

Bamboo: A Prospective Ingredient for Functional Food and Nutraceuticals

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Abstract

Bamboo is a multi-utility plant being used as a building material, for industrial purposes, as a food source and a versatile raw material for various products. In recent times, it is gaining importance for its health benefits and is emerging as a potential ingredient for modern functional foods and nutraceuticals. The leaves possess antioxidant properties due to the presence of phenolic compounds and have been used for enhancing immunity, preventing degenerative diseases and also in the food industry. The young shoots in addition to being used as a vegetable in the conventional form in various cuisines are now being used as an ingredient in functional foods. The shoots have anti-hypertensive, anti-tumour and anti-oxidant properties and have also been proven to possess cholesterol-lowering activity. Bamboo salt is used as a medicinal food in many Asian countries and provides a wide range of health benefits and has attracted many pharmaceutical scientists worldwide. Thus, bamboo is an ideal plant and has great promise for the pharmaceutical, nutraceutical, cosmoceutical and the food industry.

Introduction

Most foods are considered functional in terms of providing nutrients and/or energy to sustain basic life. However, in the last decade, consumer demands in the field of food have changed considerably. With the economic development and the improvement of people's living standards, demand for natural foods, especially healthy and organic (natural) food, has greatly increased. Moreover, increasing public awareness of the link between diet and health has boosted the consumption of these foods to unparalleled levels, particularly in countries where the population is aging and health care costs are rising. Scientific evidence and a growing awareness of the correlation between diet and health, coupled with sedentary lifestyles, an aging population, and ever increasing healthcare costs have driven the interest in healthier food products (Malla et al. 2014). These products include functional foods and nutraceuticals that confer positive health benefits to consumers. Nutraceuticals and functional foods have not only captured the

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world food market, but also the psyche of the average consumers through supply of rich nutrients to the body even by simple popping of different supplement formats for example, capsules or pills. Both are intensively researched for their role in maintaining health and prevention of diseases. Functional foods are defined as whole foods along with fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis at effective levels (Crowe 2013). Such types of food include foods supplemented with bioactive and mineral substances (eg. probiotics, antioxidants, iodized salt) and derived food ingredients introduced to conventional foods (eg. prebiotics). Nutraceutical, a term arising by combining “nutrition” and “pharmaceutical”, is a product isolated or purified from foods that are generally sold in a medicinal form not usually associated with food. It should possess protective action against chronic diseases or have some physiological effects and generally consists of a concentrated form of bioactive substance originally derived from food. There is an increased interest both in functional foods and nutraceuticals, as they provide physiological and metabolic benefits by boosting the immune system and counteracting diseases and degenerative disorders. One of the most important trends in the food industry is the demand of all natural food ingredients that are free of chemical additives and they are usually obtained from edible plants and bamboo is one such plant that can be utilized for this purpose.

Bamboo is one of the most valuable plant taxa worldwide, because of its varied industrial and medicinal uses, and also because its different parts contain abundant nutrients and antioxidants. Every part of the plant - leaves, shoots, culm sheath and culms are used either as food or used for medicine and health benefits. Now it has been observed that leaves, which are generally discarded, are the best source of a number of antioxidants and bioactive compounds. Old culms are used for making bamboo salt enriched with a number of nutrients available in the culms. Young juvenile shoots (rhizomatous and apical) are now considered one of the best vegetables rich in minerals like potassium, calcium, iron and magnesium, fiber, bioactive compounds like phenols and bioactive compounds. The leaves, sap, culm shaving and young shoots are all of medicinal value used to resolve phlegm, preventing fever, convulsions, epilepsy etc. The leaves are most used for making herbal medicine and more recently cosmetics and clothing. Tabasheer is one of the main substances from bamboo used in Ayurvedic, Tibetan and Unani medicine. Similarly, different parts of bamboo have always been used in ancient Chinese medicine, Ayurveda, Tibetan and various other traditional systems of medicine and health care for treatment and cure of a number of ailments (Table 1). There are now a number of studies on modern scientific knowledge and tools to prove the age-old beliefs of bamboo as medicine or in modern terms the “nutraceuticals potential of bamboo” (Table 2). In this paper, an attempt has been made to review all the available information to

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present bamboo as a potential source for functional food and nutraceuticals based on laboratory proven scientific knowledge and tools.

Table 1. Bamboo in traditional medicinal systems

(i) Bamboo in Ayurveda, Tibetan and Unani traditional medicines			
S. No.	Name	Constituents/Ingredients	Health benefits
1.	Tabasheer	Siliceous secretion often called bamboo-manna or bamboo silica found in the hollow internodes of various species of bamboos. Tabasheer may be chalky, translucent, or transparent, mainly composed of silicic acid (upto 96.9%) with above 1% of organic matter.	Acts as stimulant, astringent, febrifuge, relieving asthma, cough, cooling tonic, antispasmodic and aphrodisiac.
2.	Sitopaladi Churna	Powder made with tabasheer as the main ingredient, plus small amounts of long pepper, cardamom, and cinnamon in a base of sugar.	A popular remedy for common cold, sore throat, sinus congestion, tuberculosis, coughs and other lung diseases.
ii) Bamboo in Chinese traditional medicine			
3.	Chenjin Wan	Bamboo shaving and Tabasheer, arisaema, citrus, hoelen, salvia, silkworm, chrysanthemum, apricot seed, ophiopogon, biota, fritillaria, ginger	For phlegm mist obstructing the orifices yielding symptoms of insomnia, restlessness, and blurred vision.
5.	Gualou Zhishi Tang	Bamboo shaving and sap, fritillaria, platycodon, trichosanthes seed, chih-shih, citrus, saussurea, licorice, scute, gardenia, etc.	For reducing thick phlegm that is difficult to expectorate.
6.	Jupi Zhuru Tang	Bamboo shavings, citrus, pinellia, licorice, hoelen	Relieving phlegm
7.	Qinghuo Ditan Tang	Bamboo shaving and tabasheer, arisaema, citrus, hoelen, salvia, silkworm, chrysanthemum, apricot seed, ophiopogon, biota, fritillaria, ginger	For phlegm mist obstructing the orifices yielding symptoms of insomnia, restlessness, and blurred vision
8.	Qinggong Tang	Bamboo leaf, ophiopogon, scrophularia, rhino horn, forsythia, lotus plumule	Fever with dryness, penetrating to the pericardium, with delirium
9.	Qingluo Yin	Bamboo leaf, lotus leaf, luffa, mirabilitum, dolichos flower, lonicera	Fever with light-headedness, blurry vision, or headache.
10.	Xiaor Qizhen	Tabasheer, arisaema, cinnabar, realgar,	For phlegm, wheezing, coughing.

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	Dan	scorpion, croton seed	
11.	Zhuye Shigao Tang	Bamboo leaf, gypsum, pinellia, ophiopogon, ginseng, licorice, oryza	Fever with dryness, irritability and insomnia

Table 2. Nutraceutical potential of bamboo proven by scientific experiments in laboratories

Sl. No.	Potential benefit	Species	Reference
1.	Anticancerous	<i>Sasa sinensis</i> , <i>Pseudosasa japonica</i> , <i>Caulis bambusae</i> , <i>S. quelpaertensis</i> , <i>Phyllostachys pubescens</i>	Tsunoda et al., 1998; Panee, 2008; Seki et al., 2010; Hong et al., 2010; Kim et al., 2013; Hiromichi, 2007
2.	Antidiabetic	<i>Phyllostachys pubescens</i> , <i>Sasa borealis</i> , <i>Pseudosasa japonica</i> , <i>Bambusa vulgaris</i>	Ding et al., 2007; Hyun and Hyeon-Sook, 2009; Senthilkumar et al., 2011; Koide et al 2011, Nam et al., 2013
3.	Anti obesity	<i>Sasa borealis</i> , <i>S. quelpaertensis</i>	Yang et al., 2010
4.	Anti inflammatory	<i>Bambusa arundinacea</i> , <i>S. quelpaertensis</i>	Hu et al., 2000; Lu et al., 2005; Muniappan and Sundararaj, 2003; Hwang et al., 2007; Carey et al., 2009
5.	Anti fatigue	<i>Phyllostachys nigra</i> , <i>Pseudosasa japonica</i> , <i>Bambusa tuldoidea</i>	Zhang and Tang, 1997; You et al., 2006; Zhang et al., 2006
6.	Anti hyperlipidemic	<i>Phyllostachys pubescens</i>	Ding et al., 2010
7.	Antimicrobial	<i>Phyllostachys pubescens</i> , <i>P. nigra</i> , <i>Bambusa arundinacea</i> , <i>P. heterocycla</i>	Fujimura et al., 2005; Park and Jhon, 2010; Tanaka et al., 2011; Singh et al., 2010; Zhanwang et al., 2005; Jin et al., 2011
8.	Cardiovascular diseases	<i>Phyllostachys pubescens</i> , <i>P. nigra</i>	Fu et al., 2006, Liu et al., 2012, 2013
9.	Cholesterol lowering	<i>P. pubescens</i> , <i>P. nigra</i> , <i>P. edulis</i> , <i>B. oldhami</i> , <i>D latiflorus</i>	Park and Jhon 2009, Lachance and He 1998

Bamboo Leaves

In bamboo, leaves are of two types, culm leaves and foliage leaves. The culms leaves are for the protection of the young juvenile shoots and are generally shed off after the shoot grows into full length. The foliage leaves are for photosynthesis, appear at nodes and generally renewed after every winter. However, dried bamboo leaves had been used by ancient Indians (as stated in the Ayurveda) and Chinese as tea by boiling the dried leaves with water and then filtering the residue before consumption. Dried

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culms leaves are used for wrapping cooked rice in China and Japan which become tastier. Now countries like Korea and China produce bamboo leaf tea at commercial level.

Antioxidant activities of Bamboo leaves

The antioxidants in bamboo leaves (AOB) have been endorsed in China's national standards (GB-2760) as a kind of dietary supplement, cosmetic ingredient and food antioxidant. The medicinal effect of bamboo leaves are mostly attributed to the presence of abundant biologically active component groups (or bio-active compounds), the phenolic which have high antioxidant capacity. The phenolic compounds are represented firstly by the flavonoids C-glycoside consisting of orientin, homoorientin, vitexin and isovitexin, and secondly phenolic acids represented by p-coumaric acid, chlorogenic acid, caffeic acid and ferrulic acid (Nakajima *et al.* 2003; Zhang *et al.* 2008). Antioxidant is a substance that delays, prevents or removes oxidative damage to a target molecule. Oxidation reactions produce free radicals that can start multiple chain reactions that eventually cause damage or death to the cell. Antioxidants remove these free radical intermediates by being oxidized themselves and inhibit their oxidation reactions thus stopping the harmful chain reactions. In order to protect tissues and organs from oxidative damage, the body possesses enzymatic systems that include superoxide dismutase (SOD), glutathione peroxidase (GHS-Px) and catalase (CAT) which are the frontline defenders of oxidative stress. Antioxidants of bamboo leaves (AOB) are able to block chain reactions of lipid autooxidation, chelating metal ions of transient state, scavenging nitrite compounds and blocking the synthetic reaction of nitrosamine (Fu *et al.* 2004). Due to the side effects of synthetic antioxidants, interest on natural antioxidants, especially of plant origin has increased many folds in recent years. Bamboos find their importance as a novel food additive due to high natural antioxidant contents (Lu *et al.* 2006).

Flavonoids: One of the main functional components in bamboo leaf extract (BLE) is flavonoids. Flavonoids are a large group of naturally occurring polyphenols possessing a wide range of pharmacological activities. Although flavonoids have generally been considered to be non-nutritive agents, in recent years, the health effects of flavonoids have attracted much attention. They confer beneficial health effects showing significant anti-inflammatory and anti-oxidant properties and can be used to treat cardiovascular diseases and different types of cancer (Zhang and Ding 1997; Tang and Ding 2000).

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A close connection between the biological effects of BLE and the activities of flavonoids has been reported. It was found that the extract of bamboo leaves which are rich in flavonoids has multiple biological activities such as cancer prevention, anti-inflammatory and anti-oxidation and can be used as a pharmaceutical intermediate and food additive. Flavonoids are extracted from bamboo leaves by conventional heat reflux extraction, alkali extraction, ultrasound assisted extraction, enzyme extraction and recently mechanochemical assisted extraction (Xie et al. 2013). Reverse phase high performance liquid chromatography (RP_HPLC) with ultraviolet diode array detection (UV-DAD) was used for the simultaneous detection of four flavones - glucosides orientin, homoorientin, vitexin and isovitexin in several food systems fortified with AOB such as high temperature sterilized milk, sunflower seed oil, meat products and extruded rice cakes (Zhang et al. 2005).

Lv et al. (2012) determined the antioxidant activities of *Dendrocalamus oldhami* BLE in cholesterol fed rats and an index of lipid peroxidation was determined. The antioxidant activity in two bamboos *Pleioblastus kongosanensis* and *Shibataea chinensis* were studied by Ni et al. (2013a, b). Since increase in the concentration of flavonoids lead to increased ROS scavenging ability, flavonoids may be responsible for the ROS scavenging activity and DNA damage prevention ability. Seasonal variations of antioxidant composition were also reported in *Sasa argenteostriatus* (Ni et al. 2012) with maximum antioxidant activity in December. Goyal et al. (2013) studied the effect of leaf extracts of *Bambusa vulgaris* var *vittata* on oxidative stress. Total phenol and flavonoid content were determined as well as their antioxidant activity through various chemical assays like DPPH radical, hydrogen peroxide scavenging and reducing power assay. The flavonoids exhibited powerful antioxidant activity and are promising natural alternatives to synthetic antioxidants as functional food ingredients. Zhang et al (2014) studied the protective effects and antioxidant mechanisms of bamboo leaf flavonoids (BLFs) on hepatocytes injured by CCl₄ in mice and observed that BLFs have remarkable protective effects on acute liver injury which is related to the antioxidant capacity to reduce damage in the liver caused by oxidative stress and cell (NCTC-1469) apoptosis. The study provides pharmacological evidence to support the clinical applications of BLFs.

Polysaccharides: Recent studies have shown that bamboo leaves contain a large number of bioactive polysaccharides and other active ingredients such as phenolic acids, flavones and special amino acids (Lu et al. 2003; Yang et al. 2004). These polysaccharides have several health benefits such as regulating immunity, anti-oxidation and tumor prevention (Zhang et al. 2009). Hemicellulosic polysaccharides have been fractionated and characterized from leaves of *Phyllostachys pubescens* (Peng et al. 2013). Yanni et al. (2012) have reported that bamboo leaf polysaccharide is capable of scavenging

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superoxide and hydroxyl radicals, the scavenging capacity increasing with increasing concentration. Polysaccharides have also been extracted from Moso bamboo leaves and were studied for anti-oxidant activities (Mao et al. 2013). Results of the studies demonstrated that the polysaccharides had high antioxidant activity and showed scavenging effect on superoxide radical, hydroxyl radical, DPPH radical and ferrous metal-chelating capacities.

Bamboo shoots

A traditional forest vegetable in China for more than 2,500 years, bamboo shoots are not only delicious but are also rich in nutrients and phytochemicals which are beneficial for health. The young shoots are eaten fresh, dried, canned and fermented are important ingredients in many exquisite Asian culinary preparations such as soups, stir fried, salads, curries etc. They have also been used as a medicine in ancient medical practices in various parts of the world. These medical practices have now been substantiated by scientific evidences with various workers reporting about the nutritive value and the medicinal properties of the young shoots. Nutritive value was reported by Shi and Yang (1992); Kumbhare and Bhargava (2007); Nirmala et al. (2011). Singhal et al. (2013). Recent studies have indicated the antioxidant, anticancer, antimicrobial and cholesterol lowering properties of the juvenile shoots and shoot skins (Park and Jhon 2009, 2010; Fujimura et al. 2005; Hiromichi 2007; Woo et al. 2012; Tanaka et al. 2011, 2013).

Bamboo shoots as health food and medicine: In the present time, demand for bamboo shoots is increasing worldwide for food to be consumed as fresh, dried, canned and fermented forms. Rarely people know that it is one of the best health food, endowed with various bioactive compounds and mineral nutrients and dietary fibers. Bamboo shoots are considered a heart protective vegetable due to the high content of potassium. Prospective cohort studies and outcome trials show that increasing potassium intake reduces cardiovascular disease mortality. This is mainly attributed to the blood pressure-lowering effect and may also be partially because of the direct effects of potassium on the cardiovascular system. A high-potassium diet may also prevent or at least slow the progression of renal disease. Selenium is another important nutrient mineral present in very high amount in the shoots. Selenium is essential for several metabolic pathways, including thyroid hormone metabolism, antioxidant defense system and immune function. Bamboo shoots are the rich source of dietary fiber ranging from 3.5 to 26.1 g/100g fresh weight in fresh, fermented and canned shoots (Nirmala et al. 2009). Fiber has several health benefits

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and is useful in the management of hypertension and obesity and is associated with decreased low density lipoprotein cholesterol, increased stool bulk, increased laxative properties etc.

Since ancient times, bamboo shoots have been used as medicine for treatment of ailments for chicken pox, skin diseases, infections, ulcers etc. (Burkill 1935; Sangtam et al. 2012). These traditional medical treatments have now been supported by recent scientific investigations, which reveals that the health benefits of shoots is due to the presence of bioactive compounds. Bioactive compounds occur in small amounts in food and influence physiological or cellular activities resulting in a beneficial health effect. Phenolic compounds contained in food are thought to be the major bioactive compounds for health benefits.

Bamboo shoots are known to have high content of phenols and phytosterols. They are used in Chinese traditional herbal medicine due to their antihypertension effect. Hypertension is major cause of cardiovascular disease which is one of world's leading causes of death each year. Pathogenesis of hypertension is usually associated with oxidative stress and antioxidant therapy has a beneficial effect on the prevention and treatment of hypertension. Angiotensin converting enzyme (ACE) is an important factor causing hypertension and is considered as a key point in the prevention and therapy of hypertension. Methanol extracts of *Phyllostachys pubescens* shoots were reported to possess ACE inhibitory activity and were proven to have an antihypertensive effect on hypertensive rats (Park and Jhon 2010; Liu et al. 2012). The key active ingredients and antihypertensive mechanism of bamboo shoot was studied on hypertensive rats. Fresh bamboo shoots have limitations of storage or consumption as they become quickly lignified within 2-3 days of being harvested. For long term usages, the shoots are canned and during this process, the excessive aqueous extract fraction (AEBS) or by product including boiled water and squeezed juice is wasted. For 1 ton of canned bamboo shoots approximately 2 tons of waste water is produced. AEBS are a good functional food source that contains amino acids, peptides and phytochemicals. Liu et al. (2013) evaluated the bamboo shoot extract derived from byproducts of canned bamboo shoots and found that the extract showed both antihypertensive and antioxidant activity in vitro and short term antihypertensive activity in vivo. Asp-Tyr was isolated and identified as the key component of bamboo shoot ACE inhibitory peptide. Antioxidant activities were attributed to phenolic compounds such as ferulic acid and p-coumaric acid.

A phytosterol containing extract was isolated from bamboo shoot which has a hypocholesterolemic effect in-vivo and in-vitro (Lachance and He 1998). The extract when administered to adult Wistar rats was able to reduce serum total cholesterol, LDL cholesterol and total liver lipids. The extract was derived from a variety of bamboo species *B. oldhami*, *B. edulis*, *Dendrocalamus latiflorus*, *P. pubescens* and *P. edulis*.

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Effects of bamboo shoot consumption as a dietary fiber source on blood glucose, lipid profiles, hepatic function and constipation symptoms were studied in healthy young women (Park and Jhon 2009). It was observed that total cholesterol and low density lipoprotein cholesterol level was significantly decreased by 9.6 % and 15.3 % respectively after a 6 day bamboo shoot diet.

An antitumor agent has been extracted from shoots of *P. pubescens* by Hiromichi (2007) for which a patent was awarded. Alcohol extracts of the shoots showed an excellent anti-tumor effect when administered on mice with malignant sarcoma cells. Accordingly, if a health food comprising such an alcohol bamboo extract is orally consumed on a regular basis, the progression of malignant tumors can be prevented or limited.

Bamboo culm Salt

Bamboo salt as a medicinal food originated in Korea and has been adapted widely in many Asian countries. The salt is prepared by placing sea salt in the internodes of three year old bamboo, sealing the ends with natural red clay and baked at 1000°C -15000°C using pine as a combustible fuel. In ancient times, the bamboo salt was baked for only 2-3 times. However it was found that the salt attained its highest medical efficacy when baked for 9 times. This salt is also known as purple bamboo salt.

Additionally, it was observed that if bamboo salt is completely melted, the toxic characteristics of the salt disappeared. Baking the bamboo salt at such a high temperature allows the salt to absorb highly therapeutic elements including copper, zinc and iron and eliminates toxicity, impurities and heavy metals that could be harmful to the body. Now bamboo salt is well known as one of the most famous traditional medical treatments. It serves as a natural detoxifying agent because bamboo salt generates large amounts of saliva and gastric juice, allowing for the complete digestion of our food, keeping toxins from building up in the intestine and bloodstream. Bamboo salt also has a strong penetrative ability so it is able to eliminate toxins from the body quickly and efficiently. It contains an array of minerals such as Calcium, Phosphorus, Magnesium, Iron, Manganese, Copper, Potassium and Zinc and provides a wide range of health benefits including prevention against or treatment of cancer, obesity, allergy, inflammation, infection, chemotherapy side effects, gastric ulcer, diabetes, sore throat and arthritis. Many pharmaceutical scientists all around the world are researching bamboo salt's special therapeutics like anti-cancer effect and anti-viral effect.

The anticancer effect of bamboo salt is well documented (Park and Zhao 2012; Zhao et al. 2013; Choi et al. 2013). Bamboo salt was evaluated for the anti-cancer effect in human cancer cells and determined preventive hepatitis on Sprague-Dawley rats (Park and Zhao 2012). The *in-vitro* anti-cancer effect of bamboo salt was evaluated in HepG2 human hepatoma cells using 3-(4-5-dimethyl-thiazol)-2-,5-diphenyl

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tetrazolium (MTT) assay. Bamboo salt inhibited the growth of HepG2 cells and showed better *in-vitro* cancer activity compared to solar salt and purified salt.

Zhao et al. (2013) have demonstrated that bamboo salt is effective in prevention of carbon tetrachloride (CCl₄) induced hepatic damage in rats. The hepatoprotective effects of bamboo salt may be due to decreased serum levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT) lactate dehydrogenase (LDH) and proinflammatory cytokinines such as TNF- α , IL-6 and IFN- γ . In addition, mRNA and protein expression levels of inflammation related genes such as iNOS, COX-2, TNF- α and IL-1 β in the liver were significantly reduced in bamboo salt treated rats. Histopathological studies indicated that bamboo salt prevented CCl₄ induced inflammation in the liver. These results suggest the potential usefulness of bamboo salts in treatment or prevention of chemically induced hepatic damage *in-vivo*.

Anti-obesity effect of bamboo was evaluated on high fat induced obese mice (Park et al. 2014). When bamboo salt was added to the high fat diet with 4% concentration, it showed improvement on obesity related parameter; it suppressed weight gain, food efficiency ratio and adipokine secretion.

Bamboo in the Functional Food Industry and Nutraceuticals

Leaves

In recent years, there has been considerable interest in the potential for using natural food components as functional foods. Antioxidants have a long history of use in the nutrition, health and in the food industry. The understanding is that antioxidants improve health by removing reactive species that may otherwise exert harmful metabolic effects. To food scientists, antioxidants implies to a substance used for functional characteristics e.g. retard oxidation whereas others understand the term as describing foods or substances with high values for in-vitro measures for radical quenching ability test. Many dietary compounds are capable of negating the danger of ROS – vitamin C, tocopherols, carotenoids, polyphenols etc. It has been suggested that including these compounds in foods will enhance their capacities to support protection against ROS damage and reduce the risk of chronic diseases. Synthetic chemical compounds are used as preservative in foods, cosmetics and medical products that have caused health concerns to consumers. The emergence of natural products with less harmful effects has become highly desirable. Natural antioxidants derived from plant products have been proposed as replacements for synthetic food antioxidants to prevent edible oils from rancidity. In addition, antioxidant activities of different agents have claimed to have potential health functions for reducing aging and possible prevention of cancer and

heart diseases. Phenolic compounds are known for their antioxidant activity and bamboo is rich in these compounds.

The antioxidant of bamboo leaves as a natural, nutritional, and multi-functional additive can be used in food industry. It may be extensively used in edible oil, oil-containing food, Chinese or Western meat products, aquatic products, fruit juice, milk products, soft drinks, brewed wine, condiments, puffed food, cakes, etc., with vast potential in future application. A patent US20080233242 A1 for antioxidants of bamboo leaf has been obtained by Zhang and colleagues. It has good water-solubility and stable quality. It may effectively resist against acid, heat, and enzyme, therefore suitable for many food systems. In addition to effective lipid anti-oxidation, its multi-functions are represented in that, it is a natural yellow pigment, and has antibacterial, bacteriostatic, deodorizing, and fragrance-increasing effects. Compared with products of the same kind, its outstanding advantages are also represented with excellent performance in processing meat products. AOB has antioxidant and color-protecting effects, which may help to increase its stability, improve color of meat products, and increase their commercial value. Meanwhile, due to presence of multi-hydroxy phenolic compounds, AOB has good water-maintaining and moistening performance, which may help to improve texture of meat products.

With the characteristics of good quality, high safety, low cost, and natural, nutritional, multi-functional, but no peculiar smell, AOB is used in but not limited to the following aspects: edible oil (vegetable oil and fish oil, etc.), oil-containing food (mayonnaise, etc.), meat products (Western and Chinese products), aquatic products (shrimps, crabs, and fish, etc.), fruit juice, soft drinks (carbonated drinks, non-carbonated drinks, and tea drinks), brewed wine (grape wine, yellow wine, and beer), milk products (fresh milk and milk-containing drinks), condiments (oyster sauce, etc.), puffed food (oil-covering type), and cakes, etc. The suggested used level is 0.005-0.05% w/w.

The efficiency of antioxidants of bamboo leaves (AOB) on reducing acrylamide formation in potato crisps and french fries during thermal processing was studied by Zhang et al. (2007). Acrylamide, a potential genetic and reproductive toxin with mutagenic and carcinogenic properties has been found in a large range of fried and baked carbohydrate-rich foods which has attracted worldwide concern. Potatoes and cereals have a major free amino acid asparagine which is an important precursor in the formation of acrylamide. Potato and French fries were immersed into different contents of AOB solutions and the frying processing parameters were optimized. It was seen that nearly 74.1% and 76.1% of acrylamide in potato crisps and French fries was reduced and crispiness and flavor of potato matrixes were retained. Hence, AOB could be used as a natural antioxidant for the reduction of acrylamide in various foods. After adding to various food systems in appropriate proportion, AOB may remove active free oxygen-radicals, resist lipid peroxidation, prolong the shelf life, decrease the use level and residue of coloring agents

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(nitrates or nitrites), and exhibit multiple functions such as antibacterial, bacteriostatic, freshness-keeping, color-protecting, odor-removing, and taste-modifying effects. If required, AOB of this invention may be manufactured in various forms, such as powder, aqueous solution, micro-emulsion, and micro-capsule. Bamboo leaves are used in making various nutraceutical products (Table 3)

Table 3. Nutraceutical products from bamboo.

Sl.No.	Product Name	Plant part used	Health benefits
1.	Bamboolex	Leaf	Antioxidant, antibacterial, antiacrylamide
2.	Bambooflex Phytoceutic	Leaf	Antiinflammatory, remineralization and development of bone structure
3.	Guozen Bamboo Leaf Essence	Leaf	Regulates blood fat, purifies blood, strengthens heart and protects brain
4.	Fenioux Bambou Tabashir	Tabashir exudate	Maintains balance of connective tissue, strengthens bones and improves endurance, increases immunity and fights fatigue
5.	Lambert Silica capsules	Tabashir exudate	Contributes to the structure and resilience of connective tissue, synthesis of bone collagen and cartilage, recommended for healthy skin
6.	Silice de Bambou	Tabashir exudate	Prevent premature aging, preserves skin youthfulness, builds healthy bones and teeth, promotes growth of strong hair
7.	Solary bamboo capsules	Culm	Stimulates collagen synthesis in bone and connective tissue, remineralization effect
8.	Hawlik Cappillary active capsules	Shoot	Improves hair health, restructures hair surface layer
9.	Shenghi Herbal extract	Shoot	Weight loss, slimming food supplements
10.	Bamboo extract	Culm, leaf, shoot, Tabashir exudate	Resolves phlegm, remedy for fever, lung inflammation, helps in absorption and maintenance of calcium levels
11.	Bonusan forte	Tabashir exudate	Reduces fatigue, supports energy metabolism, good for nervous system

Shoots

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Bamboo shoots are mostly consumed fresh followed by canned, dried, fermented and pickled. The shoots are also used for making various nutraceutical products (Table 3). The availability of bamboo shoot is seasonal and moreover they are highly perishable with a very short shelf life of two to three days. Hence, processing is necessary to make the shoots available off season, enhance marketability and reduce post harvest loss. Appropriate processing methods allow the preservation of many of the health promoting factors. Also, with the changing food habits where consumers not only prefer ready to eat items, but also because people have become more health conscious, value addition is an important aspect which needs to be concentrated upon. Value addition refers to any activity that enhances the value of the food product in the market, specially the nutritional aspect thereby increasing its market value in terms of utility and profit. Through this, the nutritional quality of the product is enhanced. Worldwide, bamboo shoots are being used as fermented, dried, powdered and as paste in various items like bakery, meat dairy products, pet foods, pharmaceuticals etc. (Nirmala 2011). In order to increase the utilization of bamboo shoots and provide quality products to the consumer when the fresh shoots are not available, value addition in bamboo shoots have been done by making a number of edible products (Pandey et al. 2012; Bisht et al. 2012; Sood et al. 2013). A list of food items made of bamboo shoots is given in Table 4. Pandey et al. (2012) developed food products with bamboo shoots such as

Table 4. Value added edible products from bamboo shoots.

Sl No.	Bamboo Species	Shoot type	Product	Reference
1.	<i>Bambusa bambos</i> , <i>B. tulda</i> , <i>Dendrocalamus asper</i> , <i>D. strictus</i>	Fresh	Crackers, nugget, pickle	Pandey et al., 2012
2.	<i>D. hamiltonii</i>	Fresh	Candy, chutney, chukh, cracker, nugget	Sood et al., 2013
3.	<i>D.hamiltonii</i>	Fresh	Cookies, chapatties, buns, snacks	Bisht et al., 2013
4.	<i>B. auriculata</i>	Fermented	Chicken nugget	Das et al., 2013
5.	<i>B. polymorpha</i>	Fermented	Pork nugget	Thomas et al., 2014

nuggets, pickle and cracker which were good in taste and texture as assessed by organoleptic and sensory evaluation. The products were also accepted in terms of flavor, odour, appearance and taste. Bamboo candy, chutney, cracker, nuggets and chukh were prepared and their nutritional and organoleptic properties evaluated (Sood et al. 2013). Results revealed that the prepared formulations were nutritionally rich and acceptable as determined by sensory scores. Fresh shoot paste of *D. hamiltonii* has been used for making chapatties, buns, biscuits and snacks (Bisht et al. 2012). Das et al. (2013) used fermented shoots to prepare nuggets from hen meat and tested its potential as a phytopreservative to enhance the physico-chemical, microbiological and keeping quality of the nuggets. Results revealed that the nuggets were superior to the control and addition of 10% fermented bamboo shoots gave a highly ideal physiochemical, microbial and sensory qualities and the nuggets could be suitably stored for 15 days under refrigeration. Fermented bamboo shoots have also been incorporated in pork nuggets and their physio-chemical, microbiological and sensory characteristics were evaluated during 35 day storage at 4°C (Thomas et al. 2014). Addition of bamboo shoot significantly affected the pH, moisture, protein, fat, fiber, colour, and texture profiles of nuggets. Microbial and sensory qualities of the pork nuggets also improved significantly their shelf life that increased by at least two weeks. Farris et al. (2008) added bamboo fiber to improve the overall quality of an almond based cookie “Amaretti”. The added fiber promoted water retention in the matrix of the cookie for a longer time and consequently extended their shelf life.

Conclusion

Bamboo has been catering to the needs of 1.2 billion people for their livelihood. Its utility to mankind has increased considerably with the development of modern technology. It now plays a very important role in pharmaceuticals, cosmoceuticals, nutraceuticals and the food industry. Due to the presence of bioactive compounds, it confers health benefits to consumers and this potential has been used for developing nutraceuticals and functional foods. The development of natural food additives is a priority in food industries and much emphasis is being paid on those which are able to maintain food quality, safety and are also not expensive. The development of such type of additives is focused on natural, nutritional, multifunctional, safe and reliable additives. It is a top priority to replace synthetic antioxidants which may affect health, with natural edible antioxidants which are more effective and non-expensive. Thus, bamboo has all the ideal characteristics for being used as a food additive and also exhibit potential as raw materials for the pharmaceutical, nutraceutical and food industries.

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