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Review

Bamboo: A rich source of natural antioxidants and its applications in the food and pharmaceutical industry

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ABSTRACT

Background: Bamboo is a multipurpose plant known mostly for its industrial uses but is now being recognized as a potential source of bioactive compounds and natural antioxidants. All the parts of the bamboo plant such as rhizome, culm shaving, leaves, roots, shoots and seeds have clinical applications. Studies have revealed that bamboo is a rich source of antioxidants and regular consumption of bamboo-based products may reduce the risk of age-related chronic diseases including cardiovascular diseases, Alzheimer's disease, Parkinson's disease, cancer and diabetes.

Scope and approach: This review article reports a comprehensive insight concerning antioxidants and antioxidant properties of bamboo shoots and leaves and their prospects for utilization in the development of functional foods and nutraceuticals. Antioxidants are vital constituents in the food and pharmaceutical industry as they scavenge free radicals that cause deterioration of products during processing and storage. They also promote human health by neutralizing cell damage caused by free radicals.

Key findings and conclusion: Antioxidants are known to confer health benefits such as prevention of cancer and degenerative diseases, slowing down the aging process and promotion of cardiovascular health. The main antioxidants in bamboo leaves and shoots are phenols, vitamin C & E and mineral elements such as selenium, copper, zinc, iron and manganese. At present, natural antioxidants are in great demand as synthetic antioxidants being used in food and pharmaceuticals may be deleterious to health. Hence, bamboo a fast growing plant with huge biomass can serve as an alternative for the production of natural antioxidants.

1. Introduction

Over the last decade, there is increasing awareness that diet markedly affects health and well being of individuals. Association between nutrition and health outcomes has become a matter of concern and understanding this association is important as nutrition related chronic diseases such as obesity, diabetes, cardiovascular diseases and some forms of cancer are major contributions to the global burden of diseases (Dangour, Mace, & Shankar, 2017). Rapid changes in diets and lifestyles due to industrialization, urbanization and economic development are having a significant impact on nutritional status and overall health of population worldwide (Kumar, Kumari, Devi, Choudhary, & Sangeetha, 2017). That food has a direct and substantial impact on health has been known since centuries as indicated in a quote of Hippocrates which aptly says “let food be thy medicine and medicine be thy food” and this concept has been followed since long in many cultures like Chinese, Indian and Greek. In recent years, there has been an upsurge, particularly in the western world, for finding ways to prevent diseases rather than curing them. In this context, antioxidant rich foods have generated a lot of interest and attention as it plays an important role in disease prevention. Antioxidants are substances or compounds which inhibit the oxidation of other molecules in our body and prevent the formation of free radicals by scavenging them. Most of the health benefits of antioxidants arise from their anti-inflammatory properties within the body. The important role of antioxidants is to promote cardiovascular health, to inhibit the growth of cancerous tumors, to slow the aging process in the brain and nervous system, and to lessen the risk and severity of neurodegenerative diseases including Alzheimer's disease and Parkinson's disease (Sanguigni, Manco, Sorge, Gnessi, & Francomano, 2017). Antioxidants are also of immense importance in industries dealing with petrochemicals, food, cosmetics and medicine where they are used for stabilization of polymeric products (Pisochi & Negulescu, 2011). In the food and pharmaceutical industries, antioxidants are used to prevent deterioration, rancidity and discoloration caused by oxidation during processing and storage (Schillaci, Nepravishta, & Bellomaria, 2013). There are several known natural compounds with antioxidant properties that can be extracted from plants, which are mainly phenols, polyphenols, vitamin C, vitamin E, beta-carotene, flavonoids, amino acids and amines that are known

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to have the potential to reduce disease risk. However, due to lack of natural antioxidants, nowadays most food and pharmaceutical products contain synthetic antioxidants that cause concerns about their adverse effect on health. Hence, more emphasis is given to the use of natural antioxidants (Schillaci et al., 2013).

Bamboo, the fastest growing, multipurpose woody plant with a myriad of industrial and domestic uses is intricately associated with the cultural, social and economic conditions of people in many Asian countries. Its uses are not only limited to being used as a substitute for wood in construction, furniture, scaffolding, and flooring, but it has been a source of food and medicine in China and South East Asia since ancient times. All parts of the bamboo plant viz. rhizome, culm and bark shaving, shoots, leaves, roots and seeds have clinical applications. Presently, bamboo has gained global attention for its nutritive and therapeutic potential and plays an important role in the food, pharmaceutical and cosmeceutical industry. Bamboo leaves and shoots have great therapeutic potential and can provide a natural and eco-friendly way of health care in a sustainable manner (Nirmala & Bisht, 2017; Tiwari, 1988). From ancient times, bamboo has been an important ingredient of traditional Asian medicines in general and Chinese and Indian (Ayurveda) medicines in particular (Nirmala, Bisht, & Sheena, 2011). Bamboo medicinal applications were first mentioned in India around 10,000 years ago for preparing Chyawanprash, a health tonic prepared from a number of herbs, including bamboo manna to impart youth, beauty and longevity. Chyawanprash is now famous in the world for its anti-stress and anti-aging properties. Ayurveda, the ancient Indian system of medicine recommends bamboo and its products such as Banslochan, Tabasheer and Sitopaladi Churna for treatment of various ailments. This traditional knowledge is now being used for the preparation of modern bamboo-derived pharmaceutical preparations such as bamboo salt, bamboo vinegar, bamboo extracts, bamboo charcoal, bamboo silica and more, for the treatment of various health related problems (Nirmala & Bisht, 2017; Park & Jhon, 2009). Though bamboo is known for its therapeutic properties, it is rarely considered for its antioxidant properties. Several identified antioxidants derived from bamboo shoot and leaves, display certain biological roles, including anti-oxidative (Hu, Zhang, & David, 2000), anti-cancer (Shi & Yang, 1992), anti-hypertensive (Akao et al., 2004), and anti-bacterial (Fujimura, Ideguchi, Minami, Watanabi, & Tadera, 2005) functions. This potential of bamboo has received attention from food, nutraceutical, cosmeceutical and pharmaceutical sectors. The intent of this paper is to discuss antioxidants and antioxidant properties of bamboo and their potential in the food and pharmaceutical industry.

2. Antioxidant compounds and antioxidant properties of bamboo leaves

Bamboo leaves have been used as a herbal medicine since ancient time for the treatment of fever, hypertension, arteriosclerosis, detoxification, respiratory diseases, chest inflammation, oedema, diarrhea, vomiting, excessive thirst, and also to enhance the flavor and colour of foods (Liu et al., 2016). The important biological and therapeutic properties of bamboo leaf extracts including anti-oxidant, anti-microbial, anti-inflammatory, anti-helmintic, anti-diabetic and anti-ulcer have been confirmed by several *in-vitro* and *in-vivo* experiments (Daswad et al., 2017; Tripathi, Jhumka, & Anjum, 2015). Antioxidants of bamboo leaves (AOB) are capable of blocking chain reactions of lipid auto-oxidation, chelating metal ions of transient state, scavenging nitrile compounds and blocking the synthetic reaction of nitrosamine (Lou, Zhang, Wu, Qi, & Zhuo, 2004). The main components in AOB are flavonoids, lactones and phenolic acids. In addition to their medicinal applications, bamboo leaves have been officially certified as natural antioxidants in China, which can be used in edible oils, fish and meat products as a novel food additive (Lu, Wu, Shi, Dong, & Zhang, 2006).

It has been reported, that two main groups of polyphenols are responsible for most of the biological activities of bamboo leaves. These are C-glycoside flavonoids, represented by orientin, homoorientin, isoorientin, vitexin, homovitexin, and tricin and phenolic acids such as, *p*-coumaric acid, chlorogenic acid, caffeic acid, and ferulic acid (Fig. 1; Table 1) (Jiao, Zhang, Lou, Wu, & Zhang, 2007; Lu et al., 2011; Zhang, Jiao, Liu, Wu, & Zhang, 2008). Several compounds with antioxidative properties have been isolated from the leaves of many bamboo species. Hu et al. (2000) identified phenolic compounds such as chlorogenic acid, caffeic acid, and luteolin-7-glucoside from the leaf extract of *Phyllostachys nigra* var. *henonis* and evaluated their radical scavenging and antioxidant activities. Kweon, Hwang, and Sung (2001) identified and isolated two novel chlorogenic acid derivatives from the leaves of *Phyllostachys edulis*, and also reported that these two compounds have even stronger antioxidant activity when compared with α-tocopherol. Bamboo leaf flavonoids (BLFs) can significantly decrease the serum triglyceride level, increase high density lipoprotein content, regulate blood lipids and reduce the risk of atherosclerosis, and have also displayed strong anti-oxidative, anti-aging, and anti-fatigue activities. Park, Lim, Kim, Choi, and Lee (2007) isolated two antioxidative flavonoid C-glycoside derivatives, isoorientin and isoorientin 2′—O-α-i-rhamnoside from n-BuOH extract of leaves of *Sasa borealis*, which is a major source of bamboo leaves for use in traditional medicine in Korea and reported that, these two compounds possess antioxidative and cytoprotective effects against oxidative damage. The young leaves are also marketed as bamboo tea. The oils obtained from the leaves of three cultivars of *Phyllostachys heterocycla* (cv. *pubescens, gracilis, hetrocycla*), showed significant antioxidant and antimicrobial activities (Jin, Yuan, & Zhang, 2011). The methanol extract of culm and leaves of moso bamboo (*Phyllostachys pubescens*) and madake bamboo (*P. bambusoides*), were evaluated for their antioxidative effects by DPPH (1,1-diphenyl-2-picrylhydrazyl) scavenging activity assay, the inhibition activity for peroxidation of linoleic acid, and the reduction power. It was found that methanol extract of moso bamboo culms and madake bamboo leaves presented stronger antioxidative activity compared with DPPH scavenging activity (Jun, Tohru, & Ujianzhang, 2004). Ni et al. (2014) studied the effect of different harvesting seasons and drying methods on the antioxidative activity from the leaves of two bamboo species namely, *Pleioblastus kongosanensis f. aureostriatus* and *Shibataea chinensis*, and concluded that the leaves show highest antioxidative activity in winter and lyophilization is the most effective method for maintaining the activity of antioxidant compounds.

The leaves of *Bambusa nutans*, *B. vulgaris*, *B. textilis* McClure, *B. vulgaris* var. *vittata*, and *Dendrocalamus oldhami* are reported as promising natural alternatives to synthetic antioxidants as functional food ingredients (Tripathi et al., 2015). Luo et al. (2015), identified two novel flavonoids namely, 40-O-(700R, 800S)-800-guaiacylglyceryl)-pleioside, and apigenin 6-C-b-D-fucopyranosyl-7-O-b-D-glucopyranoside from the leaves of *Neosinocalamus affinis*, with significant antioxidative activity. Eleven compounds out of fourteen compounds which were identified and isolated from the leaves of *Phyllostachys prominens*, possess significant antioxidative activity (Xu et al., 2016). Liu et al. (2016) identified 38 compounds including organic acids, flavonoids and other substances and quantified 13 polyphenols. The methanolic extract of *B. texilis* leaves showed antioxidant and antiobesity activities when evaluated using a high fat diet rat model. Daswad et al. (2017) reported that aqueous and methanolic extract of *Dendrocalamus strictus* leaves possess promising antioxidant activity. Bamboo leaf antioxidants may thus offer promising avenues to prevent and control oxidative-stress related chronic and degenerative diseases.

3. Antioxidant compounds and antioxidant properties of bamboo shoots

Bamboo shoot, the emerging young culm is a popular ingredient in Asian cuisine and is used in the preparation of variety of dishes. The young juvenile shoots of many bamboo species are consumed as vegetables, salads, pickles, and in preparation of different types of curries

Table 1
Isolated compounds and antioxidant activity of leaves of different bamboo species.

Name of the species	Isolated compounds	Scavenging ability on DPPH free radicals	Reference
Phyllostachys nigra var. *henonis*	Chlorogenic acid	[a]BLE, 1 μg/mL 8.9 ± 0.0	Hu et al. (2000)
	Caffeic acid	BLE, 5 μg/mL 19.3 ± 0.6	
	Luteolin 7-glucoside	BLE, 20 μg/ml 40.9 ± 0.5	
P. edulis	Chlorogenic acid derivatives:		Kweon et al. (2001)
	1) 3-O-(3′-methylcaffeoyl)quinic acid	[b]16.0	
	2) 5-O-caffeoyl- 4-methylquinic acid	8.8	
	3) 3-O-caffeoyl-1-methylquinic acid	6.9	
	Chlorogenic acid	12.3	
	Caffeic acid	13.7	
	Ferulic acid	36.5	
P. pubescens	–	[a]17.52	Jun et al. (2004)
P. bambusoides	–	[a]34.76	Jun et al. (2004)
P. nigra var. *henonis*	Tricin	–	Jiao et al. (2007)
Sasa borealis	Tricin7-O-β-D-glucopyranoside	–	Park et al. (2007)
	Isoorientin (luteolin 6-C-β-D-glucopyranoside)	[b]9.5	
	Apigenin 6-C-β-D-xylopyranosyl-8-C-β-D-glucopyrano- side	161.5	
	Isoorientin 2-O-α-L-rhamnoside	34.5	
P. nigra var. *henonis*	Orientin, homoorientin, vitexin, isovitexin	–	Zhang et al. (2008)
P. heterocycla cv. pubescens	63 components	[c]3.1622	Jin et al. (2011)
P. heterocycla cv. gracilis		4.9353	
P. kwangsiensis		5.4746	
P. heterocycla cv. heterocycla		4.2473	
Bambusa textilis	Isoorientin 4″—O-β-D-xylopyranoside	–	Wang, Yue, Tang, and Sun (2012a)
	Isoorientin 2″—O-α-L-rhamnoside		
Pleioblastus kongosanensis f. aureostriatus	orientin, isoorientin, vitexin, homovitexin and *p*-coumaric acid, chlorogenic acid, caffeic acid, ferulicacid	[d]594.57–306.99 202.19–484.48	Ni et al. (2014)
Shibataea chinensis			
P. nigra	Trans-coniferyl alcohol	[e]1.1	(Shang, Kim, and Um (2014)
	p-coumaric acid	–	
	N-feruloylserotonim	0.0077	
	Caffeic acid ethyl ether	0.067	
	Tricin,	1.3	
	p-coumaryl alcohol	–	
	p-coumaric acid ethyl ether	–	
	Ferulic acid ethyl ether	–	
Neosinocalamus affinis	40-O-((700R,800S)-800-guaiacylglyceryl)-pleioside B apigenin 6-C-b- D-fucopyranosyl-7-O-b-D-glucopyranoside	[a]19.5 –	Luo et al. (2015)
P. prominens	14 compounds	[d]33.52–100.58	Xu et al. (2016)
Dendrocalamus strictus	–	[a]57.80–77.31(Aq. extract) [a]57.31–77.2 (Met. extract)	Daswad et al. (2017)

a = Percentage of scavenging; b = IC_{50} (μM); c = IC_{50} (μl/ml); d = IC_{50} (μg/ml); e = SC_{50} (mM); Aq = Aqueous; Met = Methanol; *P* = *Phyllostachys*.

and dishes in many Asian countries such as China, Korea, Japan, Thailand, Malaysia and India. In Korea, there are many traditional foods in which bamboo shoots are a prominent ingredient. One such dish that is now widely acquainted with global tastes and emerging as one of the representative dishes of Korean food is “bibimbap” which is a colorful dish with various vegetables and symbolizes the philosophy of blending with others. Bamboo shoot is being projected as a health food due to its nutritive value and presence of health promoting bioactive compounds with potential antioxidant activity (Kalita, Ganguly, & Devi, 2016; Nirmala et al., 2011). However, in addition to the nutritional and health benefits, the young shoots of many species contain the anti-nutrient cyanogenic glucosides which, is toxic and causes acridity in the shoots and is a major constraint for several people to have bamboo shoots as food. Hence, before consumption, the young shoots need to be processed by soaking, boiling, drying or fermentation to remove the cyanogenic glucosides to make the shoots palatable and safe to eat. According to ancient Chinese medicinal books, the consumption of young shoots help in improving digestion, relieving hypertension, preventing cardiovascular diseases, and cancer.

The juvenile bamboo shoots are rich in nutrients, bioactive compounds, vitamins (vitamin A, vitamin B1, vitamin B3, vitamin B6, vitamin C, vitamin E), amino acids and minerals and hence, play a significant role in maintaining good health (Kumbhare & Bhargava, 2007; Park & Jhon, 2009). It contains arginine and tyrosine as the major amino acids that otherwise is a minor component in common fruits and vegetables. Arginine plays a key role in the synthesis of glycoproteins. Tyrosine is a major precursor of several neurotransmitters and may directly affect processes in the brain including cognitive function. It also acts as a natural diuretic and helps to get rid of excess salts. *Phyllostachys manii* shoots have a high content of asparagine followed by tyrosine and valine. Asparagine is known for its key role in the biosynthesis of glycoproteins; it increases the resistance to fatigue and improves the smooth functioning of the liver. Valine is an essential amino acid important for maintaining muscle regulation of the immune system and cognitive functioning. Bamboo shoot also contains selenium, an important antioxidant in trace amount (Nirmala et al., 2011) and lysine, which lacks in cereals, plays an important role in growth and development. Fresh bamboo shoots have been found to be rich in potassium which helps to prevent blockage of blood vessels. Bamboo shoots are also rich in antioxidants and their antioxidant activity has been screened by several researchers (Kalita et al., 2016; Neményi et al., 2015). Realizing their nutritive value and health benefits, in some countries, the shoots have been used as additives in a variety of health foods, beverages, and medicines. Phenols, vitamin C, E and trace mineral elements (selenium, copper, zinc, manganese, iron) are the main antioxidant components present in bamboo shoots.

3.1. Phenols

It is well known that phenolic compounds in the plants are very important antioxidants. Interest in natural and food derived phenolics has increased because of their roles as scavengers of free radicals and

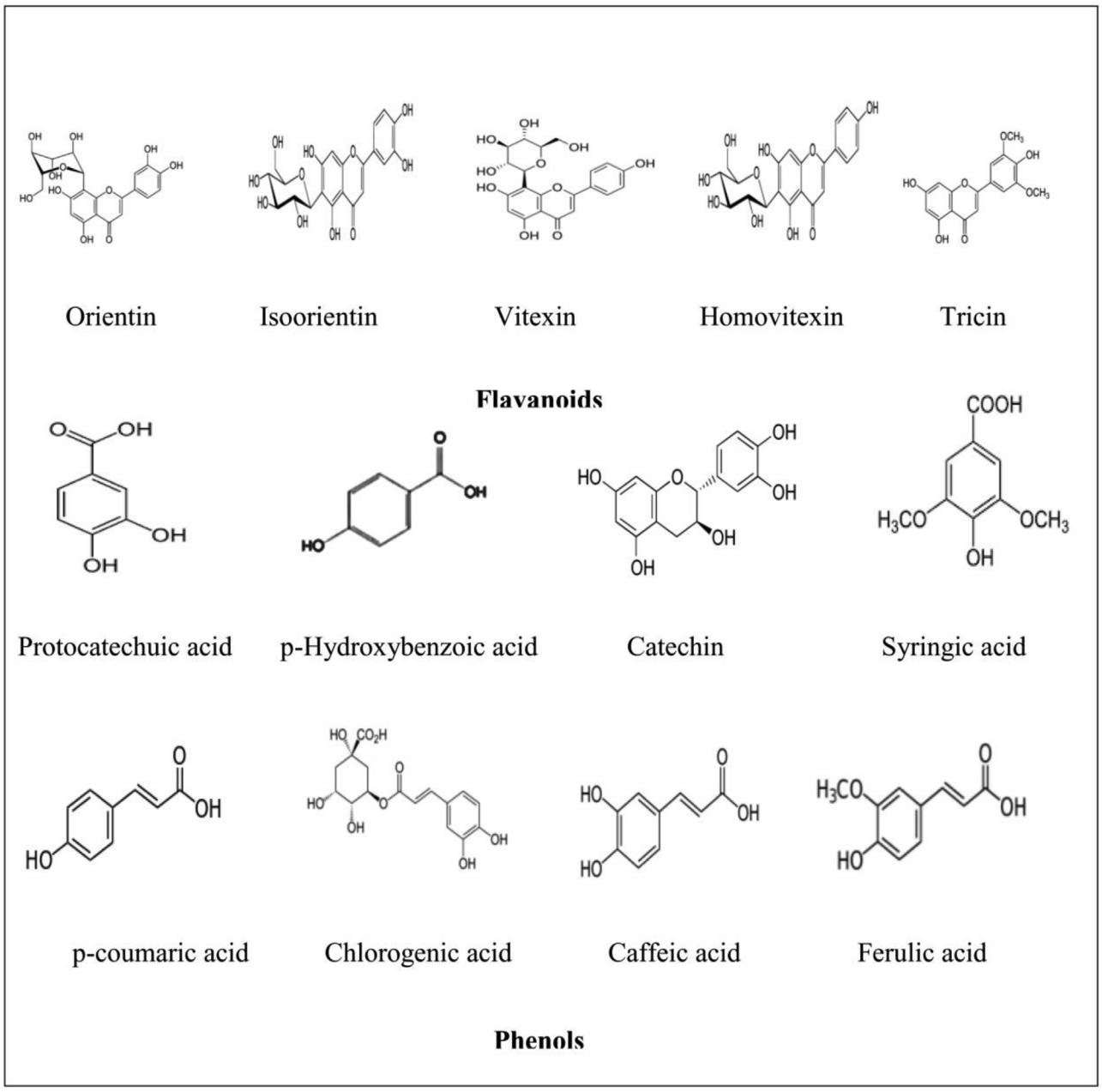

Fig. 1. Chemical structure of phenols and flavonoids isolated from bamboo shoots and leaves.

their implications in the prevention of several diseases. Bamboo shoots are one of the best sources of phenolic compounds in the plants (Nirmala, Bisht, & Laishram, 2014a; Neményi et al., 2015). Park and Jhon (2010), identified eight phenolic acids in the shoots of *Phyllostachys pubescence*, these are protocatechuic acid, *p*-Hydroxybenzoic acid, catechin, caffeic acid, chlorogenic acid, syringic acid, *p*-Coumaric acid, and ferulic acid (Fig. 1). The phenolic content of shoots of different bamboo species ranges from 191.37 mg/100 g to 630.0 mg/100 g, fresh weight (Table 2). The shoots of four bamboo species, *Bambusa nutans*, *Dendrocalamus giganteus*, *D. hamiltonii* and *D. latiflorus* were evaluated for their total phenolic content (Bajwa, Nirmala, Koul, & Bisht, 2015). Results showed that *D. latiflorus* (612.24 mg/100 g, fresh weight) has highest phenolic content, followed by *D. hamiltonii* (586.36 mg/100 g, fresh weight), *B. nutans* (489.83 mg/100 g, fresh weight), and *D. giganteus* (336.56 mg/100 g, fresh weight). Similarly, Neményi et al. (2015), analyzed the total phenolic content of shoots of 14 *Phyllostachys* species (*P. aureosulcata*, *P. aureosulcata f. aureocaulis*, *P. aureosulcata f. spectabilis*, *P. bissetii*, *P. flexuosa*, *P. humilis*, *P. nigra* var. *nigra*, *P. nigra* var. *henonis*, *P. mannii*, *P. sulphurea* var. *sulphurea*, *P. viridiglaucescens*, *P. vivax f. aureocaulis*), harvested at different time duration. The highest value of total phenolic content was measured in the shoots of *P. aureosulcata* (1321.95 µg GA/ml) and lowest was reported in the shoots of *P. vivax f. aureocaulis* (826.22 µg GA/ml). It was also reported that the highest total phenolic content was measured in taxa harvested on the first collection date and the values consequently decreased in taxa collected at later harvest dates. Phenolic acids present in the tender bamboo shoots have mild anti-inflammatory properties and potent antioxidative activity that may prevent cancer and blood vessel injury. These features make phenols a potentially interesting material for the development of functional foods.

3.2. Vitamin C (ascorbic acid)

Vitamin C is known to have many biological functions, such as

Table 2
Vitamin C, vitamin E, phenolic content and scavenging activity of bamboo shoots.

Bamboo species	Vitamin C (mg/100 g, fresh weight/[a]dry weight)	Vitamin E (mg/ 100 g, fresh weight	Phenols (mg/100 g, fresh weight/μg GA/ml)[b]	Scavenging Activity (%)/(μg AA/ml)[c]	Reference
Bambusa arundinacea	7.50	–	–	–	Bhargava et al. (1996)
	2.72	–	101.65	27.12	Badwaik, Gautam, and Deka (2015)
B. bambos	1.09	0.61	–	–	Nirmala et al. (2011)
B. kingiana	2.10	0.51	–	–	-do-
B. nutans	1.19	0.47	489.83	–	Nirmala et al. (2011, 2014a)
B. pallida	2.10	–	79.85	19.17	Badwaik et al. (2015)
B. polymorpha	2.60	0.49	–	–	Nirmala et al. (2011)
	17.5	–	–	–	Bhargava et al. (1996)
B. tulda	1.42	0.61	443.97	–	Nirmala et al. (2011, 2014a)
	1.39	–	80.54	21.73	Badwaik et al. (2015)
B. vulgaris	4.80	0.52	–	28.21	Nirmala et al. (2011); Singhal, Bal, Satya, Sudhakar, and Naik (2013)
	13.70	–	–	–	Bhargava et al. (1996)
Dendrocalamus asper	3.20	0.91	580.0	13.97	Nirmala et al. (2011, 2014a); Singhal et al. (2013)
D. brandisii	1.59	0.42	–	–	Nirmala et al. (2011)
D. giganteus	3.28	0.69	347.27	–	Nirmala et al. (2011; 2014a)
	2.21	0.56	616.50	–	Rawat et al. (2016)
D. hookerii	9.9	–	–	–	Bhatt et al. (2005)
D. hamiltonii	2.45	0.71	505.93	–	Nirmala et al. (2011; 2014a)
	1.45	–	88.23	23.12	Badwaik et al. (2015)
D. latiflorus	2.38	0.52	612.24	–	Rawat et al. (2016)
D. longispathus	23.0	–	–	–	Bhargava et al. (1996)
	5.3	–	–	–	Bhatt et al. (2005)
D.membranaceus	1.58	0.65	–	–	Nirmala et al. (2011)
D. sikkimensis	3.0	–	450.29	–	Bhatt et al. (2005)
	2.43	0.59	271.23	–	Rawat et al. (2016)
D. strictus	2.43	0.58	630.0	–	Nirmala et al. (2011; 2014a)
Gigantochloa albociliata	1.00	0.60	–	–	Nirmala et al. (2011)
G.rostrata	3.20	0.49	–	–	-do-
Melocanna bacciferra	7.6	–	–	–	Bhatt et al. (2005)
	15.0	–	–	–	Bhargava et al. (1996)
Phyllostachys praecox	12.0	–	–	–	Zhang, Ji, Hu, Chen, and Ye (2011)
P. bambusoides	6.1	–	–	–	Bhatt et al. (2005)
P. nigra	231.8[a]	–	–	–	Park and Jhon (2010)
P. pubescens	136.3[a]	–	–	–	-do-
Teinostachyum wightii	6.6	–	–	–	Bhatt et al. (2005)
P. aureosulcata	–	–	1321.95[b]	177.99[c]	Neményi et al. (2015)
P. aureosulcata f. aureocaulis	–	–	1208.74[b]	137.4[c]	-do-
P. aureosulcata f. spectabilis	–	–	1187.77[b]	135.24[c]	-do-
P. bissetii	–	–	1193.81[b]	142.93[c]	-do-
P. flexuosa	–	–	1306.05[b]	170.42[c]	-do-
P. humilis	–	–	983.18[b]	89.63[c]	-do-
P. iridescens	–	–	1217.96[b]	184.24[c]	-do-
P. nigra var. *nigra*	–	–	1178.17[b]	163.39[c]	-do-
P. nigra var. *henonii*	–	–	1130.49[b]	162.73[c]	-do-
P.mannii	–	–	1082.41[b]	117.83[c]	-do-
P. sulphurea	–	–	970.14[b]	166.18[c]	-do-
P.viridiglaucescens	–	–	1203.84[b]	145.42[c]	-do-
P.vivax f. aureocaulis	–	–	826.22[b]	123.15[c]	-do-
P. violascens	–	–	1270.51[b]	137.77[c]	-do-

collagen formation, absorption of inorganic iron, reduction of plasma cholesterol level, and enhancement of immune system. It is also required for prevention of scurvy and maintenance of healthy skin, gums, and blood vessels. Vitamin C as an antioxidant, reportedly, reduces the risk of arteriosclerosis, cardiovascular problems, and some forms of cancer. It is capable of neutralizing reactive oxygen species in the aqueous phase before lipid peroxidation is initiated. Several investigators have worked on vitamin C content of shoots of many bamboo species (Table 2). The vitamin C content, as determined by Nirmala et al. (2011) in the fresh shoots of various bamboo species ranges from 1.00 mg to 4.80 mg/100 g, fresh weight. Bhatt, Singha, Sachan, and Singh (2005) also reported vitamin C content for a number of bamboo species ranging from 3.0% to 12.9%, highest being in *Dendrocalamus hamiltonii* and lowest being in *D. sikkimensis*. According to Bhargava, Kumbhare, Srivastava, and Sahai (1996) vitamin C content ranges from 8% to 23% in the shoots of various bamboo species. Rawat, Sharma, Saini, Nirmala, and Bisht (2016) evaluated the vitamin C content of shoots of three bamboo species namely, *Dendrocalamus giganteus*, *D. latiflorus*, and *D. sikkimensis* and found that *Dendrocalamus sikkimensis* (2.43 mg/100 g, fresh weight) has higher vitamin C content followed by *D. latiflorus* (2.38 mg/100 g, fresh weight), and *D. giganteus* (2.21 mg/100, fresh weight).

3.3. Vitamin E (tocopherols)

Vitamin E is the major lipid soluble antioxidant in the cell antioxidant defense system, and it can only be obtained from the diet. The term 'vitamin E' refers to a group of eight naturally occurring homologues that are synthesized by plants from homogentisic acid. Out of eight isomers of vitamin E, α-tocopherol is the most biologically important antioxidant. Vitamin E shows protective effects against the coronary heart diseases due to the inhibition of Low Density

Lipoprotein (LDL) oxidation. Other reported health benefits of vitamin E include enzymatic activities, gene expression, and neurological functions.

Fresh bamboo shoots are a good source of vitamin E (Nirmala et al., 2011; Shi & Yang, 1992) and the content in various bamboo species ranges from 0.42% to 0.91%, (Table 2). Vitamin E works synergistically with vitamin C in enhancing the immune functions of the body. It is also required for the development of retina in the eyes. Recent research evidence indicate that regular use of vitamin E from diet helps to prevent Alzheimer's disease. Bamboo shoot is not only rich in vitamin C and vitamin E, but it is a good multivitamin food that can act as a foundation for good health.

3.4. Trace mineral elements

Dietary minerals are of great interest for health specialist and consumers, due to the number of processes they are involved in, and the benefits of their adequate and balanced intake have been highlighted. The role of trace minerals in enzyme functions have been studied extensively in nutrition and biochemistry (Soetan & Oyewole, 2009). Selenium, copper, zinc, iron, and manganese are indispensable metals, for the activities of various antioxidant enzymes and their deficiencies have profound effects on metabolism and tissue structure. Bamboo shoots are endowed with rich quantities of useful minerals. Trace elements in bamboo shoots associated with antioxidant defense system are selenium, zinc, copper, iron, and manganese. Selenium is an essential trace element and co-factor for an enzyme, glutathione peroxidase. Since the discovery of glutathione peroxidase as a selenium-dependent enzyme, selenium has been identified as an essential co-factor for selenoproteins. Dietary deficiency of selenium markedly decreases tissue glutathione peroxidase activity by 90% and results in peroxidative damage and mitochondrial dysfunction (Xia, Hill, & Burk, 1985). Chinese scientists discovered a disease namely, 'Keshen disease' that occurs due to the severe deficiency of dietary selenium (Yang, Wang, Zhou, & Sun, 1983). Copper, zinc, and manganese are other indispensable minerals, which are required for the activities of enzyme superoxide dismutase (SOD). Iron is the most abundant trace element in the body, and almost all iron occurs bound to proteins.

Very few bamboo species have been evaluated for selenium content in the shoots. Selenium content in shoots of two bamboo species namely, *Bambusa tulda* and *Dendrocalamus hamiltonii* were estimated and it was found that *D. hamiltonii* (0.8 μg/100 g, fresh weight) has higher selenium content than *B. tulda* (0.4 μg/100 g, fresh weight) (Nirmala et al., 2011). Iron content in shoots of different bamboo species as reported by Christian et al. (2015) ranges from 10.3 μg to 43.2 μg/g. Zinc, copper, and manganese content in *Phyllostachys* species ranges from 11.5 μg to 54.6 μg/g, 0.6 μg to 35.0 μg/g, and 11.5 μg to 176.7 μg/g, respectively (Christian et al., 2015; Mainka, Zhao, & Li, 1989; Tabet, Oftedal, & Allen, 2004). Saini, Rawat, Bisht, and Nirmala (2017) detected five micro mineral elements in fresh and processed shoots of *Bambusa balcooa* and *B. bamboos* by Wavelength Dispersion X-ray Fluorescence Spectroscopy. Iron content ranged from 8.0-8.2 mg/100 g, dry weight, Zinc 6.8–10.0 mg/100 g, dry weight, Copper 2.5–2.6 mg/100 g, dry weight, Manganese 2.5–3.6 mg/100 g, dry weight and Nickel 0.7–0.9 mg/100 g, dry weight.

3.5. Antioxidant properties

Antioxidant properties are very significant in terms of food and nutraceuticals, because a high dietary intake of antioxidants is associated with protection against a broad range of human chronic diseases including cancer and cardiovascular diseases. The results of several studies have shown that bamboo shoots are a good source of antioxidants, and their antioxidant properties have been screened by many researchers using different oxidation assays (Table 2). Research on bamboo shoot antioxidants began in the 1990s with a study by Ishii and Hiroi (1990) who identified a compound namely, diferuloyl arabinoxylan hexasaccharide containing 5-5-linked diferulic acid from bamboo shoots and reported that ferulic acid is a naturally occurring antioxidant present in the plant-based products.

Several bamboo species have been analyzed for their antioxidant activities viz. *Dendrocalamus asper*, *D. hamiltonii*, *Bambusa tulda*, *B. vulgaris*, *B. balcooa*, *B. pallida*, and *Phyllostachys* species, using different antioxidative assays to acquire comprehensive information about the overall antioxidant capacity of bamboo shoots (Park & Jhon, 2010; Neményi et al., 2015). In one of the studies, it was found that bamboo shoots contributed 46% of the daily antioxidant activity intake among different vegetables consumed in China (Yang, Tsou, Lee, Hanson, & Lai, 2005). Neményi et al. (2015) reported a significant correlation between total phenolic content and antioxidant activity of bamboo shoots. Antioxidant and antimicrobial effects of bamboo shoot extracts incorporated in pork nuggets were observed by Thomas, Jebin, Saha, and Sarma (2016). Addition of bamboo shoot extract not only increased the storage life but also significantly improved the microbial and sensory qualities of the products. This property was attributed to the presence of total phenols and ascorbic acids in the bamboo shoot extracts. The antioxidant system of bamboo shoots is also considered to be crucial in the resistance against chilling stress. Zeng, Jiang, Wang, and Luo (2015) carried out a study on shoots of *Phyllostachys praecox f. prevernalis* and determined that UV-C treatment alleviated chilling injury through strengthening antioxidant competence and promoting proline biosynthesis.

4. Application of bamboo in the food and pharmaceutical industry

For decades, the application of antioxidants in the food and pharmaceutical industry has been widespread. In the past, antioxidants were previously used to control oxidation and retard spoilage but today, many are used because of putative health benefits. With increasing health consciousness in consumers, there is much demand of food for well being and health (Kumar et al., 2017). In recent years, attention is being paid to the foods that have valuable amounts of minerals, vitamins, micronutrients, dietary fiber and antioxidants. Young bamboo culm flour has been found as a new ingredient for production of healthier food products (Felisberto, Beraldo, & Clerici, 2017). Bamboo leaf antioxidants are very effective in retarding lipid oxidation and preventing biogenic amine formation in pork sausage when combined with tea polyphenols (Fan, Yi, Zhang, & Diao, 2015). During storage of sausages, toxic biogenic amines are formed which are nitrogenous compounds formed mainly during microbial decarboxylation of amino acids and they are a concern of food safety. High amount of biogenic amine consumption may cause nausea, headache, cardiac palpitation, hypotension or hypertension, intracerebral hemorrhage and even death (Bodmer, Imark, & Kneubühl, 1999). Addition of antioxidant of bamboo leaves (AOB) combined with tea polyphenols to the sausages inhibited bacterial growth and decarboxylase-positive spoilage activities as they acted as antimicrobial agents. The efficiency of AOB on the reduction of acrylamide during thermal processing of fried chicken wings, potato chips, and French fries was demonstrated by Zhang, Chen, Zhang, Wu, and Zhang (2007a). Acrylamide is a neurotoxin with carcinogenic properties that is found in a large range of fried and baked carbohydrate rich foods. Immersion of the potato crisps and French fries into AOB solution significantly reduced the acrylamide formation retaining the original crispness and flavor of potato matrixes.

Bamboo is endowed with several health beneficial properties due to which its application in the pharmaceutical industry is gaining much importance. Singh et al. (2010) studied the antimicrobial activity of the aqueous and ethanolic leaf extracts of *Bambusa arundinaceae* against *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aurenginosa* and *Bacillus* sp. The ethanolic extract was found to be more effective in inhibiting the microbes compared to aqueous extract against the standard penicillin. Antidiabetic activity of *Sasa borealis* has been studied in

rats which illustrated hypoglycemic effect. The leaf extract of this bamboo was substituted for meat in patty which significantly lowered plasma glucose indicating antidiabetic activity (Panee, 2008). The antidiabetic activity of the petroleum extract of the leaf of *Bambusa vulgaris* in streptozotocin induced diabetic rats were studied and it was found that oral administration of the extract for a period of 15 days was effective in significantly reducing the blood glucose level in a dose dependant manner when compared to the standard drug glibenclamide (Senthilkumar, Sivakumar, Changanakkattil, Rajesh, & Perumal, 2011). The alkaline extract prepared from the leaves of *S. senanensis* popularly known as "Sasa health" has been proven to have anti-tumor activity (Seki, Kida, & Maeda, 2008). Oral administration of the extract at a concentration of 0.05% or more was found to be effective in suppressing tumor growth in mouse models S-180 and C38. Anti-fatigue activity of leaf extract of various bamboo species viz. *Phyllostachys nigra* var *henonis*, *Pseudosasa japonica*, *Bambusa tuldoides* etc. have also been studied by several researchers. Zhang, Yao, Bao, and Zhang (2006) studied the anti-fatigue activity of *Bambusa tuldoides* using BALB/c mice models. It was found that the extract at an appropriate concentration not only could prolong the weight-loaded swimming and climbing time, but also exerted active effect on the serum urea nitrogen, hepatic glycogen and blood lactic acid level in BALB/c mice thus personified its anti-fatigue activity. *Sasa quelpaertensis* have been studied for its anti-obesity effects. Leaf extract (SQE) of *Sasa quelpaertensis* when administrated to HFD mice, it not only decreased the body weight, adipose tissue weight, serum cholesterol and triglycerides but also reduced the serum levels of several enzymes along with deposition of lipid droplets in the liver when compared to untreated mice (Kang et al., 2012).

Bamboo shoots, with their high nutritive and therapeutic value, are now used for food fortification (Nirmala & Bisht, 2017). Several value-added products such as nuggets, crackers, chutney, snacks, cookies, cakes, chappaties, and buns have been prepared from bamboo shoots (Table 3). Dietary fiber from bamboo shoots is a common ingredient in bakery, dairy, and meat products. Most of the fiber used as an additive in foods is derived from wheat, oats, corn, and apples. Bamboo shoots with high fiber content can be conveniently used as an alternative for extraction of fiber for subsequent use in the food industry. Bamboo shoot-based products commercially available in China, Korea, Japan, Thailand and Malaysia include canned bamboo shoots, fermented bamboo shoots, bamboo shoot pickle, bamboo shoot powder, bamboo vinegar and bamboo shoot juice. These novel products have also been analyzed for their sensory and nutritional qualities. Farris and Piergiovanni (2008) prepared a popular Italian food namely, 'Amaretti cookies' using bamboo fiber as an ingredient. Incorporation of bamboo fiber imparted a characteristic flavor, texture and taste to the cookies. Sood, Walia, Gupta, and Sood (2013) also prepared some edible products such as preserve, candy, chutney, nuggets, cracker and chukh using juvenile shoots of *Dendrocalamus hamiltonii*. Results showed that bamboo shoots improved their nutritional and organoleptic qualities. Zheng, Wu, Dai, and Zhang (2017) reported that milk pudding fortified with bamboo shoot fiber increased the yield stress, consistency coefficient values, hardness viscosity and gumminess, whereas the fluid index value decreased. Similarly, other products such as pork nuggets, chicken nuggets, pork pickle, chips, and biscuits have been prepared, using fresh or fermented shoots of different bamboo species such as *Bambusa auriculata, B. bambos*, *B. tulda*, *B. polymorpha, B. balcooa, B. vulgaris, Dendrocalamus asper*, *D. strictus.* Analysis of these products for their nutritional and organoleptic qualities revealed that the products fortified with fresh or fermented bamboo shoots revealed significantly higher mean sensory scores in terms of flavor, texture, juiciness and overall acceptability. Bamboo shoots not only improved their shelf-life, sensory and nutritional qualities but also increased their physico-chemical and nutraceutical properties (Choudhury, Badwaik, Borah, Nandan, & Deka, 2015; Das, Nath, Kumari, & Saha, 2013; Gazi, Hosseini, Yakhchali, & Borajee, 2017; Mustafa, Naeem, Masood, & Farooq, 2016; Thomas, Jebin, Barman, & Das, 2014; Thomas et al., 2016). By adding dietary fiber from fermented bamboo shoots, Zheng et al. (2016) observed a significant reduction of fat absorption in deep fried battered and breaded fish balls. These findings proved that low fat fried fish balls can be produced by the addition of bamboo shoot dietary fiber from fermented shoots in the batter.

Consumption of bamboo shoot fiber reportedly decreased serum total cholesterol, LDL, and the atherogenic index, and increased fecal volume and bowel movement frequency in healthy young women when compared with controls on a dietary fiber-free diet (Park & Jhon, 2009). These lipid-lowering effects have been attributed to inhibition of cholesterol absorption and increase of cholesterol excretion. They are also a good source of potassium that helps to maintain a normal blood pressure and a steady heart rate. Potassium deficiency may raise blood pressure, and dietary supplements to replace low potassium level are routinely recommended on hypertensive individuals. A study by Jiao et al. (2007) on the anti-hyperlipidemic and anti-hypertensive effect of triterpenoid-rich extract from bamboo shaving and the vasodilator effect of friedelin on phenylephrine-induced vasoconstriction in thoracic aortas of rats, demonstrated that extract from bamboo shavings could reduce the serum total cholesterol and total triglyceride levels, which are the main factors directly leading to pathological changes in cardiovascular diseases. Bamboo shoots have high content of silica which plays an important role in maintaining the structural integrity, elasticity, and permeability of the arteries thereby regulating the blood pressure. Silica may be useful in reducing blood fats and cholesterol, and atherosclerosis can occur as a result of its deficiency. It also enhances the function of calcium that helps regulate heart beat as well as potassium that helps control hypertension. Considering the health

Table 3
Bamboo shoot fortified food products.

Sl. no.	Product	Bamboo Species	Form used	References
1.	Milk pudding	*Dendrocalamus latiflorus*	Dried	Zheng et al. (2017)
2.	Pork Nuggets	*Bambusa polymorpha*	Fresh, Fermented	Thomas et al. (2014, 2016)
3.	Cookies	*Not mentioned*	Fresh	Mustafa et al. (2016)
4.	Cookies, Chapatties, Parantha,Buns, Snacks,Bujiya, Bread,Paneer, Pickles	*Dendrocalamus hamiltonii, Phyllostachys mannii, Bambusa tulda*	Fresh	Bisht, Nirmala, and Vyas (2012); Bisht, Nirmala, and Santosh (2015)
5.	Biscuit	*Bambusa balcooa*	Fresh	Choudhury et al. (2015)
6.	Candies	*Not mentioned*	Fresh	Nimisha et al. (2015)
7.	Chips	*Bambusa vulgaris*	Fresh	Maroma (2015)
8.	Pork Pickles	*Not mentioned*	Fermented	Chavhan, Hazarika, Brahma, Hazarika, and Rahman (2015)
9.	Candy, chutney, chukh, cracker, nugget	*D. hamiltonii*	Fresh	Sood et al. (2013)
10.	Chicken nuggets	*Bambusa auriculata*	Fermented	Das et al. (2013)
11.	Crackers, nugget, pickle	*Bambusa bambos, B. tulda, Dendrocalamus asper, D. strictus*	Fresh	Pandey, Ojha, and Choubey (2012)
12.	Yogurt	*Not mentioned*	Salted	Park and Jhon (2006)
13.	Amaretti cookies	*Not mentioned*	Dried	Farris and Piergiovanni (2008)

Table 4
Bamboo based nutraceutical products.

Product Name	Content	Health benefits
Bamboo Nutra	Bamboo fiber	Anti-ageing, Anti-obesity
Bamboo silica	Bamboo silica	Anti ageing, preserves skin youthfulness
Bamboo flex	Bamboo leaf	Anti-inflammatory, remineralization and development of bone structure
Bonusan forte	Tabashir exudates	Anti-fatigue, supports energy metabolism, good for nervous system
Guozen bamboo leaf essence	Bamboo leaf	Purifies blood and strengthens bones
Hawlik Cappillary capsules	Bamboo shoot	Improves hair health
Lambert silica capsules	Tabashir exudates	Contributes to structure and resilience of connective tissue, synthesis of bone collagen and cartilage
Sanacel	Bamboo fiber	Improves digestion
Silice de Bambou	Tabashir exudates	Prevents premature ageing, preserves skin youthfulness, promotes strong hair, healthy bones and teeth
Solary bamboo capsules	Culm powder	Stimulates collagen synthesis in bone and connective tissue

enhancing properties of bamboo, many bamboo based nutraceuticals are commercially available for various ailments (Table 4).

5. Conclusion

A complete understanding of the nutritional and therapeutic role of dietary antioxidants from food plants is very important for developing a healthy diet to counter under nutrition and to prevent major oxidation linked diseases such as cardiovascular diseases, diabetes, cancer, and cognitive diseases. Research has proposed several health benefits associated with bioactive compounds and antioxidants present in bamboo leaves and shoots. Synthetic chemical compounds, popularly used as preservatives in medical products have harmful effects and now consumers demand for natural and safe additives are increasing. Currently, synthetic antioxidants are used both in the food and pharmaceutical industry in order to prolong product shelf life mainly by preventing the oxidation of unsaturated double bonds of fatty acids. This involves many risks because of the carcinogenic and toxic effect of the synthetic antioxidants thus fueling an intense search for natural and efficient antioxidants. Both, bamboo leaves and shoots are a good source of natural antioxidants and can play a vital role in the food and pharmaceutical industry. Bamboo shoots are delicacies used in the preparation of many dishes and they can be included in our daily diets. Moreover, they can be used for fortifying various food products. Thus, bamboo leaves and shoots both being a good source of natural antioxidants, can play a vital role in the food and pharmaceutical industry.

Conflicts of interest

The author's declares none.

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References

Akao, Y., Seki, N., Nakagawa, Y., Yi, H., Matsumoto, K., Ito, Y., et al. (2004). A highly bioactive lignophenol derivative from bamboo lignin exhibits a potent activity to suppress apoptosis induced by oxidative stress in human neuroblastoma SH-SY5Y cells. *Bioorganic & Medicine Chemistry, 12*(18), 4791–4801.

Badwaik, L. S., Gautam, G., & Deka, S. C. (2015). Influence of blanching on antioxidant, nutritional and physical properties of bamboo shoot. *Journal of Agricultural Science, 10*(3), 140–150.

Bajwa, H. K., Nirmala, C., Koul, A., & Bisht, M. S. (2015). Effects of processing and preservation on phenols and phytosterol content in bamboo shoots. *Proceedings of 10th world bamboo congress, theme: Food and pharmaceuticals, September 17-22, Damyang, Korea*.

Bhargava, A., Kumbhare, V., Srivastava, A., & Sahai, A. (1996). Bamboo parts and seeds for additional source of nutrition. *Journal of Food Science and Technology, 33*(2), 145–146.

Bhatt, B. P., Singha, L. B., Sachan, M. S., & Singh, K. (2005). Commercial edible bamboo species of the north-eastern himalayan region, India. Part II: Fermented, roasted, and boiled bamboo shoots sales. *Journal of Bamboo and Rattan, 4*(1), 13–31.

Bisht, M. S., Nirmala, C., & Santosh, O. (2015). Bamboo shoots for food in north-east India: Conventional and contemporary. *Proceedings of the 10th world bamboo congress, Korea*http://www.worldbamboo.net/proceedings/wbcx.

Bisht, M. S., Nirmala, C., & Vyas, P. (2012). Bamboo shoot a neglected natural resource: A source of food and prosperity for north-east India. *Proceedings of national Seminar: Recent advances in natural product research, Mizoram university, aizawl, India, 29 November-1 December* (pp. 18–22). .

Bodmer, S., Imark, C., & Kneubühl, M. (1999). Biogenic amines in foods: Histamine and food processing. *Inflammation Research, 48*, 296–300.

Chavhan, D. M., Hazarika, M., Brahma, M. L., Hazarika, R. A., & Rahman, Z. (2015). Effect of incorporation of fermented bamboo shoot on physicochemical and microbial quality of pork pickle. *Journal of Food Science & Technology, 52*(2), 1223–1227.

Choudhury, M., Badwaik, L. S., Borah, P. K., Nandan, S., & Deka, C. S. (2015). Influence of bamboo shoot powder fortification on physico-chemical, textural and organoleptic characteristics of biscuits. *Journal of Food Science & Technology, 52*(10), 6742–6748.

Christian, A. L., Knott, K. K., Vance, C. K., Falcone, J. F., Bauer, L. L., Jr., Fahey, G. C., et al. (2015). Nutrient and mineral composition during shoot growth in seven species of *Phyllostachys* and *Pseudosasa* bamboo consumed by giant panda. *Journal of Animal Physiology and Animal Nutrition, 99*(6), 1172–1183.

Dangour, A. D., Mace, G., & Shankar, B. (2017). Food systems, nutrition, health and the environment. *The Lancet, 1*, 8–9.

Das, A., Nath, D. R., Kumari, S., & Saha, R. (2013). Effect of fermented bamboo shoot on the quality and shelf life of nuggets prepared from desi spent hen. *Veterinary World, 6*(7), 419–423.

Daswad, A. K., Shendarkar, G. R., Shelke, D. P., Pohare, J. G., Wangawar, S. N., & Dhadwe, A. K. (2017). Phytochemical evaluation and antioxidant study of *Dendrocalamus strictus* leaf extracts. *World Journal of Pharmaceutical and Medical Research, 3*(3), 147–152.

Fan, W., Yi, Y., Zhang, Y., & Diao, P. (2015). Effect of an antioxidant from bamboo leaves combined with tea polyphenol on biogenic amine accumulation and lipid oxidation in pork sausages. *Food Science and Biotechnology, 24*(2), 421–426.

Farris, S., & Piergiovanni, L. (2008). Effects of ingredients and process conditions on 'Amaretti' cookies characteristics. *International Journal of Food Science and Technology, 43*, 1395–1403.

Felisberto, M. H. F., Beraldo, A. L., & Clerici, M. T. P. S. (2017). Young bamboo culm flour of Dendrocalamus asper: Technological properties for food applications. *LWT - Food Science and Technology, 76*, 230–235.

Fujimura, M., Ideguchi, M., Minami, Y., Watanabi, K., & Tadera, K. (2005). Amino acid sequence and antimicrobial activity of chitin binding peptides, Pp-AMP1 and Pp-AMP2, from Japanese bamboo shoots (*Phyllostachys pubescens*). *Bioscience Biotechonology and Biochemistry, 69*, 642–645.

Gazi, S. K. N., Hosseini, S. E., Yakhchali, S. H., & Borajee, H. (2017). The application of the statistical methods to measure the effect of adding a bamboo fiber and combine it with animal collagen on the physical, chemical and sensory characteristics of Nags Tilapia Fish. *International conference on literature, history, humanities and social sciences (LHHSS-17) Jan. 1-2, 2017 Dubai (UAE)*.

Hu, C. H., Zhang, Y., & David, D. K. (2000). Evaluation of antioxidant and prooxidant activities of bamboo *Phyllostachys nigra* var. *henonis* leaf extract in vitro. *Journal of Agricultural and Food Chemistry, 48*(8), 3170–3176.

Ishii, T., & Hiroi, T. (1990). Linkage of phenolic acids to cell wall polysaccharides of bamboo shoot. *Carbohydrate Research, 206*(2), 297–310.

Jiao, J., Zhang, Y., Lou, D., Wu, X., & Zhang, Y. (2007). Antihyperlipidemic and antihypertensive effect of a triterpenoid-rich extract from bamboo shavings and vasodilator effect of friedelin on phenylephrine-induced vasoconstriction in thoracic aortas of rats. *Phytotherapy Research, 21*(12), 1135–1141.

Jin, Y. C., Yuan, K., & Zhang, J. (2011). Chemical composition, and antioxidant and antimicrobial activities of essential oil of *Phyllostachys heterocycla* cv. *Pubescens* varieties from China. *Molecules, 16*(5), 4318–4327.

Jun, M., Tohru, & Ujianzhang, L. (2004). Identification and evaluation of antioxidant activities of bamboo extracts. *Forestry Studies in China, 6*, 1–5.

Kalita, C., Ganguly, M., & Devi, A. (2016). Evaluation of antioxidant capacity and antimicrobial properties of ethnic bambuseae species and identification of the active components. *International Journal of Pharmaceutical & Biological Archives, 7*(1), 61–71.

Kang, S., Shin, H. S., Kim, H. M., Hong, Y. S., Yoon, S. A., Kang, S. W., et al. (2012). Anti-

obesity properties of a *Sasa quelpaertensis* extract in high-fat diet-induced obese mice. *Bioscience, Biotechnology, and Biochemistry, 76*(4), 755–761.
Kumar, P. S., Kumari, K. U., Devi, M. P., Choudhary, V. K., & Sangeetha, A. (2017). Bamboo shoot as a source of nutraceuticals and bioactive compounds: A review. *Indian Journal of National Products and Resources, 8*(1), 32–46.
Kumbhare, V., & Bhargava, A. (2007). Effect of processing on nutritional value of central Indian bamboo shoots. *Part 1. Journal of Food Science & Technology, 44*(1), 29–31.
Kweon, M. H., Hwang, H. J., & Sung, H. C. (2001). Identification and antioxidant activity of novel chlorogenic acid derivatives from bamboo (*Phyllostachys edulis*). *Journal of Agricultural and Food Chemistry, 49*(10), 4646–4655.
Liu, M. H., Ko, C. H., Ma, N., Tan, P. W., Fu, W. M., & He, J. Y. (2016). Chemical profiles, antioxidant and anti-obesity effects of extract of *Bambusa textilis* McClure leaves. *Journal of Functional Foods, 22*, 533–546.
Lou, D. D., Zhang, Y., Wu, X. Q., Qi, J. J., & Zhuo, Y. X. (2004). Application of antioxidant of bamboo leaves (AOB) in Weixin western sausages. *China Food Fermentation Industries, 30*(8), 13–17.
Lu, B., Cai, H., Huang, W., Wu, X., Luo, Y., Liu, L., et al. (2011). Protective effect of bamboo shoot oil on experimental nonbacterial prostatitis in rats. *Food Chemistry, 214*(3), 1017–1023.
Luo, G. Y., Luo, Y. G., Zhou, R., Zhou, M., Gu, J., Ye, Q., et al. (2015). Antioxidant compounds from ethanol extracts of bamboo (*Neosinocalamus affinis*) leaves. *Journal of Asian National Product and Research, 17*(3), 248–255.
Lu, B., Wu, X., Shi, J., Dong, Y., & Zhang, Y. (2006). Toxicology and safety of antioxidant of bamboo leaves. Part 2: Developmental toxicity tests in rats with antioxidant of bamboo leaves. *Food Chemistry Toxicology, 44*(10), 1739–1743.
Mainka, S. A., Zhao, G. L., & Li, M. (1989). Utilization of a bamboo, sugar cane, and gruel diet by two juvenile giant pandas (*Ailuropoda melanoleuca*). *Journal of Zoo and Wildlife Medicine, 20*(1), 39–44.
Maroma, D. P. (2015). Utilization of bamboo shoots (*Bambusa vulgaris*) in chips production. *Open Access Library Journal, 2*, 1–6.
Mustafa, U., Naeem, N., Masood, S., & Farooq, Z. (2016). Effect of bamboo powder supplementation on physicochemical and organoleptic characteristics of fortified cookies. *Food Science and Technology, 4*(1), 7–13.
Neményi, A., Stefanovitsné-Bányai, E., Pék, Z., Hegedus, A., Gyuricza, C., Barócsi, Z., et al. (2015). Total antioxidant capacity and total phenolics content of *phyllostachys* taxa shoots. *Notulae Botanicae Horti Agrobotanici, 43*(1), 64–69.
Nimisha, S. M., Chauhan, A. S., Rekha, M. N., Negi, P. S., Nusrath, N., & Asha, M. R. (2015). Composition of edible portion of tender bamboo shoot (TBS) and development of various candies with and without incorporation of ginger and pineapple flavours. *American Journal of Nutrition and Food Science, 2*(1), 7–15.
Nirmala, C., & Bisht, M. S. (2017). Bamboo: A prospective ingredient for functional food and nutraceuticals. *Bamboo Journal (Japan Bamboo Society), 30*, 82–99.
Nirmala, C., Bisht, M. S., & Laishram, M. (2014a). Bioactive compounds in bamboo shoots: Health benefits and prospects for developing functional foods. *International Journal of Food Science and Technology, 49*(6), 1425–1431.
Nirmala, C., Bisht, M. S., & Sheena, H. (2011). Nutritional properties of bamboo shoots: Potential and prospects for utilization as a health food. *Comprehensive Review in Food Science and Food Safety, 10*(3), 153–165.
Ni, Q., Zhang, Y., Xu, G., Gao, Q., Gong, L., & Zhang, Y. (2014). Influence of harvest season and drying method on the antioxidant activity and active compounds of two bamboo grass leaves. *Journal of Food Processing and Preservation, 38*(4), 1565–1576.
Pandey, A. K., Ojha, V., & Choubey, S. K. (2012). Development and shelf-life evaluation of value added edible products from bamboo shoots. *American Journal of Food Technology, 7*(6), 363–371.
Panee, J. (2008). Bamboo extract in the prevention of diabetes and breast cancer. In R. R. Watson (Ed.). *Complementary and alternative therapies and the aging Population: An evidence-based approach* (pp. 159–177). San Diego: Elsevier.
Park, E. J., & Jhon, D. Y. (2006). Preparation and characteristics of yogurt prepared with salted bamboo shoots. *Korean Journal of Food Culture, 21*(2), 179–186.
Park, E. J., & Jhon, D. Y. (2009). Effects of bamboo shoot consumption on lipid profiles and bowel function in healthy young women. *Nutrition, 25*(7–8), 723–728.
Park, E. J., & Jhon, D. Y. (2010). The antioxidant, angiotensin converting enzyme inhibition activity, and phenolic compounds of bamboo shoot extracts. *Food Science and Technology, 43*(4), 655–659.
Park, H. S., Lim, J. H., Kim, H. J., Choi, H. J., & Lee, I. S. (2007). Antioxidant flavones glycosides from the leaves of *Sasa borealis*. *Archives of Pharmacal Research, 30*(2), 161–166.
Pisochi, A. M., & Negulescu, G. P. (2011). Methods for total antioxidant activity determination: A review. *Biochemistry & Analytical Biochemistry, 1*(1), 1–10.
Rawat, K., Sharma, V., Saini, N., Nirmala, C., & Bisht, M. S. (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. *American Journal of Food Science and Nutriition Research, 3*(3), 31–41.
Saini, N., Rawat, K., Bisht, M. S., & Nirmala, C. (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. *International Journal of Innovative Research in Science, Engineer and Technology, 6*(5), 8262–8270.
Sanguigni, V., Manco, M., Sorge, R., Gnessi, L., & Francomano, D. (2017). Natural antioxidant ice cream acutely reduces oxidative stress and improves vascular function and physical performance in healthy individuals. *Nutrition, 33*, 225–233.
Schillaci, C., Nepravishta, R., & Bellomaria, A. (2013). Antioxidants in food and pharmaceutical research. *Albanian Journal of Pharmaceutical Science, 1*(1), 15–25.
Seki, T., Kida, K., & Maeda, H. (2008). Immuno-stimulation mediated anti-tumor activity of bamboo (*Sasa senanensis*) leaf extracts obtained under 'vigorous' condition. *Journal of Evidence based Complementary and Alternative Medicine, 4*, 447–457.
Senthilkumar, M. K., Sivakumar, P., Changanakkattil, F., Rajesh, V., & Perumal, P. (2011). Evaluation of anti-diabetic activity of *Bambusa vulgaris* leaves in streptozotocin induced diabetic rats. *International Journal of Pharmaceutical Sciences and Drug Research, 3*, 208–210.
Shang, Y. F., Kim, S. M., & Um, B. H. (2014). Optimisation of pressurised liquid extraction of antioxidants from black bamboo leaves. *Food Chemistry, 154*, 164–170.
Shi, Q. T., & Yang, K. S. (1992). Study on relationship between nutrients in bamboo shoots and human health. *Proceedings of the international symposium on industrial use of bamboo. International tropical timber organization and Chinese academy, Beijing, China, bamboo and its use* (pp. 338–346). .
Singhal, P., Bal, L. M., Satya, S., Sudhakar, P., & Naik, S. N. (2013). Bamboo shoots: A novel source of nutrition and medicine. *Critical Reviews in Food Science and Nutrition, 53*, 517–534.
Singh, V. K., Shukla, R., Satish, V., Kumar, S., Gupta, S., & Mishra, A. (2010). Antibacterial activity of leaves of bamboo. *International Journal of Pharma Bio Sciences, 6*, 1–5.
Soetan, K. O., & Oyewole, O. E. (2009). The need for adequate processing to reduce the anti-nutritional factors in plants used for human food and animal feeds- A review. *African Journal of Food Science, 3*(9), 123–132.
Sood, S., Walia, S., Gupta, M., & Sood, A. (2013). Nutritional characterization of shoots and other edible products of an edible bamboo – *Dendrocalamus hamiltonii*. *Current Research in Nutrition and Food Science, 1*(2), 169–176.
Tabet, R. B., Oftedal, O. T., & Allen, M. E. (2004). Seasonal differences in composition of bamboo fed to giant pandas (*Ailuropoda malanoleuca*) at the National Zoo. *Proceedings of the fifth comparative nutrition society symposium* (pp. 176–180). .
Thomas, R., Jebin, N., Barman, K., & Das, A. (2014). Quality and shelf life evaluation of pork nuggets incorporated with fermented bamboo shoot (*Bambusa polymorpha*) mince. *Meat Science, 96*(3), 1210–1218.
Thomas, R., Jebin, N., Saha, R., & Sarma, D. K. (2016). Antioxidant and antimicrobial effects of kordoi (*Averrhoa carambola*) fruit juice and bamboo (*Bambusa polymorpha*) shoot extract in pork nuggets. *Food Chemistry, 190*, 41–49.
Tiwari, D. N. (1988). Bamboo as poverty alleviator. *Indian Forestry, 114*, 610–612.
Tripathi, Y. C., Jhumka, Z., & Anjum, N. (2015). Evaluation of total polyphenol and antioxidant activity of leaves of *Bambusa nutans* and *Bambusa vulgaris*. *Journal of Pharmacology Research, 9*(4), 271–277.
Wang, J., Yue, Y. D., Tang, F., & Sun, J. (2012a). TLC screening for antioxidant activity of extracts from fifteen bamboo species and identification of antioxidant flavone glycosides from leaves of *Bambusa textilis* McClure. *Molecules, 17*(10), 12297–12311.
Xia, Y., Hill, K. E., & Burk, R. F. (1985). Effect of selenium deficiency on hydroperoxide-induced glutathione release from the isolated perfused rat heart. *Journal of Nutrition, 115*(6), 733–742.
Xu, X. B., Yue, Y. D., Jiang, H., Sun, J., Tang, F., Guo, X. F., et al. (2016). Chemical constituents and antioxidant properties of *Phyllostachys prominens* gramineae (wy xiong) leaf extracts. *Tropical Journal of Pharmaceutical Research, 15*(3), 569–575.
Yang, R. Y., Tsou, S. C. S., Lee, T. C., Hanson, P. M., & Lai, P. Y. (2005). Antioxidant capacities and daily antioxidant intake from vegetables consumed in Taiwan. *Symposium on Taiwan-America agricultural cooperative projects, national taiwan university, taipei, taiwan* (pp. 69–77). .
Yang, G. Q., Wang, S. Z., Zhou, R. H., & Sun, S. Z. (1983). Endemic selenium intoxication of humans in China. *American Journal of Clinical Nutrition, 37*(5), 872–881.
Zeng, F., Jiang, T., Wang, Y., & Luo, Z. (2015). Effect of UV-C treatment on modulating antioxidative system and proline metabolism of bamboo shoots subjected to chilling stress. *Acta Physiology Plant, 37*, 244.
Zhang, Y., Chen, J., Zhang, X., Wu, X., & Zhang, Y. (2007a). Addition of antioxidant of bamboo leaves (AOB) effectively reduces acrylamide formation in potato crisps and French fries. *Journal of Agricultural and Food Chemistry, 55*(2), 523–528.
Zhang, Y., Jiao, J., Liu, C., Wu, X., & Zhang, Y. (2008). Isolation and purification of four flavones *C*-glycosides from antioxidant of bamboo leaves by macroporous resin column chromatography and preparative high-performance liquid chromatography. *Food Chemistry, 107*(3), 1326–1336.
Zhang, J. J., Ji, R., Hu, Y. Q., Chen, J. C., & Ye, X. Q. (2011). Effect of three cooking methods on nutrient components and antioxidant capacities of bamboo shoot (*Phyllostachys praecox* C.D. Chu et C.S. Chao). *Journal of Zhejiang University - Science, 12*(9), 752–759.
Zhang, Y., Yao, X., Bao, B., & Zhang, Y. (2006). Anti-fatigue activity of a triterpenoid rich extract from Chinese bamboo shavings (*Caulis bamfusae* in *taeniam*). *Phytotherapy Research, 20*(10), 872–887.
Zheng, J., Wu, J., Dai, Y., & Zhang, F. (2017). Influence of bamboo shoot dietary fiber on the rheological and textural properties of milk pudding. *LWT-Food Science and Technology, 84*, 364–369.
Zheng, Y., Zhang, S., Wang, Q., Lu, X., Lin, L., Tian, Y., et al. (2016). Characterization and hypoglycemic activity of pyranpolysaccharides from bamboo shoot (*Leleba oldhami* Nakal) shells. *Carbohydrate Polymers, 144*, 438–446.