016; Thounaojam et al. 2017; Santosh et al. 2019) (Table 17.6).

17.6 Application of Bamboo Shoot in Food Fortification

An adequate diet is one of the important factors influencing growth and immunity as it supplies the proper amount of nutrients, minerals, and vitamins that are critical for the human body. Research suggests that a plant-based diet provides us with almost all macronutrients (proteins, lipids, carbohydrates), micronutrients (minerals, trace elements, vitamins), and bioactive compounds in sufficient amount. In addition, people who eat primarily plant-based diets tend to have a lower body mass index and lower rates of obesity, diabetes, and heart diseases. There is a significant change in the food industries due to the shifting of consumer's choice from healthy foods to food that prevents nutrition-related diseases and improves the physical and mental well-being of consumers leading to the development of modern functional foods. Fortification of foods is an effective means to prevent micronutrient deficiencies. Foods which have already been used successfully as food vehicle include wheat, rice, milk, salt, cooking oils, sugar, and condiments. Basic foods such as bread, biscuits, dairy products, packaged cereals, flours, and ready-to-eat products are a convenient means for the maximum intake of micronutrients in the population. Over the years, several important and nutritious plants remain neglected in the world of food and nutrition diversity due to the emphasis given only on few major crop plants

Table 17.6 Dietary fiber % (crude fiber/NDF) content of fresh bamboo shoots

Bamboo species	Dietary fiber	Reference
Bambusa arundinacea	6.9	Rajyalakshmi and Geervani (1994)
B. bamboos	3.54	Nirmala et al. (2011)
B. balcooa	26.4[a]	Bhatt et al. (2005)
	6.75	Nirmala et al. (2014)
B. kingiana	4.49	Nirmala et al. (2011)
B. nutans	28.5[a]	Bhatt et al. (2005)
	2.28	Nirmala et al. (2011, 2014)
	0.76	Kumbhare and Bhargava (2007)
B. polymorpha	3.82	Nirmala et al. (2011)
B tulda	24.6[a]	Bhatt et al. (2005)
	3.97	Nirmala et al. (2011, 2014)
B. vulgaris	0.97	Kumbhare and Bhargava (2007)
	4.24	Nirmala et al. (2011)
D. asper	0.71	Kumbhare and Bhargava (2007)
	3.54	Nirmala et al. (2011)
D. brandisii	4.03	Nirmala et al. (2011)
D. giganteus	27.6[a]	Bhatt et al. (2005)
	2.65	Nirmala et al. (2008, 2011, 2014)
D. hamiltonii	25.4[a]	Bhatt et al. (2005)
	3.9	Nirmala et al. (2011)
	8.52	Bajwa et al. (2015)
	5.5	Santosh et al. (2019)
D. hookeri	34.7[a]	Bhatt et al. (2005)
D. latiflorus	5.88	Rawat et al. (2016)
	5.39	Thounaojam et al. (2017)
D. longispathus	26.7[a]	Bhatt et al. (2005)
D. membranaceus	2.91	Nirmala et al. (2011, 2014)
D. sikkimensis	23.5[a]	Bhatt et al. (2005)
D. strictus	2.26	Nirmala et al. (2011, 2014)
	0.98	Kumbhare and Bhargava (2007)
G. albociliata	4.15	Nirmala et al. (2011)
G. rostrata	4.2	Nirmala et al. (2011)
Melocanna baccifera	35.5[a]	Bhatt et al. (2005)
Phyllostachys bambusoides	23.1[a]	Bhatt et al. (2005)
Teinostachyum wightii	23.7[a]	Bhatt et al. (2005)

[a]Crude fiber % dr. wt

(Haq 2007). Neglected plants have been explored and received much attention recently for several biologically active substances such as dietary fibers, amino acids, proteins, minerals, vitamins, phytochemicals, and antioxidant properties which are used in the development of functional foods through fortification in the food industry (Rawat and Indrani 2015). Bamboo is one such neglected plant as food which has the potential of being used for food fortification.

Nowadays, the importance of food fortification is gaining momentum with the increasing urbanization and changing lifestyle for the prevention of several nutrition-related diseases. The present generation is aware of the relationship between healthy living and a healthy diet and also the cost-effectiveness of healthcare. The development of nutritious and health-promoting functional foods is very important in the food industries with the identification of new sources of nutraceuticals (Kris-Etherton et al. 2002). Fortification of widely consumed foods has been practiced in many developed countries as an effective strategy to address several nutrition-related diseases through existing food delivery systems, without requiring major changes in existing consumption (Serdula 2010). Interest in utilizing bamboo shoot which is rich in nutrients, bioactive compounds, and minerals for the production of natural functional food is gaining popularity in the food industries (Nirmala et al. 2011; Santosh et al. 2019). For long-term preservation and removal of antinutrient from bamboo shoots, many processing techniques are reported for the application in the production of value-added food products (Choudhury et al. 2012; Santosh et al. 2019). Recently, bamboo shoot has been used for several value-added products such as pickles, candies, nuggets, crackers, chutney, chips, cookies, chapatis, and buns (Farris and Piergiovanni 2008; Bisht et al. 2012; Choudhury et al. 2012; Pandey et al. 2012; Sood et al. 2013; Das et al. 2013; Thomas et al. 2014; Chavhan et al. 2015; Maroma 2015; Nimisha et al. 2015; Mustafa et al. 2016; Zhang et al. 2017; Felisberto et al. 2019) (Table 17.7).

Bamboo shoot fortified products hold great potential as a health food and a good source for nutraceutical and pharmaceutical products. Bamboo fiber was used in the preparation of the well-known Italian food "Amaretti" cookies which shows improvement in the texture and shelf life of the product (Farris and Piergiovanni 2008). Choudhury et al. (2015) investigated the influence of fortifying biscuits with the shoots of *Bambusa balcooa* for physicochemical, texture, and organoleptic characteristics. The study observed a decrease in the gluten content and an increase in moisture, fiber, protein, fat, ash, and phenolic and antioxidant properties with an increase in the fortification level. Sensory observation recommended a 10% level of bamboo shoot incorporation without affecting the overall quality. Mustafa et al. (2016) also analyzed the physical characteristics and sensory acceptance of cookies fortified with dried bamboo shoot powder and recommended a 6% level of fortification. The enhancement of nutritional and organoleptic properties of biscuit fortified with a processed form of bamboo shoot paste and freeze-dried powder of *Dendrocalamus hamiltonii* was also reported (Santosh et al. 2018, 2019) (Table 17.8). The study observed an increase in the nutritional and bioactive compounds and mineral content in a fortified biscuit; however, the sensory acceptability for aroma, texture, taste, and overall quality was maximum in the biscuits fortified with boiled shoots. Cookies fortified with the flour obtained from dried bamboo culm were reported to increase its crispness (Felisberto et al. 2019). Pandey et al. (2012) evaluated the nutritional profile in several value-added products such as nuggets, crackers, and pickles from different bamboo species, viz., *Dendrocalamus asper*, *D. strictus*, *Bambusa bambos*, and *B. tulda*. Sood et al. (2013) prepared products such as candy, chutney, nuggets, crackers, and chukh from shoots of

Table 17.7 Products fortified with bamboo shoots

Sl.	Fortified products	Bamboo species	Processed form	References
1	Amaretti cookies	*Not mentioned*	Bamboo fiber	Farris and Piergiovanni (2008)
2	Crackers, nugget, pickle	*Bambusa bambos*, *B. tulda*, *Dendrocalamus asper*, *D. strictus*	Brine-treated boiled shoot	Pandey et al. (2012)
3	Chicken nuggets	*B. auriculata*	Shoot fermented for 2 months	Das et al. (2013)
4	Candy, chutney, chukh, cracker, nugget	*D. hamiltonii*	Boiled shoot	Sood et al. (2013)
5	Pork nuggets	*B. polymorpha*	Brine-treated, boiled, and fermented for 6 months	Thomas et al. (2014)
6	Biscuit	*B. balcooa*	Boiled, dried, and powdered	Choudhury et al. (2015)
7	Chips	*B. vulgaris*	Shoot boiled for 2 h	Maroma (2015)
8	Pork pickles	*Not mentioned*	Minced shoot exposed to sun and fermented for 21 days, dried, and powdered	Chavhan et al. (2015)
9	Candies	*Not mentioned*	Boiled shoot	Nimisha et al. (2015)
10	Cookies	*Not mentioned*	Boiled shoot, dried, and powdered	Mustafa et al. (2016)
11	Pork nuggets	*B. polymorpha*	Brine-treated boiled shoot extract	Thomas et al. (2016)
12	Battered and breaded fish balls	*Not mentioned*	Bamboo shoot fiber of Hubei Ruifa biological engineering co., LTD	Zeng et al. (2016)
13	Fried potato chips	*Bambusa balcooa*	Bamboo shoot powder and bamboo shoot extract	Shanmugam et al. (2016)
14	Frozen dough	*Not mentioned*	Bamboo shoot fiber of Zhejiang Geng sheng tang ecological agriculture co., ltd.	Zhang et al. (2017)
15	Milk pudding	*D. latiflorus*	Shoot fiber extracted with cellulase and papain enzyme method	Zheng et al. (2017)
16	Biscuit	*D. hamiltonii*	Freeze-dried powder of fresh, boiled, and soaked shoots	Santosh et al. (2018)
17	Biscuit	*D. hamiltonii*	Fresh, boiled, and soaked shoot paste	Santosh et al. (2019)
18	Cookies	*D. asper*	Bamboo culm treated with metabisulfite, dried, and powdered	Felisberto et al. (2019)

Table 17.8 Phenol and dietary fiber/ADF (g/100 g) of bamboo shoot fortified products

Product	Shoot species	Processed form of shoot	Phenol	Fiber/ADF	Reference
Nugget	*D. strictus*	Boiled shoots and green gram	2.43 ± 0.03	–	Pandey et al. (2012)
	D. hamiltonii	Boiled bamboo shoot	–	6.40 ± 0.26	Sood et al. (2013)
Papad/ crackers	*D. asper*	15-min boiled shoots	1.02 ± 0.06	–	Pandey et al. (2012)
	D. hamiltonii	Boiled bamboo shoot	–	3.90 ± 0.31	Sood et al. (2013)
Pickle	*D. asper*	15-min boiled shoots	0.5 ± 0.03	–	Pandey et al. (2012)
Biscuit	*B. balcooa*	10% fortification of 30-min balanced dried powder	0.02 ± 0.01	1.85 ± 0.09	Choudhury et al. (2015)
	D. hamiltonii	10% fortification of 20-min boiled freeze-dried powder	0.20 ± 0.01	3.82 ± 0.01	Santosh et al. (2018)
	D. hamiltonii	10% fortification of 20-min boiled shoot paste	0.14 ± 0.01	3.58 ± 0.01	Santosh et al. (2019)

Note: *D., Dendrocalamus; B., Bambusa.* Data presented in mean values ± standard deviation ($n = 3$)

Dendrocalamus hamiltonii and analyzed their nutritional and sensory attributes. The study revealed good sensory acceptability of all the products in terms of color, flavor, aroma, taste, and texture. A good profile of moisture content, protein, ash, fiber, and total carbohydrates was also reported in shoot fortified nuggets and crackers. Nimisha et al. (2015) observed that the sensory acceptability of bamboo shoot candy flavored with pineapple was higher compared to the candy flavored with ginger with a stable storage period of 6 months under the normal condition without any microbial contamination during storage. Maroma (2015) utilized shoots of *Bambusa vulgaris* for the preparation of bamboo shoot chips, and the study revealed that the product was safe for consumption in terms of microbiological analysis and the sensory score was good for aroma, flavor, texture, and audible crispness. Shanmugam et al. (2016) investigated the reduction of acrylamide levels in fried potato chips with the application of bamboo shoot powder and bamboo shoot extract of *Bambusa balcooa*. Reduction in acrylamide level of potato chips was reported upto 50% in 1 g/L bamboo extract treatment and 25% in 50 g/L bamboo shoot powder treatment. Das et al. (2013) studied the effect of the fermented bamboo shoot of *Bambusa auriculata* in the fortified chicken nuggets and observed improvement in the emulsion stability, cooking yield, and sensory attributes of the fortified products. Improved sensory and microbial qualities of pork nuggets fortified with fermented bamboo shoots of *Bambusa polymorpha* were reported which also increased the shelf life of the nuggets for 2 weeks (Thomas et al. 2014). Thomas

et al. (2016) also compared the antioxidant and antimicrobial effects of boiled bamboo shoot extract and *Averrhoa carambola* extract in the preparation of pork nuggets. Improvement in the sensory and increased shelf life of pork nuggets with the 6% level of the extract incorporated were observed from 21 days to 35 days compared to control samples. The increase in the shelf life of pork pickles fortified with fermented bamboo shoot was reported by Chavhan et al. 2015.

Bamboo shoots are a good source of dietary fiber, and the utilization of bamboo fiber which has several health benefits is reported in fortified bakery products, meat, sausage, beverages, spices, pasta, and ketchup (Nirmala et al. 2011). The inclusion of bamboo shoot dietary fiber in the diet has a beneficial effect on healthy digestion and lowering of lipid profile (Park and Jhon 2009). Fortification of dietary fiber in food lowers the fat content in deep-fried products which will also solve the problems of obesity and various cardiovascular diseases due to the over-ingestion of high fat-containing food items (Mellema 2003). Sensory acceptability of deep-fried fish balls was improved with a 6% level of dried bamboo shoot dietary fiber fortification and a decreased fat content of the crust and the core from 25.5% to 17.7% and 2.4% to 1.3%, respectively (Zeng et al. 2016). The importance of dietary fiber in the dairy industries for the improvement of rheological and texture properties is also gaining interest. Improvement in the mechanical properties, freezable water content, and thermal stability of the dough with the incorporation of bamboo shoot dietary fiber was reported (Zhang et al. 2017). Zheng et al. (2017) extracted fiber from the shoots of *Dendrocalamus latiflorus* through the compound enzyme method of cellulase and papain and observed that milk pudding fortified with 2 g/100 g of bamboo fiber was observed to have better rheological and texture properties due to the improved elasticity where the system stability was attained. Hemicellulose components of bamboo, a mixture of xylose and xylo-oligosaccharides (XOS) isolated from *Sasa senanensis* by steaming and subsequent water extraction, are reported to be a potential raw material of functional food and pharmaceutical industries (Peng and She 2014). Miura et al. (2013) reported the presence of xylitol in *Phyllostachys pubescens* which is converted from hemicelluloses through microbial activity. Since the compound has several health benefits such as anticaries, anti-inflammatory, and sweetening properties, it is of great interest in the food industries (Mäki-Arvela et al. 2011).

17.7 Conclusion

Bamboo, the "plant with a thousand faces," has indeed etched out a place in the food and pharmaceutical sector. Bamboo shoots in particular are gaining worldwide importance as health food being a rich repository of nutrients and health-promoting bioactive compounds. It has always been a herbal component of the traditional medicinal system since ancient times for the treatment of several diseases. Scientific reports of nutrient richness and proven health benefits have led to the emergence of bamboo as a highly potent ingredient for the development of novel functional foods

and pharmaceutical products. Thus, bamboo shoots with a good source of nutrients and natural bioactive compounds are aptly considered as a superfood and can play a vital role in the food and pharmaceutical industries.

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References

Adlercreutz H, Hamalainen E, Gorbach SL et al (1987) Association of diet and sex-hormones in relation to breast-cancer. Eur J Cancer Clin Oncol 23:1725–1726

Akakabe Y, Tamura Y, Iwamoto S et al (2006) Volatile organic compounds with characteristic odor in bamboo vinegar. Biosci Biotechnol Biochem 70:2797–2799

Akao Y, Seki N, Nakagawa Y et al (2004) A highly bioactive lignophenol derivative from bamboo lignin exhibit a potent activity to suppress apoptosis induced by oxidative stress in human neuroblastoma SH-SY5Y cells. Bioorg Med Chem 12:4791–4801

Anderson JW, Baird P, Davis RH et al (2009) Health benefits of dietary fiber. Nutr Rev 67 (4):188–205

Andriarimalala JH, Kpomasse CC, Salgado P et al (2019) Nutritional potential of bamboo leaves for feeding dairy cattle. Pesquisa Agropecuária Tropical 49

Avieli N (2005) Roasted pigs and bao dumplings: festive food and imagined transnational identity in Chinese–Vietnamese festivals. Asia Pac Viewp 46(3):281–293

Badwaik LS, Gautam G, Deka SC (2015) Influence of blanching on antioxidant, nutritional and physical properties of bamboo shoot. J Agric Sci 10(3):140–150

Bajwa HK, Nirmala C, Koul A et al (2015) Effects of processing and preservation on phenols and phytosterols content in bamboo shoots. In: 10th world bamboo congress, 2015, Korea

Bajwa HK, Santosh O, Koul A et al (2019) Phytomodulatory effects of fresh and processed shoots of an edible bamboo *Dendrocalamus hamiltonii* Nees & Arn. Ex Munro on antioxidant defense system in mouse liver. J Food Meas Charact 13(4):3250–3256

Bashir T (2010) Prospects of bamboo shoot processing in north-East India. Curr Sci 98(3):288–289

Behall KM (1997) Dietary fiber: nutritional lessons for macronutrient substitutes. Ann N Y Acad Sci 819:142–154

Bhargava A, Kumbhare V, Srivastava A et al (1996) Bamboo parts and seeds for additional source of nutrition. J Food Sci Technol 33(2):145–146

Bhatt BP, Singha LB, Singh K et al (2003) Some commercial edible bamboo species of north East India: production, indigenous uses, cost-benefit and management strategies. Bamboo Sci Cult 17(1):4–20

Bhatt BP, Singha LB, Sachan MS et al (2005) Commercial edible bamboo species of north eastern Himalayan region, India, part II: fermented, roasted and boiled bamboo shoots sale. J Bamboo Rattan 4:13–31

Bisht MS, Nirmala C, Vyas P (2012) Bamboo shoot a neglected natural resource: a source of food and prosperity for North-East India. In: Recent advances in natural products research, pp 18–22

Bisht MS, Nirmala C, Meetei OS (2015) Bamboo shoots for food in North-East India: conventional and contemporary. In: Proceedings of 10th world bamboo congress, Damyang

Biswas S, Kumar S, Mittal V (2016) A note on rodent migration following gregarious bamboo flowering in North-Eastern Hill region with particular reference to Mizoram (India) and its consequences. J Commun Dis 48(3):1–12

Black RE, Victora CG, Walker SP et al (2013) Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet 382(9890):427–451

Brennan MA, Derbyshire EJ, Brennan CS et al (2012) Impact of dietary fibre-enriched ready-to-eat extruded snacks on the postprandial glycaemic response of non-diabetic patients. Mol Nutr Food Res 56(5):834–837

Chavhan DM, Hazarika M, Brahma ML et al (2015) Effect of incorporation of fermented bamboo shoot on physicochemical and microbial quality of pork pickle. J Food Sci Technol 52 (2):1223–1227

Chen CJ, Qiu EF, Huang RZ et al (1999) Study on the spring shoot nutrient content of *Phyllostachys pubescens* of different provenances. J Bamboo Res 18(1):6–11

Cheng HP (2006) Vacuum cooling combined with hydrocooling and vacuum drying on bamboo shoots. Appl Therm Eng 26(17–18):2168–2175

Chongtham N, Bisht MS (2021) Bamboo shoot: superfood for nutrition, health and medicine. CRC Press, New York

Chongtham N, Bisht MS, Bajwa HK et al (2020) Mineral elements in bamboo shoots and potential role in food fortification. J Food Compos Anal 95:103662

Choudhury D, Sahu JK, Sharma GD (2012) Value addition to bamboo shoots: a review. J Food Sci Technol 49(4):407–414

Choudhury M, Badwaik LS, Borah PK et al (2015) Influence of bamboo shoot powder fortification on physico-chemical, textural and organoleptic characteristics of biscuits. J Food Sci Technol 52 (10):6742–6748

Collins RJ, Keilar S (2005) The Australian bamboo shoots industry: a supply chain approach. A report for rural industries research and development corporation, Australia. Community Med 33:9–10

Correia P, Beirao-da-Costa ML (2012) Effect of drying temperatures on starch-related functional and thermal properties of chestnut flours. Food Bioprod Process 90(2):284–294

Das M (2019) Bamboo: inherent source of nutrition and medicine. J Pharmacogn Phytochem 8 (2):1338–1344

Das A, Nath DR, Kumari S et al (2013) Effect of fermented bamboo shoot on the quality and shelf life of nuggets prepared from desi spent hen. Vet World 6(7):419–423

Farris S, Piergiovanni L (2008) Effects of ingredients and process conditions on 'Amaretti'cookies characteristics. Int J Food Sci Technol 43(8):1395–1403

Felisberto MHF, Beraldo AL, Costa MS et al (2019) Characterization of young bamboo culm starch from *Dendrocalamus asper*. Food Res Int 124:222–229

Ferreira VLP, Yotsuyanagi K, Carvalho CRL (1995) Elimination of cyanogenic compounds from bamboo shoots *Dendrocalamus giganteus* Munro. Trop Sci 35:342–346

Fu XC, Wang MW, Li SP et al (2005) Vasodilatation produced by orientin and its mechanism study. Biol Pharm Bull 28(1):37–41

Fujimura M, Ideguchi M, Minami Y et al (2005) Amino acid sequence and antimicrobial activity of chitin binding peptides, Pp-AMP 1 and Pp-AMP2, from Japanese bamboo shoots (*Phyllostachys pubescens*). Biosci Biotechnol Biochem 69:642–645

Giri SS, Janmejay L (2000) Effect of bamboo shoot fermentation and aging on nutritional and sensory qualities of soibum. J Food Sci Technol 37(4):423–426

Halvorson JJ, Cassida KA, Turner KE et al (2011) Nutritive value of bamboo as browse for livestock. Renewable Agric Food Syst 26:161–170

Haq N (2007) Underutilized fruits: a resource for sustainable livelihoods. Science Publishers, An imprint of Edenbridge Ltd., British Isles, pp 1–28

Hiromichi H (2007) Use of an antitumor agent European Patent EP1413208

Hong EJ, Jung EM, Lee GS et al (2010) Protective effects of the pyrolyzates derived from bamboo against neuronal damage and haemato aggregation. J Ethnopharmacol 128:594–599

Hu CH, Zhang Y, David DK (2000) Evaluation of antioxidant and prooxidant activities of bamboo *Phyllostachys nigra* var. henonis leaf extract in vitro. J Agric Food Chem 48(8):3170–3176
Hwang KM, Jung KO, Song CH et al (2008) Increased antimutagenic and anticlas-togenic effects of doenjang (Korean fermented soybean paste) prepared with bamboo salt. J Med Food 11 (4):717–722
Ingudam M, Sarangthem K (2016) Phytosterols content in different bamboo species of Manipur, India. Int J Curr Microbiol Appl Sci 5(8):943–948
Jeyaram K, Singh TA, Romi W et al (2009) Traditional fermented foods of Manipur. Indian J Tradit Knowl 8:115–121
Jiayan Y (2014) A comparative study of bamboo culture and its applications in China, Japan and South Korea. In: Proceedings of SOCIOINT14 - international conference on social sciences and humanities, Istanbul, 8–10 September 2014. ISBN: 978-605-64453-1-6
Kim HJ, Lee HO, Min DB (2007) Effects and prooxidant mechanisms of oxidized α-tocopherol on the oxidative stability of soybean oil. J Food Sci 72(4):223–230
Kithan N, Goswami S, Biswas S (2015) Traditional techniques for processing bamboo shoots in Northeast India as food resource. Int J Curr Res 7(3):13524–13528
Kozukue E, Kozukue N, Kurosaki T (1983) Organic acid, sugar and amino acid composition of bamboo shoots. J Food Sci 48(3):935–938
Kris-Etherton PM, Hecker KD, Bonanome A et al (2002) Bioactive compounds in foods: their role in the prevention of cardiovascular disease and cancer. Am J Med 113(9):71–88
Kumar PS, Kumari U, Devi MP et al (2017) Bamboo shoot as a source of nutraceuticals and bioactive compounds: a review. Indian J Nat Prod Resour 8(1):32–46
Kumbhare V, Bhargava A (2007) Effect of processing on nutritional value of central Indian bamboo shoots. Part I. J Food Sci Technol 44(1):29–31
Lachance PA, He YH (1998) Hypocholesterolemic composition from bamboo shoots. PCT International Patent PCT/US98/12556
Lattimer JM, Haub MD (2010) Effects of dietary fiber and its components on metabolic health. Nutrients 2(12):1266–1289
Li X, Guo J, Ji K et al (2016) Bamboo shoot fiber prevents obesity in mice by modulating the gut microbiota. Sci Rep 6:32953
Li Y, Ma G, Zhou Q et al (2020) Nutrient contents predict the bamboo-leaf-based diet of Assamese macaques living in limestone forests of Southwest Guangxi, China. Ecol Evol 10:5570–5581
Liu L, Liu L, Lu B et al (2013) Evaluation of bamboo shoot peptide preparation with angiotensin converting enzyme inhibitory and antioxidant abilities from by-products of canned bamboo shoots. J Agric Food Chem 61(23):5526–5533
Lu B, Wu X, Tie X et al (2005) Toxicology and safety of antioxidant of bamboo leaves. Part I: acute and sub chronic toxicity studies on antioxidant of bamboo leaves. Food Chem Toxicol 43 (5):783–792
Lu B, Wu X, Shi J et al (2006) Toxicology and safety of antioxidant of bamboo leaves. Part 2: developmental toxicity test in rats with antioxidant of bamboo leaves. Food Chem Toxicol 44 (10):1739–1743
Lu B, Ren Y, Zhang Y et al (2009a) Effects of genetic variability, parts and seasons on the sterol content and composition in bamboo shoots. Food Chem 112:1016–1021
Lu B, Bao J, Shan L et al (2009b) Technology for supercritical CO_2 extraction of bamboo shoot oil and components of product. Trans Chin Soc Agric Eng 25(8):312–316
Ma Y, Yang Y, Gao J et al (2020) Phenolics and antioxidant activity of bamboo leaves soup as affected by in vitro digestion. Food Chem Toxicol 135:110941
Madamba PS (2003) Physical changes in bamboo (*Bambusa phyllostachys*) shoot during hot air drying: shrinkage, density, and porosity. Dry Technol 21(3):555–568
Mäki-Arvela PI, Salmi T, Holmbom B et al (2011) Synthesis of sugars by hydrolysis of hemicelluloses: a review. Chem Rev 111(9):5638–5666
Maroma DP (2015) Utilization of bamboo shoots (*Bambusa vulgaris*) in chips production. Open Access Libr J 2(05):1

Maynard AJ (1970) Methods in food analysis. Academic, New York, p 176
Mellema M (2003) Mechanism and reduction of fat uptake in deep-fat fried foods. Trends Food Sci Technol 14:364–373
Miura M, Watanabe I, Shimotori Y et al (2013) Microbial conversion of bamboo hemicellulose hydrolysate to xylitol. Wood Sci Technol 47(3):515–522
Moon-Hee CH, Yang JH, Yang SH, et al (2017) The anti-inflammatory and anti-Adipogenic properties of bamboo (*Sasa coreana* Nakai) leaves extract. 한국생물공학회 학술대회 10:228
Mustafa U, Naeem N, Masood S (2016) Effect of bamboo powder supplementation on physico-chemical and organoleptic characteristics of fortified cookies. Food Sci Technol 4(1):7–13
Nimisha SM, Chauhan AS, Rekha MN et al (2015) Composition of edible portion of tender bamboo shoot (TBS) and development of various candies with and without incorporation of ginger and pineapple flavours. Am J Nutr Food Sci 2(1):7–15
Nirmala C, Bisht MS (2017) Bamboo: a prospective ingredient for functional food and nutraceuticals. Bamboo J 30:82–99
Nirmala C, David E, Sharma ML (2007) Changes in nutrient components during ageing of emerging juvenile bamboo shoots. Int J Food Sci Nutr 58(8):612–618
Nirmala C, Sharma ML, David E (2008) A comparative study of nutrient components of freshly harvested, fermented and canned bamboo shoots of *Dendrocalamus giganteus* Munro. J Am Bamboo Society 21(1):33–39
Nirmala C, Sheena H, David E (2009) Bamboo shoots: a rich source of dietary fibres. In: Klein F, Moller G (eds) Dietary fibres, fruit and vegetable consumption and health. Nova Science Publisher, Inc., New York, pp 173–187
Nirmala C, Bisht MS, Sheena H (2011) Nutritional properties of bamboo shoots: potential and prospects for utilization as a health food. Comp Rev Food Sci Food Saf 10:153–169
Nirmala C, Bisht MS, Laishram M (2014) Bioactive compounds in bamboo shoots: health benefits and prospects for developing functional foods. Int J Food Sci Technol 49:1425–1431
Nirmala C, Bisht MS, Bajwa HK et al (2018) Bamboo: a rich source of natural antioxidants and its applications in the food and pharmaceutical industry. Trends Food Sci Technol 77:91–99
Pandey AK, Ojha V (2013) Standardization of harvesting age of bamboo shoots with respect to nutritional and anti-nutritional components. J For Res 24:83–90
Pandey AK, Ojha V (2014) Precooking processing of bamboo shoots for removal of antinutrients. J Food Sci Technol 51(1):43–50
Pandey AK, Ojha V, Choubey SK (2012) Development and shelf-life evaluation of value-added edible products from bamboo shoots. Am J Food Technol 7(6):363–371
Park EJ, Jhon DY (2009) Effects of bamboo shoot consumption on lipid profiles and bowel function in healthy young women. Nutrition 25:723–728
Park EJ, Jhon DY (2010) The antioxidant, angiotensin converting enzyme inhibition activity, and phenolic compounds of bamboo shoot extracts. LWT-Food Sci Technol 43(4):655–659
Peng P, She D (2014) Isolation, structural characterization, and potential applications of hemicelluloses from bamboo: a review. Carbohydr Polym 112:701–720
Phithakpol B, Varanyanond W, Reungmaneepaitoon S et al (1995) The traditional fermented foods of Thailand. Institute of Food Research and development. Kasetsart University, Bangkok
Prasad SN, Hegde MS, Gadgil M (1985) An experiment in eco-development in Uttara Kannada district of Karnataka. South Asian Anthropol 6(1):73–83
Qing Y, Zhu BD, Zheng LW et al (2008) Bamboo resources, utilization and ex-situ conservation in Xishuangbanna, South-Eastern China. J For Res 19(1):79–83
Qiu FG (1992) The recent development of bamboo foods. In: Proceedings of the international symposium on industrial use of bamboo. International Tropical Timber Organization and Chinese Academy, Beijing, pp 333–337
Rajyalakshmi P, Geervani P (1994) Nutritive value of the foods cultivated and consumed by the tribal of South India. Plant Foods Hum Nutr 46(1):53–61
Rawat N, Indrani D (2015) Functional ingredients of wheat-based bakery, traditional, pasta, and other food products. Food Rev Int 31(2):125–146

Rawat K, Sharma V, Saini N et al (2016) Impact of different boiling and soaking treatments on the release and retention of Antinutrients and nutrients from the edible shoots of three bamboo species. Am J Food Sci Nutr Res 3(3):31–41

Roos N, Ponce MC, Doak CM et al (2019) Micronutrient status of populations and preventive nutrition interventions in South East Asia. Matern Child Health J 23(1):29–45

Ryou SH, Kang MS, Kim KI et al (2012) Effects of green tea or *Sasa quelpaertensis* bamboo leaves on plasma and liver lipids, erythrocyte Na efflux, and platelet aggregation in ovariectomized rats. Nutr Res Pract 6(2):106–112

Saini N, Rawat K, Bisht MS et al (2017) Qualitative and quantitative mineral element variances in shoots of two edible bamboo species after processing and storage evaluated by wavelength dispersion x-ray fluorescence spectrometry. Int J Innov Res Sci Eng Technol 6(5):8265–8270

Sangeetha R, Diea YKT, Chaitra C et al (2015) The amazing bamboo: a review on its medicinal and pharmacological potential. Indian J Nutr 2(1):1–7

Sangtam TL, Jamir NS, Deb CR et al (2012) A study on the medicinal plants used by the Sangtam Naga tribe in Kiphire District, Nagaland, India. Int J Ayurvedic Herbal Med 2(2):267–275

Santosh O, Bajwa HK, Bisht MS (2018) Freeze-dried bamboo shoot powder for food fortification: enrichment of nutritional content and organoleptic qualities of fortified biscuits. MOJ Food Process Technol 6(4):342–348

Santosh O, Bajwa HK, Bisht MS et al (2019) Functional biscuits from bamboo shoots: enrichment of nutrients, bioactive compounds and minerals in bamboo shoot paste fortified biscuits. Int J Food Sci Nutr 4(1):89–94

Sarangthem K, Singh TN (2003) Transformation of fermented bamboo (*Dendrocalamus hamiltonii*) shoots into phytosterols by microorganisms. J Food Sci Technol 40:622–625

Sarangthem K, Singh TN (2013) Fermentation decreases the antinutritional content in bamboo shoots. Int J Curr Microbiol Appl Sci 2:361–369

Satya S, Singhal P, Prabhu VG et al (2009) Exploring the nutraceutical potential and food safety aspect of bamboo shoot of some Indian species. In: VIII World bamboo conference, Bangkok

Satya S, Bal LM, Singhal P et al (2010) Bamboo shoot processing: food quality and safety aspect (a review). Trends Food Sci Technol 21:181–189

Satya S, Singhal P, Bal LM et al (2012) Bamboo shoot: a potential source of food security. Mediterr J Nutr Metabol 5(1):1–10

Serdula M (2010) Maximizing the impact of flour fortification to improve vitamin and mineral nutrition in populations. Food Nutr Bull 31(1):S86–S93

Shanmugam S, Bora A, Raju A et al (2016) Application of antioxidant from bamboo shoot (*Bambusa balcooa*) as an effective way to reduce the formation of acrylamide in fried potato chips. Curr Nutr Food Sci 12(4):256–263

Shi QT, Yang KS (1992) Study on relationship between nutrients in bamboo shoots and human health. In: Bamboo and its use. Proceedings of the international symposium on industrial use of bamboo. International Tropical Timber Organization and Chinese Academy, Beijing, pp 338–346

Silva MF, Menis-Henrique MEC, Felisberto MHF et al (2020) Bamboo as an eco-friendly material for food and biotechnology industries. Curr Opin Food Sci 33:124–130

Singh A, Singh RK, Sureja AK (2007) Cultural significance and diversities of ethnic foods of Northeast India. Indian J Trad Knowl 6(1):79–94

Singhal P, Satya S, Sudhakar P (2011) Antioxidant and pharmaceutical potential of bamboo leaves. Bamboo Sci Cult 24(1):19–28

Singhal P, Bal LM, Satya S et al (2013) Bamboo shoots: a novel source of nutrition and medicine. Crit Rev Food Sci Nutr 53(5):517–534

Sood S, Walia S, Gupta M et al (2013) Nutritional characterization of shoots and other edible products of an edible bamboo–*Dendrocalamus hamiltonii*. Curr Res Nutr Food Sci J 1 (2):169–176

Srivastava RC (1990) Bamboo: new raw materials for phytosterols. Curr Sci 59:1333–1334

Tamang JP (2005) Food culture of Sikkim. In: Sikkim study series, vol IV. Department of Information and Public Relations, Govt. of Sikkim, Gangtok

Tamang JP, Tamang N, Thapa S et al (2012) Microorganisms and nutritional value of ethnic fermented foods and alcoholic beverages of north East India. Indian J Tradi Knowl 11(1):7–25

Tangkanakul P, Trakoontivakorn G, Auttaviboonkul P et al (2006) Antioxidant activity of northern and northeastern Thai foods containing indigenous vegetables. Kasetsart J (Nat Sci) 40:47–58

Tewari DN (1992) A monograph on bamboo. International Book Distributors, Dehradun, Uttaranchal

Thomas R, Jebin N, Barman K et al (2014) Quality and shelf life evaluation of pork nuggets incorporated with fermented bamboo shoot (*Bambusa polymorpha*) mince. Meat Sci 96 (3):1210–1218

Thomas R, Jebin N, Saha R et al (2016) Antioxidant and antimicrobial effects of kordoi (*Averrhoa carambola*) fruit juice and bamboo (*Bambusa polymorpha*) shoot extract in pork nuggets. Food Chem 190:41–49

Thounaojam P, Bisht MS, Nirmala C (2017) Effect of processing on nutritional and phytochemical contents in shoots of an edible bamboo *Dendrocalamus latiflorus* Munro. Int J Agric Sci 8 (1):79–87

Tripathi YC (1998) Food and nutrition potential of bamboo. MFP News 8(1):10–11

Tripathi YC (2011) Edible bamboo shoots - a nutritional appraisal. In: Singh S, Das R (eds) Productivity enhancement and value addition of bamboos. Excel India Publishers, New Delhi, pp 272–281

Tucker LA, Thomas KS (2009) Increasing total fiber intake reduces risk of weight and fat gains in women. J Nutr 139:576–581

Vanithakumari G, Manonayagi S, Padma S et al (1989) Antifertility effect of *Bambusa arundinacea* shoot extracts in male rats. J Ethnopharmacol 25(2):173–180

Visuphaka K (1985) The role of bamboo as a potential food source in Thailand. Recent research on bamboo. In: Proceedings of the international bamboo workshop, 6–14 October 1985

WHO (2010) Global status report on noncommunicable diseases. ISBN 978 92 4 156422 9

Wongsakpairod T (2000) Bamboo shoot drying using superheated steam. Meng Thesis, King Mongkut's University of Technology, Thonburi, Bangkok

Wróblewska KB, Baby AR, Guaratini MTG et al (2019) In-vitro antioxidant and photoprotective activity of five native Brazilian bamboo species. Ind Crop Prod 130:208–215

Xia NH (1989) Analysis of nutritive constituents of bamboo shoots in Guangdong. Acta Botanica Austro Sinica 4:199–206

Xie HK, Li A, Zhao MT et al (2020) Effects of antioxidants of bamboo leaves (AOB) on the oxidative susceptibility of glycerophosphocholine and glycerophosphoethanolamine in dried scallop (*Argopecten irradians*) adductor muscle during storage. LWT Food Sci Technol 134:110214

Xu Y, Zhang M, Tu D et al (2005) A two-stage convective air and vacuum freeze-drying technique for bamboo shoots. Int J Food Sci Technol 40(6):589–595

Xue Z, Zhang W, Wang L et al (2015) The bamboo-eating giant panda harbors a carnivore-like gut microbiota, with excessive seasonal variations. M Bio 6(3). https://doi.org/10.1128/mBio.00022-15

Yang JH, Lim HS, Heo YR (2010) *Sasa borealis* leaves extract improves insulin resistance by modulating inflammatory cytokine secretion in high fat diet-induced obese C57/BL6J Mice. Nutr Res Pract 4(2):99–105

Yang JP, He H, Lu YH (2014) Four flavonoid compounds from *Phyllostachys edulis* leaf extract retard the digestion of starch and its working mechanisms. J Agric Food Chem 62 (31):7760–7770

Young RA (1954) Flavor qualities of some edible oriental bamboos. Econ Bot 8(4):377–386

Young GP, Hu Y, Leu L et al (2005) Dietary fibre and colorectal cancer: a model for environment—gene interactions. Mol Nutr Food Res 49(6):571–584

Yuming Y et al (1999) Bamboo resources and their utilization in China. In: Rao AN, Ramanatha Rao V (eds) Proceedings of training course cum workshop, 10–17 May 1998

Zeng H, Chen J, Zhai J et al (2016) Reduction of the fat content of battered and breaded fish balls during deep-fat frying using fermented bamboo shoot dietary fiber. LWT Food Sci Technol 73:425–431

Zhang Y, Yao X, Bao B et al (2006) Anti-fatigue activity of atriterpenoid-rich extract from Chinese bamboo shavings *(Caulis bamfusae* in Taeniam). Phytother Res 20(10):872–876

Zhang H, Zhang Y, Wang X et al (2017) Effects of bamboo shoot dietary fiber on mechanical properties, moisture distribution, and microstructure of frozen dough. J Chem 2017:Article ID 4513410. https://doi.org/10.1155/2017/4513410

Zheng J, Wu J, Dai Y et al (2017) Influence of bamboo shoot dietary fiber on the rheological and textural properties of milk pudding. LWT Food Sci Technol 84:364–369

Zhu D, Wang C, Zhang Y et al (2018) Insight into solvent effects on phenolic content and antioxidant activity of bamboo leaves extracts by HPLC analysis. J Food Meas Charac 12 (3):2240–2246