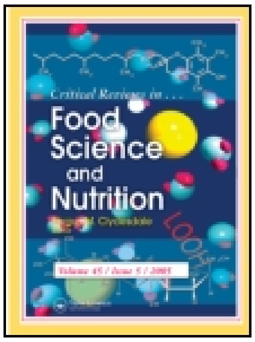


Critical Reviews in Food Science and Nutrition

ISSN: 1040-8398 (Print) 1549-7852 (Online) Journal homepage: http://www.tandfonline.com/loi/bfsn20

Bamboo Shoots: A Novel Source of Nutrition and Medicine

Poonam Singhal , Lalit Mohan Bal , Santosh Satya , P. Sudhakar & S. N. Naik

To cite this article: Poonam Singhal , Lalit Mohan Bal , Santosh Satya , P. Sudhakar & S. N. Naik (2013) Bamboo Shoots: A Novel Source of Nutrition and Medicine, Critical Reviews in Food Science and Nutrition, 53:5, 517-534, DOI: 10.1080/10408398.2010.531488

To link to this article: http://dx.doi.org/10.1080/10408398.2010.531488

Accepted author version posted online: 17 Oct 2011.
Published online: 17 Oct 2011.

Critical Reviews in Food Science and Nutrition, 53:517–534 (2013)

ISSN: 1040-8398 / 1549-7852 online
DOI: 10.1080/10408398.2010.531488

Bamboo Shoots: A Novel Source of Nutrition and Medicine

POONAM SINGHAL, LALIT MOHAN BAL, SANTOSH SATYA, P. SUDHAKAR, and S. N. NAIK

Centre for Rural Development and Technology, Indian Institute of Technology Delhi, New Delhi, India

Bamboos, a group of large woody grasses belonging to the family Poaceae *and subfamily* Bambusoideae*, are much talked about for their contribution to the environment. However, the food potential of Bamboo shoot per se remains unexploited. Literature on the nutritional and medicinal potential of bamboo shoots is scarce. This paper therefore provides insight on bamboo shoot as a food resource. Various edible species and exotic food products (fermented shoots, pickle, etc.) and recipes of bamboo shoots (bamboo beer, bamboo cookies) are consumed worldwide. Change in nutritional composition of different species of bamboo shoots with processing has also been reviewed. Bamboo shoots possess high protein, moderate fiber, and less fat content. They are also endowed for having essential amino acids, selenium, a potent antioxidant, and potassium, a healthy heart mineral. Occurrence of taxiphyllin, a cyanogenic glycoside in raw shoots, and its side effect on human health calls for the demand to innovate processing ways using scientific input to eliminate the toxic compound without disturbing the nutrient reserve. Lastly, the paper also reviews the utilization of medicinal properties acquired by bamboo shoot. Using the traditional knowledge, pharmaceutical preparations of bamboo shoots like bamboo salt, bamboo vinegar, bamboo extracts for diabetes and cholesterol control, etc. are now gaining importance. Further investigation is required by the researchers to make novel nutraceutical products and benefit the society.*

Keywords Bamboo shoots, taxiphyllin, nutritional composition, medicinal properties, pharmaceutical preparations

INTRODUCTION

Non-timber forest products (NTFPs) are products of biological origin other than wood derived from forests. NTFPs have long been an important component of the livelihood strategies of forest-dwelling people including tribals. Several million households worldwide depend heavily on NTFP for sustenance as well as for meeting family nutrition. As per FAO estimates, approximately 80% of the population of the developing world use NTFPs for health care and fulfilling nutritional needs. In addition to providing subsistence income, commercial value of NTFPs has been increasing. Over 150 NTFPs are considered significant as commodity in international trade. Important products traded from the tropics include rattan, Brazil nuts, gum arabic, lac, bamboo shoots, and spices (Arinana et al., 2008).

Bamboos a group of giant arborescent grasses belong to the family *Poaceae* and sub- family *Bambuseae*. Bamboos are mainly found in the mixed deciduous and tropical evergreen forests and partly found in the dry dipterocarps forest. More than 1250 species belonging to 75 genera have been reported to be distributed worldwide, out of which 125 species are found in India spreading over an area of 9.57 million hectare. Asia accounts for about 1000 species, covering an area of over 180,000 km^2. China alone has about 300 species in 44 genera, occupying 33,000 km^2 or 3% of the country's total forest area. Another major bamboo-producing country is India, with 130 species covering 96,000 km^2 or about 13% of the total forested area (Scurlock et al., 2000; Yuming et al., 2004). It constitutes one of the most important renewable natural resources of India and the tribal community world over has been consuming bamboo shoot as food and medicines since ancient times (Choudhury et al., 2010). Present paper explores the food and pharmaceutical potential of bamboo shoot and future scope of value addition by scientific and technological inputs.

Address correspondence to Poonam Singhal, Centre for Rural Development and Technology, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India. E-mail: singhalpoonam6@gmail.com

BAMBOO SHOOT: A FOOD RESOURCE

A bamboo shoot is the young bamboo plant that, if not harvested, will grow into a tall bamboo plant within three to four months. Bamboo shoots usually emerge after the rainy season and are harvested after attaining 20–30 cm height. Exposure to light causes bitterness as cyanogenic glycosides are formed in the shoot (Choudhury et al., 2010). It was also noted that shoots turn tougher, acrid, or bitter if not harvested as soon as they come out of ground (Sue, 1995). Young shoots of both running and clump-forming bamboos are used for edible purposes.

Bamboo is not merely the poor man's timber but is also the rich man's delicacy. Bamboo shoots exhibit a great potential as a food resource. For centuries, young edible bamboo shoots have remained one of the highly palatable dishes in delicacies. China and Taiwan are among the leading countries to export edible bamboo shoots (Bhatt et al., 2003). Fresh, fermented, and roasted tender bamboo shoots are considered culinary treats. They are consumed as vegetables, pickles, salads, and in various other forms in different countries (Christine and Wetterwald, 1992; Kumbhare and Bhargava, 2007). Tender shoots of some species are also preserved after fermenting and drying (Bhargava et al., 1996). Bamboo shoots are a popular item in Asian stir fry and as a pickled condiment (Rubatzky et al., 1997).

Bamboo shoots are crisp and tender, comparable to asparagus, and eaten fresh, but can be canned or frozen. Preparation involves removing the sheath, cutting shoots lengthwise, boiling in water for 30 minutes, and adding salt a few minutes before the boiling ends. The tender portion are cut into rings and then steamed to remove hydrocyanic acid. This is done to remove the bitterness and acridity present in the raw bamboo shoots. Homogentisic acid is known to be responsible for the disagreeable pungent taste of bamboo shoots known as *egumi* (Bhargava et al., 1996). From other reports published early in 1959, it became clear that not only the free homogentisic acid but also its glycoside were found to be the principal causes of the *egumi* taste in bamboo shoots. The glycoside had a stronger *egumi* taste than the free acid. One more reason for this peculiar taste is that bamboo shoots grown in dark brown soil have more homogentisic acid than those grown in light brown soil and there is more homogentisic acid in the upper part (117 μg) of bamboo shoot than in the base (91 μg) (Hasegawa et al., 1959).

Edible Bamboo Species

As mentioned earlier, more than 1250 species of bamboo belonging to 75 genera have been reported to be distributed in the world out of which 125 species exist in India. Out of 22 genera distributed in India, 19 are indigenous and three are exotic, introduced for cultivation. The indigenous genera of bamboo in India are *Arundinaria*, *Bambusa*, *Cephalostachyum*, *Chimonobambusa*, *Dendrocalamus*, *Dinochloa*, *Gigantochloa*, *Indocalamus*, *Melocanna*, *Neohouzeaaqa*, *Ochlandra*, *Oxytenanthera*, *Phyllostachys*, *Pseudostachyam*, *Schizostachyum*, *Semiarundinaria*, *Sinobambusa*, *Teinostachyum*, and *Thyrsostachys tachys*. The three exotic genera, i.e., *Guadua*, *Pseudosasa*, and *Thyrsostachys*, are only occasionally found in cultivation (Bahadur and Jain, 1981; Mauria and Arora, 1988). In the Asia-Pacific region, only 26 bamboo species are used for the edible purpose (Sharma, 1980).

In India, shoots of *B. bambos*, *B. multiples*, *B. tulda*, *B. vulgaris*, *D. giganteus*, *D. hamiltonii*, *D. logispathus*, *D. strictus*, and *S. elegans* are used as vegetable and pickle products (Vatsala, 2003). *M. baccifera* is identified to be the most commercial species in Mizoram; *D. hamiltonii*, *M. baccifera*, and *B. balcoa* in Meghalaya; *D. hamiltonii* and *C. hookeriana* in Sikkim (Bhatt et al., 2003, 2004); *Melocana bambusaides* in Tripura (Sankaran et al., 2007); and *M. baccifera* in Nagaland (Sinha, 2007). Another study conducted by the same investigator (Bhatt et al., 2005) explored the occurrence of 11 edible bamboo species, namely *B. balcoa* Roxb, *B. nutans* Wall ex Munro, *B. tulda* Roxb, *D. giganteus* Munro, *D. hamiltonii* Nees, *D. hookerii* Munro, *D. longispathus* Kurz, *D. sikkimensis* Gamble, *M. baccifera* Roxb Kurz, *Phyllostachys bambusoides* Sieb and Zucc, and *Teinostachym wightii* Beddome, which were being sold in the markets of North East India by primary and secondary vendors in fresh, fermented, boiled, or roasted form. According to another report, the tender shoots of *D. giganteus*, *D. hamiltonii*, *D. membranaceous*, and *D. strictus* are consumed either as vegetable or pickle. *Bambusa polymorpha* produces quality edible shoots with a distinct sweet taste in the raw form (Bhargava et al., 1996). Another recent study listed the genus of major edible bamboo shoots grown in North East India and the list includes *Bambusa* (16 sp.), *Dendrocalamus* (12 sp.), *Arundanaria* (nine sp.), *Cephalostachyum* (four sp.), *Melocanna* (one sp.), *Teinostachyum* (one sp.), *Chymonobambusa* (one sp.), and *Phullostachys* (one sp.) (Sankaran et al., 2007). According to Kennard and Freyre (1957), *Dendrocalamus membranaceous* Munro, an Indian species, is excellent from processing point of view.

In the United States, *Phyllostachys* is considered to be the most important genus for bamboo shoot production, which consists of about 60 species all of which are edible. Important food species include *P. dulcis*, *P. edulis*, *P. bambusoides*, *P. pubescens*, *P. nuda*, and *P. viridis* (Rubatzky et al., 1997; Diver, 2001). The United States imports 30,000 tonnes of canned bamboo shoots each year from Taiwan, Thailand, and China (Scurlock et al., 2000; Diver, 2001).

Recently, Arinana et al. (2008) reported that most of the species growing in Thailand produce edible shoots; the best one are *D. asper*, *D. giganteus*, *D. merrilianus*, *B. tulda*, *T. siamensis*, and *Pseudoxytenanthera albociliata*. *Thyrsostachys siamensis* is one important species and is known by a local name of *Normai huak* in North East Thailand (Somnasang, 1998). About 400 tonnes of young shoots of *Thyrsostachys* species are canned and exported to Japan from Thailand. The main source of bamboo shoots in Japan is *Phyllostachys pubescens*. In Taiwan, *P. edulis* and *D. latifera* constitute an integral part in the main course dishes (Tripathi, 1998). Taiwan consumes 80,000 tonnes of bamboo shoots annually constituting a value of US$50 million (Choudhury et al., 2010).

Table 1 shows the different species of bamboo being used for edible purpose along with other purposes. Scientific name,

Table 1 Different edible bamboo shoot species

Scientific name (synonyms); common names	Height (ft)	Diameter (inches)	Type*
Bambusa beecheyana (syn: Sinocalamus beecheyanus); beechy bamboo	12–40	4–5	C
Bambusa oldhamii (syn: Sinocalamus oldhamii); Japanese timber bamboo; oldham bamboo, clumping giant timber	15–55	3–4	C
Bambusa vulgaris; common bamboo, ohe	20–60	4	C
Dendrocalamus asper; Java bamboo	60–100	5–8	C
Dendrocalamus brandisii; kyellowa, waya wapyu (Burma), wakay, waktlu	60–120	5–8	C
Dendrocalamus giganteus; wabo (Burma), worra (Assam)	80–100	8–10	C
Dendrocalamus latiflorus; sweet shoot bamboo, mazhu	60–80	6–8	C
Dendrocalamus membranaceus; wap-yu (Malay)	50–70	4	C
Phyllostachys bambusoides (syn: Phyllostachys reticulata, P. quilioi); Japanese timber bamboo, Madake	30–70	1–6	R
Phyllostachys dulcis; sweet bamboo	30–40	2–3	R
Phyllostachys nigra “Bory” (syn: P. boryana)	30–50	3	R
Phyllostachys nigra “Henon”; Henon bamboo	35–55	3.5	R
Phyllostachys nuda; fishing pole bamboo	25–35	1–2.5	R
Phyllostachys vivax; giant edible shoot bamboo	30–70	4–5	R
Thrysostachys siamensis; monastery bamboo	25–40	3	C

*Type: C = culms clumping; R = culms running.
Source: CTAHR Fact Sheet (1997).

height, diameter, and type (whether clumping or running) of these species have been described.

Bamboo Shoot Recipes and Food Products

Bamboo shoots are a popular food in Asia, and the nutritional value is comparable to those of many commercial vegetables (Suwannapinunt and Bunvong, 1990). There are around 11 popular inter-continental dishes prepared from bamboo shoots in Indian restaurants (Fung, 1997). Bamboo shoots have been integrated in the north and south Indian cuisine. Recipes like bamboo shoot *halwa*, *chutney*, *pulao*, *curry*, *bhaji*, etc. have been standardized by Engineering Resource Group, Bangalore (NMBA, 2009). Bamboo shoots form a common ingredient of Chinese dishes (Knechtges, 1986). Products commercially available in China, Japan, Thailand, and Malaysia include canned bamboo shoots, fermented shoots, bamboo pickle, bamboo shoot powder, bamboo shoot juice, and bamboo beer (prepared from bamboo culms). Export of boiled and fresh bamboo shoots takes place in various parts of the world from the point where they are processed. Dried bamboo shoots are not exported due to an imposed ban by the local authorities (Greijmans et al., 2007). Cone-shaped and light-colored bamboo shoots are usually sold, canned, or dried in Chinese or oriental provision stores and supermarkets. These crisp shoots of tropical bamboo give a sweetness and crunch to many dishes, especially stir-fries, and are very popular in Chinese cuisine. Steamed ground pork patty and finely diced bamboo shoot sprinkled with soy sauce on top is a popular home-style dish (Chinese Food Recipes, 2009). Dishes made from Bamboo shoot in Thailand include Pai Tong (*D. asper*), Pai Seesuk (*Bambusa blumeana*), Pai Ruak (*Thyrsostachys siamensis*), Pai Ruak dam (*T. oliverii*), Pai Bong (*D. brandisii*), Pai Songdoi (*D. stictus*), and Pai Rai (*G. albaculiata*; Arinana et al., 2008). They are also consumed in Ethiopia by the rural people living near the bamboo forests. Boiled rhizomes are also eaten in these areas. Bamboo shoot could also, probably, be used to supplement food requirements in Ethiopia (Embaye, 2000). In Thailand and Vietnam, some shoots are finely grated and used in salads. In Japan, the most common preparation involves boiling the shoots in stocks, soups, or salted water for use in assorted dishes (FSANZ, 2004).

The ideal edible bamboo for processing should be white, solid, and tender and should lack bitterness and acridness. The shoots are used for making curry or chutney either alone or in combination with potatoes, tomatoes, peas, etc. (Sinha, 2007). *Tusa* (young bamboo shoots) and bamboo *tama* (fermented young shoot) are important delicacies for people in the western hills of Nepal (Shrestha et al., 2001). In the North East, pickles made of bamboo shoot are extensively used as a main ingredient in different fish preparations (curry, dry fish, etc.), and also used in some meat dishes. They are first ground and fried before using them in certain “dal” preparations. It is also preserved either with crystal salt, in brine, or in mustard oil. The bamboo shoot has interestingly been an integral part of indigenous cuisine in the remote corners of the Western Ghats in Karnataka. From pickles, snacks, *papads*, and other fried stuff to curries, *bhaajis*, and other preparations with rice, bamboo shoot is used extensively in various seasons (Report ERG-BS, 2009).

Fermented Bamboo Products

Fermented foods are not only attractive and palatable in terms of flavor, aroma, texture, and appearance but are also rich in nutrients and good for digestion (Steinkraus, 1995). In India, the fermentation of bamboo shoots has extensively been carried out in the states of Manipur, Meghalaya, Sikkim, Mizoram, etc. since ancient times. Some of the popular fermented bamboo

Table 2 Fermented bamboo shoots eaten by various tribes in India

State	Tribe	Species of bamboo	Local name of fermented bamboo shoot	Reference
Arunachal Pradesh	Apatani	*D. giagnteus Munro*, *Phyllostaychs assamica Gamble ex Brandis*, *Bambusa tulda* Roxb.	Hikhu, Hiring, Hithyi	Singh et al. (2007), Tamang and Tamang (2009)
	Adi	*Dendrocalamus hamiltonii Nees* and Arnott ex Munro, *B. balcoa Roxb.*, *D. giagnteus Munro*, *Phyllostaychs assamica Gamble ex Brandis*, *Bambusa tulda* Roxb.	Ekung, Eyup, Eting	Singh et al. (2007), Tamang and Tamang (2009)
Manipur	Meitei	*Dendrocalamus hamiltonii*, *Dendrocalamus sikkimensis*, *D. giagnteus, Melocana bambusoide*, *Bambusa tulda*, and *B. balcoa*	Soibum, Soidon	Devi and Singh (1986), Jeyaram et al. (2009), Tamang and Tamang (2009), Singh et al. (2007)
Meghalaya	Khasi	*Dendrocalamus hamiltonii*	Lungseij	Agrahar-Murugkar and Subbulakshmi (2006), Singh et al. (2007), Tamang and Tamang (2009)
Tripura	Barman	–	Godhak	Singh et al. (2007)
Darjeeling Hills, Sikkim		*Dendrocalamus hamiltonii Nees* and Arnott, *Bambusa tulda* Roxb. and *Dendrocalamus sikkimensis*	Mesu	Tamang and Sarkar (1996), Tamang and Tamang (2009)

shoot delicacies of the North East include *mesu* (Tamang and Sarkar, 1988), *soibum* (Giri and Janmejay, 2000; Singh et al., 2003b), and *shoidon* and *soijum* (Tamang and Sarkar, 1996). They are eaten as a curry, pickle, or soup in different communities. Table 2 describes various fermented bamboo shoot dishes locally eaten by various tribes of India.

Bamboo Juice

In ancient China, the fresh culm of *Phyllostachys glauca* was roasted to produce fresh bamboo juice for medicine. Its output was as low as 3.5 kg of juice per 100 kg of fresh culms. However, now a days bamboo juice is produced by squeezing the pulp or cooking. The juice is also used to make beverages and specific liquor (Fu, 2009).

Bamboo Beer

Several factories in China are producing bamboo beer from Moso bamboo (*Phyllostachys heterocycla* var. *pubescens* or *Phyllostachys. edulis*.) juice (Fu, 2001). The extract left after boiling the green dry leaves of *Phyllostachys* plant is concentrated in vacuum to give a fine bamboo leaf juice. The bamboo beer is prepared by adding the juice to the original beer, then mixed, filtered, and bottled. The resultant beer contains 10–50 mg of total flavanoids per liter of beer (Fu, 2009).

Bamboo Crisps

Bamboo crisps comprising less fat contain bamboo shoot and wheat flour as ingredients. Bamboo shoot pulp is mixed with cornstarch and extruded into sticks using high and low compression ratio equipment. While maintaining the sticks under cool, wet conditions for 8–12 hours, they are cut into small round pieces and are then dried at low temperature for an extended period to reduce the water content to 10–12%. After this, the pieces are fried at 150–160°C for about 20–30 seconds and they expand and become crisp. Finally, the oil content of the crisps is reduced. The final crisps are satisfactorily crunchy and can also be flavored differently (Feng'e, 2002). Using similar technology, bamboo shoots can be made into breads, cakes, scones, and cookies.

NUTRITIVE VALUE OF FRESH BAMBOO SHOOTS AND CHANGE WITH PROCESSING: A BROAD PROFILE

Although different parts of bamboo are used as a food resource by humans and animals, systematic conclusive study on its nutritional significance is not available. Bamboo shoots contain several nutritional components like protein, carbohydrates, fat, vitamins, minerals, enzymes, coenzymes, reducing and nonreducing sugars, lactic and citric acids (fermented products), etc. Bamboo shoot is rich in fiber and low in fat. A 100 g of edible portion of bamboo shoots contains 2.6 g of protein and 0.3 g of fat (Yamaguchi, 1983). However, some Indian studies have reported the protein value to be high in the range 21.1–25.8% on dry weight basis (Kumbhare and Bhargava, 2007). It contains tyrosine as the major amino acid that otherwise is a minor component in common fruits and vegetables (Kozukue et al., 1983). It also contains selenium, an important antioxidant in trace amounts, and lysine, "a limiting amino acid," which lacks in cereals and is an important amino acid for growth and development. The main fatty acids present in bamboo shoots are palmitic, linoleic, and linolenic acids (Kozukue and Kozukue, 1981). Fresh bamboo shoot has also been found to be rich in potassium (533 mg/100 g), which help prevents heart diseases and blockage of blood vessels (Tsaltas, 1969). Bamboo shoots are a good source of thiamine, vitamin B6, and potassium.

However, the process of canning greatly reduces the vitamin content. One cup of cooked bamboo shoots provides approximately 14 calories, 0.3 g fat, 1.2 g fiber, 1.8 g of protein, and 640 mg potassium (FSANZ, 2004).

In fact, Young (1954) was the first to report the nutrients present in raw bamboo shoot (species not mentioned) in terms of crude protein, crude fat, carbohydrate, and ash. Gradually, interest in this non-forest product was revived after about three decades. Subsequently, detailed analysis of nutrients in different species was performed by various scientists (Young, 1954; Gopalan et al., 1978; Giri and Janmejay, 1994; Rajyalakshmi and Geervani, 1994; Bhargava et al., 1996; Tripathi, 1998; Vatsala, 2003; Bhatt et al., 2005; Kumbhare and Bhargava, 2007; Nirmala et al., 2007, 2008). The nutritive value of 100 g of edible bamboo shoots (macronutrients and micronutrients) by different investigators has been compiled in Table 3 and 4.

Macronutrients

Various macronutrients like protein, carbohydrate, fat, fiber, etc. present in bamboo shoots and changes in their content with different processing methods have been discussed in this section.

All the species have been reported to contain huge amount of moisture ranging from 54% in *Bambusa arundiancea* to 94.7% in *B. nutans* in the raw state. The canned shoots of *D. giganteus* species were found to contain as high as 95.16% moisture (Nirmala et al., 2008) while the dried shoot powder contained as low as 11.6% moisture (Rajyalakshmi and Geervani, 1994).

Calories

The calories in different species are in the range 14–27 Kcal/100 g of bamboo shoot. It has been noticed that calories provided by raw bamboo shoots are comparable to calories provided by any other vegetable.

Protein

Great variation has been observed in the protein content of bamboo shoots of various species from different origin, ranging from 1.8% to 25.8% (dry weight basis). Investigation by Kumbhare and Bhargava (2007) on *B. nutans*, *B. vulgaris*, *D. strictus*, and *D. asper* species of shoots reported values that ranged from 19.2% to 25.8% (dry weight basis) and were found in accordance with the earlier reports. Apical and basal portion of *D. giganteus* were found to have higher values, i.e., 46.1% and 40.4%, respectively (Ferreira et al., 1992). Crude protein estimated by CHN Analyzer in IIT Delhi for *D. strictus*, *B. tulda*, *B. vulgaris*, and *B. balcoa* was found to be 21.51, 18.74, 20.60, and 25.84, respectively (Satya et al., 2009). The wide variation in the protein content of bamboo shoots may be attributed to differences in species, growing site, climatic factors, and method of analysis.

The crude protein content decreased after boiling the shoots at increasing temperature. The content decreased from 17.3% to 11.6% on dry weight basis, highest being in *B. nutans*. Cooking diminishes the biological value of proteins by destroying the essential amino acids. Such a decrease in crude protein content of 1.7% in peeled potato as compared to the uncooked potato (2.1%) has been mentioned in FAO report (1990). The content was also found to decrease in the 10-days-old shoots (2.17–2.60%) when compared with the freshly harvested juvenile shoots (3.10–3.71%) in four different species (Nirmala et al., 2007). This detailed study (Nirmala et al., 2008) revealed that canned shoots had the lowest protein content (1.93%) followed by fermented (2.57%), 10-days-old (2.6%), and juvenile shoots (3.11%) in the *D. giaganteus* species. The reason for such a reduction could be disintegration of protein content leading to the formation of a milky white colloid. Another study (Rajyalakshmi and Geervani, 1994) exhibited the highest protein value of 29.6% in the processed and dried shoots among all the processed forms. Devi and Singh (1986) showed an increase in the soluble protein content from 3.1% to 7.8% and 8.1% on the third and fifth days of fermentation, respectively. But according to Giri and Janmeay (2000), protein got digested appreciably on the 20th day of *Soibum* fermentation with significant enhancement of individual amino acids except aspaginine. Extensive proteolysis could be by the mutual proteolytic role of lactics and yeasts. In a recent study (Agrahar-Murugkar and Subbulakshmi, 2006), fermented bamboo *lungsiej* was found to have a better nutritive value in terms of its protein content (8.5%).

Amino acid. Amino acid content of bamboo is much higher than found in other vegetables such as cabbage, carrot, onion, and pumpkin. Almost all eight essential amino acids that are not synthesized in the human body are available in bamboo shoots. Bamboo shoot contains 17 different types of amino acids (ICFRE, 2009). The amino acid content as determined by Nirmala et al. (2007) for juvenile shoots of *B. bamboos*, *B. tulda*, *D. asper*, *D. giganteus*, and *D. hamiltonii* was found to be 3.98%, 3.65%, 3.11%, 3.87%, and 3.20% equivalent of leucine, respectively. Approximately 42% decrease in amino acid content upon keeping the shoots for 10 days was observed. The total free amino acid content in the apical portion of *D. giganteus* was reported to be 3.9% protein (Ferreira et al., 1992). The total free amino acids content in fresh shoots ranged from 0.11% to 0.70% equivalent of leucine in *B. nutans*, *B. vulgaris*, *D. strictus*, and *D. asper.* The content decreased upon boiling in all the species but it decreased to an exceptional extent by 87.14% in D. *strictus* (Kumbhare and Bhargava, 2007). According to a study by Giri and Janmejay (2000), the individual amino acids depleted during aging (300 days) of *B. tulda* but cysteine remained dominating followed by tyrosine and lysine. Bhatt et al. (2005) also examined the tryptophan and methionine content and the values were in the range 0.4–1.7 g/16 g N for tryptophan and 0.3–0.8 g/16 g N for methionine in different species. Tyrosine, which is a minor component in common fruits and vegetables, was found to be the most abundant free amino acid and a major component of white clumpy substances produced after

Table 3 Nutritive value of bamboo shoot (macronutrients) harvested from different bamboo species

S. No	Name of the species	Form*	Calories (%)	Moisture (%)	Crude protein (%)	Crude at (%)	Carbohydrate (%)	Ash (%)	Crude fiber (%)	References
1	Species not mentioned	1	–	–	2.60	0.30	4.50	0.90	–	Young (1954)
		1	43.0	88.8	3.90	0.50	5.70	1.10	–	Gopalan et al. (1978)
		1	27.0	91.0	2.60	0.30	5.20	–	–	Yamaguchi (1983)
		1	–	87.10	3.90	–	7.50	1.40	–	Vatsala (2003)
		1	14.0	–	1.80	0.30	2.00	–	1.29	Report ERG-BS (2009)
		1	–	88.8	3.90	0.50	5.70	1.10	–	ICFRE (2009)
2	*Bambusa arundinacea*	2	294.0	11.60	29.6	0.40	43.0	8.50	6.90	Rajyalakshmi and Geervani (1994)
		1	–	54.0	5.33	–	10.0	–	–	Bhargava et al. (1996)
3	*B. bamboos*	1	–	88.80	3.90	0.50	5.70	–	–	Tripathi (1998)
		1	–	89.83	3.57	3.53	5.42	1.38	3.53	Nirmala et al. (2007)
		3	–	90.80	2.32	9.64	2.30	1.22	9.64	Nirmala et al. (2007)
4	*B. balcoa*	1	15.5–15.64	84–86.3	3.3–3.87	0.6–1.0	5.2–5.23	3.1	26.4	Bhatt et al. (2005)
		1	–	91.65	2.74	0.817	3.90	0.99	–	NMBA (2009)
		1			25.84					Satya et al. (2009)
5	*B. polymorpha*	1	–	74.0	7.46	–	8.0	–	–	Bhargava et al. (1996)
		1	–	91.65	2.10	0.44	4.86	0.91	–	NMBA (2009)
6	*B. pallida*	1	–	92.29	2.31	0.34	3.83	1.12	–	NMBA (2009)
7	*B. nutans*	1	15.4	94.70	3.30	1.0	4.90	2.70	28.50	Bhatt et al. (2005)
		1	–	–	21.10	–	3.30	0.90	0.76	Kumbhare and Bhargava (2007)
		4	–	–	17.30		5.10	0.72	0.75	Kumbhare and Bhargava (2007)
8	*B. vulgaris*	1	–	77.0	4.16	–	5.0	–	–	Bhargava et al. (1996)
		1	–	–	25.70	–	3.40	0.80	0.97	Kumbhare and Bhargava (2007)
		4	–	–	13.50	–	5.0	0.66	0.97	Kumbhare and Bhargava (2007)
		1			20.60					Satya et al. (2009)
9	*B. tulda*	1	15.90	92.80	3.40	0.9	4.70	3.0	24.60	Bhatt et al. (2005)
		1	–	83.60	3.69	3.97	6.92	0.85	3.97	Nirmala et al. (2007)
		3	–	89.33	2.49	10.69	2.58	0.74	10.69	Nirmala et al. (2007)
					18.74					Satya et al. (2009)
10	*Melocanna bambusoides*	1	–	91.22	3.29	0.518	3.93	0.98	–	NMBA (2009)
11	*M. baccifera*	1	–	84.0	7.36	–	2.0	–	–	Bhargava et al. (1996)
		1	15.8	75.5–93.0	2.4–3.62	0.57–1.0	4.5–6.12	2.30	35.5	Bhatt et al. (2005)
12	*Dendrocalamus strictus*	1	–	–	19.20	–	2.60	0.90	0.98	Kumbhare and Bhargava (2007)
		4	–	–	17.10	–	5.0	0.82	0.96	Kumbhare and Bhargava (2007)
		1	–	85.98	1.98	0.82	9.94	1.14	–	NMBA (2009)
		1			21.51					Satya et al. (2009)
13	*D. hamiltonii*	1	16.40	87.0–93.6	3.7–3.9	0.5–0.9	4.8–5.7	2.80	25.4	Bhatt et al. (2003, 2005)
		1	–	92.51	3.72	3.90	5.50	0.86	3.90	Nirmala et al. (2007)
		3	–	92.60	2.56	8.20	2.98	0.84	8.20	Nirmala et al. (2007)
		1	–	92.37	2.60	0.314	4.00	1.01		NMBA (2009)
14	*D. giganteus*	1	16.9	92.00	2.80	0.80	4.90	2.20	27.60	Bhatt et al. (2005)
		1	–	90.7	3.11	2.64	5.10	0.89	2.64	Nirmala et al. (2007)
		3	–	91.8	2.60	13.84	5.02	0.74	13.84	Nirmala et al. (2007)
		5	–	88.83	2.57	0.315	1.50	0.78	–	Nirmala et al. (2008)
		6	–	95.16	1.93	0.25	1.45	0.75	–	Nirmala et al. (2008)
		1	–	91.19	2.59	0.502	4.78	0.89	–	NMBA (2009)
15	*D. asper*	1	–	–	25.8	–	2.90	0.80	0.71	Kumbhare and Bhargava (2007)
		4	–	–	11.60	–	3.10	0.75	0.70	Kumbhare and Bhargava (2007)
		1	–	89.40	3.59	3.54	4.90	0.95	3.54	Nirmala et al. (2007)
		3	–	90.20	2.17	10.85	4.46	0.94	10.85	Nirmala et al. (2007)
16	*D. hookerii*	1	16.80	93.50	3.40	1.0	4.50	3.2	34.7	Bhatt et al. (2005)

(*Continued on next page*)

Table 3 Nutritive value of bamboo shoot (macronutrients) harvested from different bamboo species *(Continued)*

S. No	Name of the species	Form*	Calories (%)	Moisture (%)	Crude protein (%)	Crude at (%)	Carbohydrate (%)	Ash (%)	Crude fiber (%)	References
17	*D. logispathus*	1	–	19.0	3.20	–	ND	–	–	Bhargava et al. (1996)
		1	16.60	91.70	2.60	0.60	4.70	3.40	26.70	Bhatt et al. (2005)
18	*D. sikkimensis*	1	16.90	92.40	3.10	0.60	4.70	2.6	23.50	Bhatt et al. (2005)
19	*Phyllostachys bambusoides*	1	16.30	85.60	3.70	0.70	4.80	2.1	23.10	Bhatt et al. (2005)
20	*Chimonobambusa hookeriana*	1	15.96	79.0	3.56	0.62	5.94	–	–	Bhatt et al. (2005)
21	*Teinostachyum wightii*	1	14.60	78.60	3.60	0.90	4.90	3.7	23.70	Bhatt et al. (2005)

*1 = fresh shoots; 2 = processed and dried shoots; 3 = 10-days-old emerged shoots; 4 = boiled shoots; 5 = fermented shoots; 6 = canned shoots.

blanching, and comprised 89% of the total material of young shoots of *Phyllostachys pubescens* (Kozukue et al., 1983).

Carbohydrates

The carbohydrate content ranges from 2.0% to 9.94% in the raw form of bamboo shoots. The carbohydrate content as reported by Kumbhare and Bhargava, (2007) was 3.3%, 3.4%, 2.6%, and 2.9% in *B. nutans*, *B. vulgaris*, *D. strictus*, and *D. asper*, respectively. The content was found to increase after boiling ranging from 3.1% to 5.1%, which might be due to fibrous nature of bamboo. During processing, the polysaccharides got hydrolyzed into simple sugars and resulted in the formation of monosaccharide. The oligosaccharides such as stachyose and raffinose, which cause flatulence, can be converted to monosaccharides and thus cooking might benefit. Surprisingly, the carbohydrate content decreased upon storage ranging from 4.9–6.92% in the juvenile shoots to 4.46–2.3% in the 10-days-old shoot sample (Nirmala et al., 2007). The carbohydrate content seemed to be quite low in fermented (1.5%) and canned shoots (1.45%) of *D. giagnteus* species (Nirmala et al., 2008). On the other hand, study by Rajyalakshmi and Geervani (1994) showed carbohydrate percentage to be high in processed and dried shoots (43%). Significant reduction in total sugar content was observed on third- and fifth-day samples of *Shoidon* (20.1 mg and 18.5 mg/100 g, respectively) as compared to 78.40 mg/100 g for the raw sample of the *M. humilis* species (Devi and Singh, 1986). Similar results were confirmed in another study by Giri and Janmejay (2000) where total soluble sugar content decreased significantly upon an extended fermentation period of *soibum* up to 300 days from 16.67% on 0 day to 0.37% on the 300th day.

Reducing sugar content in four fresh bamboo species were 1.05%, 0.81%, 0.72%, and 1.14% in *B. nutans*, *B. vulgaris*, *D. strictus*, and *D. asper*, respectively, and were found in agreement with the earlier report (Ferreira et al., 1992) where values of the basal and apical portions of *D. giganteus* varied from 1.1% to 1.2% on fresh weight basis (Kumbhare and Bhargava, 2007). The reducing sugar content decreased on boiling shoots and ranged from 0.01% to 0.59%. Prolonged heating under moist conditions degrades reducing sugars by browning reaction. This could be of nutritional importance as cooking results in the release of oligosaccarides like raffinose and other sugars that produce flatulence. In *M. humilis* shoots the reducing sugar content was 0.048 g/100 g, which was very low as compared to the above mentioned values, but interestingly the content was found to increase with the fermentation period from 0.0512 g/100 g on the third day and 0.0513 g/100 g on the fifth day (Devi and Singh, 1986).

Fructose, glucose, and sucrose were the major sugar constituents in all the sections of *Phyllostachys pubescens* (Kozukue et al., 1983). A variety of soluble sugars like sucrose, galactose, glucose, and either mannose or arabinose or both were formed during the course of fermentation but with prolonged fermentation, degradation of these sugars takes place by the action of the microorganisms (Giri and Janmejay, 1994).

Organic Acids

When tested for organic acids, oxalic, malic, and citric acids were found to be the principal organic acid components in all sections of *Phyllostachys pubescens*. Oxalic acid ranged from 462 mg (top) to 157 mg (base) per 100 g fresh weight. Citric acid was rich in the upper half, while malic acid was rich in the lower 3/4th portion (Kozukue et al., 1983). The acidic content in different species of shoots was determined by Bhatt et al. (2005) and it ranged from 3.3% to 5.2%. Total acids in terms of percent lactic acid were very low (0.02%) as obtained by Devi and Singh (1986) for raw shoots. However, the content increased tremendously to 0.21% and 0.25% on third and fifth days of fermentation, respectively. According to Tamang and Sarkar (1996), the titrable acidity increased from 0.04% to 0.95% upon fermentation resulting in the decline in pH from 6.4 to 3.8.

Fats

Bamboo shoots are known for their low fat content. The fat content ranged from 0.3% to 3.97% in the fresh shoots, highest being in *B. tulda*. Canned shoots were reported to contain the lowest content of crude fat, i.e., 0.25%, as compared to the raw shoots of different species. As shown by Nirmala et al. (2007), fat content increased upon keeping the shoots for 10 days by

Table 4 Micronutrients present in different species of bamboo shoots

S. No	Name of the species	Form*	Micronutrients: Vitamins (mg/100 g) A	B_1	B_2	B_3	C	Minerals (mg/100 g) Ca	P	Fe	Na	K	Mg	References
1	Species not mentioned	1	20 (I.U.)	0.15	0.07	0.60	4.0	13.0	59.0	0.50	–	–	–	Yamaguchi (1983)
		1	–	–	–	–	–	20.0	65.0	0.10	–	–	–	Gopalan et al. (1978)
2	*Bambusa arundinacea*	1	–	–	–	–	7.50	400	150	–	140	1400	50	Bhargava et al. (1996)
		2	–	0.05	0.01	0.03	–	3.0	1049	22.0	–	–	–	Rajyalakshmi and Geervani (1994)
3	*B. balcoa*	1	–	–	–	1.40	–	24.01	30.99	1.02	–	–	–	NMBA (2009)
		1	–	–	–	–	3.8	1400	900	–	–	30.0	40.0	Bhatt et al. (2005)
		–	–	–	–	–	6.6	–	–	–	–	–	–	Satya et al. (2009)
4	*B. polymorpha*	1	–	–	–	2.60	–	180.69	15.06	1.53	–	–	–	NMBA (2009)
		1	–	–	–	–	17.5	560	100	–	120	560	140	Bhargava et al. (1996)
5	*B. bamboos*	1	–	–	–	–	1.90	0.36	30.12	3.00	10.1	576	5.38	Nirmala et al. (2007)
		3	–	–	–	–	1.31	0.30	29.0	1.30	3.60	566	5.20	Nirmala et al. (2007)
6	*B. pallida*	1	–	–	–	1.40	–	21.17	32.27	1.11	–	–	–	NMBA (2009)
7	*B. nutans*	1	–	–	–	–	5.3	1500	900	–	–	30.0	40.0	Bhatt et al. (2005)
		1	–	–	–	14.92	1.94	400	130	–	80	680	–	Kumbhare (2003)
8	*B. vulgaris*	1	–	–	–	–	13.7	320	220	–	400	920	100	Bhargava et al. (1996)
		1	–	–	–	3.87	2.43	80	100	–	40	460	–	Kumbhare (2003)
		1	–	–	–	–	5.0	–	–	–	–	–	–	Satya et al. (2009)
9	*B. tulda*	1	–	–	–	–	7.6	1300	700	–	–	20.0	40.0	Bhatt et al. (2005)
		1	–	–	–	–	1.42	4.1	19.31	3.2	12.96	408	10.14	Nirmala et al. (2007)
		3	–	–	–	–	1.00	2.42	18.70	1.58	3.60	398	7.50	Nirmala et al. (2007)
		1	–	–	–	–	5.0	–	–	–	–	–	–	Satya et al. (2009)
10	*D. strictus*	1	–	–	–	2.10	–	139.5	58.13	2.917	–	–	–	NMBA (2009)
		1	–	–	–	4.20	2.23	30.0	60.0	–	100	570	–	Kumbhare (2003)
		1	–	–	–	–	5.8	–	–	–	–	–	–	Satya et al. (2009)
11	*D. hamiltonii*	1	–	–	–	2.60	–	44.16	27.76	1.65	–	–	–	NMBA (2009)
		1	–	–	–	–	2.45	3.00	28.12	2.70	9.32	416	6.91	Nirmala et al. (2007)
		3	–	–	–	–	1.79	2.05	27.56	0.76	3.64	210	5.97	Nirmala et al. (2007)
		1	–	–	–	–	12.9	1500	600	–	–	20.0	40.0	Bhatt et al. (2005)
12	*D. giganteus*	1	–	–	–	6.40	–	26.93	12.57	1.06	–	–	–	NMBA (2009)
		1	–	–	–	–	6.8	1200	700	–	–	30.0	50.0	Bhatt et al. (2005)
		1	–	–	–	–	3.28	6.80	15.90	2.43	8.22	288	10.09	Nirmala et al. (2007)
		3	–	–	–	–	2.15	1.47	15.01	1.23	3.64	275	9.57	Nirmala et al. (2007)
13	*D. hookerii*	1	–	–	–	–	9.9	1600	1000	–	–	20.0	40.0	Bhatt et al. (2005)
14	*D. logispathus*	1	–	–	–	–	5.3	1300	600	–	–	20.0	40.0	Bhatt et al. (2005)
		1	–	–	–	–	23.0	560	190	–	160	1300	90.0	Bhargava et al. (1996)
15	*D. sikkimensis*	1	–	–	–	–	3.0	1900	700	–	–	20.0	40.0	Bhatt et al. (2005)
16.	*D. asper*	1	–	–	–	–	3.20	5.51	40.95	3.37	10.14	464	10.14	Nirmala et al. (2007)
		1	–	–	–	5.24	2.85	60	60	–	380	440	–	Kumbhare (2003)
		3	–	–	–	–	2.12	1.68	29.08	2.52	4.42	460	8.20	Nirmala et al. (2007)
17	*Melocanna bambusoides*	1	–	–	–	6.70	–	47.58	14.28	0.879	–	–	–	NMBA (2009)
18	*M. baciferra*	1	–	–	–	–	7.6	1400	800	–	–	20.0	40.0	Bhatt et al. (2005)
		1	–	–	–	–	15.0	400	140	–	20	240	50	Bhargava et al. (1996)
19	*Phyllostachys bambusoides*	1	–	–	–	–	6.1	1300	700	–	–	20.0	40.0	Bhatt et al. (2005)
20	*Teinostachyum wightii*	1	–	–	–	–	6.6	1300	500	–	–	20.0	40.0	Bhatt et al. (2005)

*1 = fresh shoots; 2 = processed and dried shoots; 3 = 10-days-old emerged shoots; 4 = boiled shoots; 5 = fermented shoots; 6 = canned shoots.

almost three-fold in the three species (*B. bamboos*, *B. tulda*, and *D. asper*), and in one species *D. giganteus* the increase was exceptionally high by six-fold. The fat content in the juvenile shoots ranged from 2.64% to 3.97%, but for the 10-days-old shoots the content ranged from 8.2% to 13.84%.

Variation in the distribution of lipids between different sections of the shoot has been reported. Total lipids (TL) ranged from 800 mg (top) to 380 mg (base) per 100 g fresh weight and the ratio of non-polar lipids (NPL):glycolipids (GL):phospholipids (PL) was about 17:27:56. The main fatty acids were palmitic, linoleic, and linolenic acids, but composition was remarkably different among different sections (Kozukue and Kozukue, 1981).

Fiber

M. baccifera contained the highest content of crude fiber (35.5%) as examined by Bhatt et al. (2005). The study revealed higher crude fiber content ranging from 23.1% to 35.5% in different species of shoots. Duke and Atchley (1986) and Kumbhare and Bhargava (2007) found the lowest value of 0.71% in *D. asper* among all the species. The fiber content as determined by Kumbhare and Bhargava (2007) in the raw shoots ranged from 0.71% to 0.98% and there was not much significant reduction in the fiber content after boiling the shoots. Apical and basal portions of *D. giganteus* shoots contained 0.96% and 0.97% crude fiber on fresh weight basis (Ferreira et al., 1992). Nirmala et al. (2007), however, pointed out that dietary fiber in shoots increased approximately three-fold after keeping for 10 days. After bamboo shoots were harvested, the fiber content increased quickly from the cut end towards the tip. The fiber content in the juvenile shoots ranged from 2.64% to 3.97% whereas for 10-days-old shoots the increase ranged from 8.2% to 13.84%. Study done by Nirmala et al. (2008) on different fractions of fiber, i.e., neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, hemicellulose, and cellulose, in *D. giaganteus*, their content increased upon fermentation (4.18%, 3.28%, 1.40%, 0.9%, and 1.88%, respectively) as compared to the fresh shoots (2.64%, 2.15%, 0.56%, 0.50%, and 1.60%, respectively). In a study, it was evident that upon storage the enhancement of the enzyme phenylalanine ammonia lyase (PAL) activity was closely correlated with the increase of crude fiber and lignin (Chen et al., 1989).

Micronutrients

Studies by various researchers suggest that bamboo shoot not only contains macronutrients but are also enriched with some of the vitamins and minerals that are required in trace amounts by the human body.

Vitamins

Vitamins are organic compounds required as nutrients in tiny amounts by an organism because they cannot be synthesized in sufficient quantities by an organism, and must be obtained from the diet (Lieberman and Bruning, 1990).

Yamaguchi (1983) examined the vitamins A (20 I.U.), B_1 (0.15 mg/100 g), B_2 (0.07 mg/100 g), B_3 (0.60 mg/100 g), and vitamin C (4.0 mg/100 g) content in shoots. Rajyalakshmi and Geervani (1994) revealed thiamine (0.05%), riboflavin (0.01%), and niacin (0.03%) content in the processed and dried shoots. Earlier work by Duke and Atchley (1986) reported nicotinic acid content ranging from 0.20 mg to 0.80 mg/100 g and later on the content as determined by Kumbhare (2003) that ranged from 3.87 mg to 14.92 mg/100 g in the four species of shoots, highest being in *B. nutans*. The amount of pyridoxine (B_6) in raw bamboo shoots ranged from 0.53 mg to 1.70 mg/100 g Kumbhare (2003). Vitamin C content reported by Bhargava et al. (1996) in a few species was 23%. Bhatt et al. (2005) also reported vitamin C content for a number of bamboo species ranging from 3.0% to 12.9%, highest being in *D. hamiltonii* and lowest being in *D. sikkimensis*. Decrease in the vitamin C content upon storage (2.15%), fermentation (1.09%), and canning (1.8%) was evident as compared to the juvenile shoots (3.28%) in *D. giganteus.* The trend was found to be similar in case of vitamin E that ranged from 0.61% to 0.91% in different bamboo species and kept on reducing with older (0.24%) and fermented (0.21%) shoots for *D. giganteus* (Nirmala et al., 2008). In a recent study, compounds of nutritional importance like α-tocopherol (0.26 mg/100 g), γ-tocopherol (0.42 mg/100 g), β-carotene (1.9 μg/100 g), and lutein (35.6 μg/100 g) have been reported in raw bamboo shoot (Kim et al., 2007).

Minerals

A number of the inorganic elements are regarded as absolutely essential to all of life's processes. They are supplied by the diet as their salts; e.g., sodium chloride. They are classified as essential macro and trace (micro) elements. A deficiency of these elements in an otherwise nutritionally adequate diet can lead to very diverse and indefinite metabolic abnormalities (Mc Dowell, 2003; Minerals, 2009).

From Table 4 on micronutrients, it is evident that the calcium content ranged from 0.36 mg to 1900 mg/100 g shoots. Huge variation is observed in calcium content estimated by different investigators and among different species. Calcium content given in early reports varied from 0.01% to 0.03% (Duke and Atchley, 1986; Ferriera et al., 1992). Later on, calcium estimated by Kumbhare and Bhargava (2007) was found to be 30–400 mg/100 g, which matched the earlier values. The content determined by Bhargava et al. (1996) who took a mixture of leaves and shoots also revealed values in the range 320–560 mg/100 g for different species. Bhatt et al. (2005) depicted very high values of calcium ranging from 1200 mg to 1900 mg/100 g. Report by Nirmala et al. (2007) examined that reduction in calcium content took place in *D. giganteus* from 6.80 mg to 1.48 mg/100 g upon keeping the shoots for 10 days. A recent study by NMBA (2009) also reported values ranging from 21.17 mg to 180.69 mg/100 g, highest being in *B. polymorpha* and lowest in *B. pallida*. Magnesium content ranged from 5.38 mg to 140 mg/100 g as examined by different investigators (Bhargava et al., 1996; Bhatt et al., 2005; Nirmala et al., 2007). The content did not decrease significantly upon keeping, fermenting, and canning (Nirmala et al., 2007). The work done during the early 80s reported phosphorous values ranging from 40 mg to 65 mg/100 g (Gopalan et al., 1978; Yamaguchi, 1983; Duke and Atchley, 1986). Work reported by Bhargava et al. (1996) and Bhatt et al. (2005) showed values ranging from 150 mg to 1000 mg/100 g. Processed and dried shoots have shown to possess a very high phosphorous content, i.e., 1049 mg/100 g (Rajyalakshmi and Geervani, 1994). Significant reduction in the phosphorous content upon storage was not observed except in *D. asper* where the content decreased from 40.95 mg to 29.08 mg/100 g (Nirmala et al., 2007). The potassium content in bamboo shoot varied from as low as 20 mg to as high as 1400 mg/100 g according to reports by different investigators (Bhargava et al., 1996; Kumbhare, 2003; Bhatt et al., 2005; Nirmala et al., 2007). The content did not decrease significantly in five different species upon keeping except in *D. hamiltonii* where the content reduced to half in 10-days-old shoots (Nirmala et al., 2007). Potassium content examined in fresh or frozen bamboo shoots (533 mg/100 g) decreased to 450 mg/100 g on boiling for 5–10 minutes. The content further decreased to 300 mg/100 g when the shoots were soaked for two hours and boiled at 50°C for 5–10 minutes (Tsaltas, 1969). Sodium content ranged from 8.22 mg to 400 mg/100 g in different species as examined by different investigators. The content was found to decrease drastically, i.e., three to four folds in 10-days-old shoots as compared to the raw shoots in all the five species tested (Nirmala et al., 2007). The sodium content remained almost same in 10-days-old (3.64 mg), fermented (3.62 mg), and canned shoots (3.24 mg) for *D. giganteus* species.

Recently, Nirmala et al. (2007) determined many essential microelements like cobalt, copper, cadmium, lead, manganese, nickel, selenium, iron, and zinc in different bamboo species.

The iron content ranged from 0.1 mg to 3.37 mg/100 g in different species (Gopalan et al., 1978; Yamaguchi, 1983; Nirmala et al., 2007; NMBA, 2009). A higher value (22 mg/100 g) was reported by Rajyalakshmi and Geervani (1994) in processed and dried shoots. The iron content reduced in 10-days-old shoots in all the species. Selenium on the other hand was found in trace amounts (0.0003 mg/100 g) in the juvenile shoots. The content of zinc ranged from 0.57 mg to 1.01 mg/100 g shoots in five species of shoots tested by Nirmala et al. (2007).

Nutraceutical Component

Antioxidant

Antioxidant properties are very significant in terms of food and nutraceuticals, but have been given less attention in case of bamboo shoot. For example, first study on this aspect was carried out by Ishii and Hiroi (1990), where a diferuloyl arabinoxylan hexasaccharide containing 5-5 linked diferulic acid had been obtained by the enzymatic hydrolysis of bamboo shoot cell walls. Ferulic acid is a naturally occurring antioxidant present in the plant-based products. In vivo, peroxidase catalyzes the oxidation of ferulic acid, resulting in the formation of ferulic acid dehydrodimers. It is considered to participate in the regulation of cellular expansion by preventing oxidation of free radicals.

A recent study revealed that fresh shoots of *D. strictus*, *B. tulda*, *B. vulgaris*, and *B. balcoa* possess antioxidant activity of 13.97%, 15.94%, 28.21%, and 39.85%, respectively, when assayed for free radical scavenging by DPPH method (Satya et al., 2009). A few studies also report the antioxidant or free radical scavenging activity exhibited by methanol extracts of bamboo shoots. Earlier reports suggest that methanol extracts of culm of moso bamboo (*Phyllostachys pubescens*) showed a higher free radical scavenging activity (41.41%) as compared to madake bamboo (*P. bambusoides*, 29.44%) when determined by DPPH scavenging assay (Jun et al., 2004). Bamboo shoot exhibited a value of 17.8 mmol trolox equivalent (TE) per kg fresh weight and hence seemed to show moderate antioxidant capacity as compared to the other light colored vegetables (32.3–0.7 mmol TE/kg) when determined by hydrophilic assays such as the oxygen radical absorbance capacity (ORAC; Cho et al., 2007). *Kaeng kae* and *Kaeng naw mai bai* (North Eastern Thai foods) containing 6.9% and 21.6% bamboo shoot as the main ingredient were found to possess some antioxidant activities. *Kaeng kae* exhibited moderate antioxidant capacity at a level of 54.77 ± 0.29 mg.vit.C equiv./100 g food whereas *Kaeng naw mai bai* possessed a lower value at 30.25 ± 1.23 mg.vit.C equiv./100 g food (Tangkanakul et al., 2006).

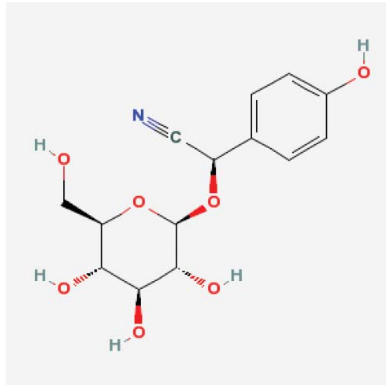
In one of the studies, it was found that bamboo shoot contributed 46% of the daily antioxidant activity (AOA) intake among different vegetables consumed in China (Yang et al., 2005). One important point depicting general characteristics of bamboo shoot has been noted. The bamboo shoots were difficult to disintegrate during cooking because of the presence of glucose and xylose rich low methoxyl pectin, which affected the solubilization of pectic polysaccharides and thermal disintegration of bamboo shoots. Hence, bamboo shoots could retain considerable firmness during cooking (Fuchigami, 1990).

TOXICITY OF BAMBOO SHOOT AND ITS EFFECT ON HUMAN HEALTH

As discussed earlier, bamboo shoots undoubtedly are rich source of various macro and micronutrients but the fact that they contain cyanogenic glycoside, which can prove to be hazardous to health if consumed in excess, cannot be ignored. Raw bamboo shoots have been identified as reservoirs of cyanide. Raw bamboo shoots are one of the recorded cyanogenic plant species in the world.

The Toxic Compound

Taxiphyllin (4-hydroxy-(R)-mandelonitrile-β-D-glucopyranoside), a cyanogenic glycoside (Conn, 1969), has been found to be the potential toxic component present in the different species of bamboo shoots like *Dendrocalamus latiflorus*, *D. giganteus*, *D. hamiltonii*, *Bambusa vulagris*, and *B. guadua* (Schwarzmaier, 1976, 1977; Tjon Sie Fat, 1978; Vetter, 2000). The cyanide (HCN) content varies in different parts of a plant and also between the same parts of different portions of the same species (Jones, 1998). For example, the



IUPAC Name	4-hydroxy-(R)-mandelonitrile-b-D-glucopyranoside
Molecular Weight	311.28728 [g/mol]
Molecular Formula	$C_{14}H_{17}NO_7$

Source: Pubchem, 2009

Figure 1 Structure of taxiphyllin. (Figure available in color online).

top, middle, and base portion of bamboo shoots differ in their cyanogenic content (Figure 1, Pubchem 2009).

Level of Toxicity

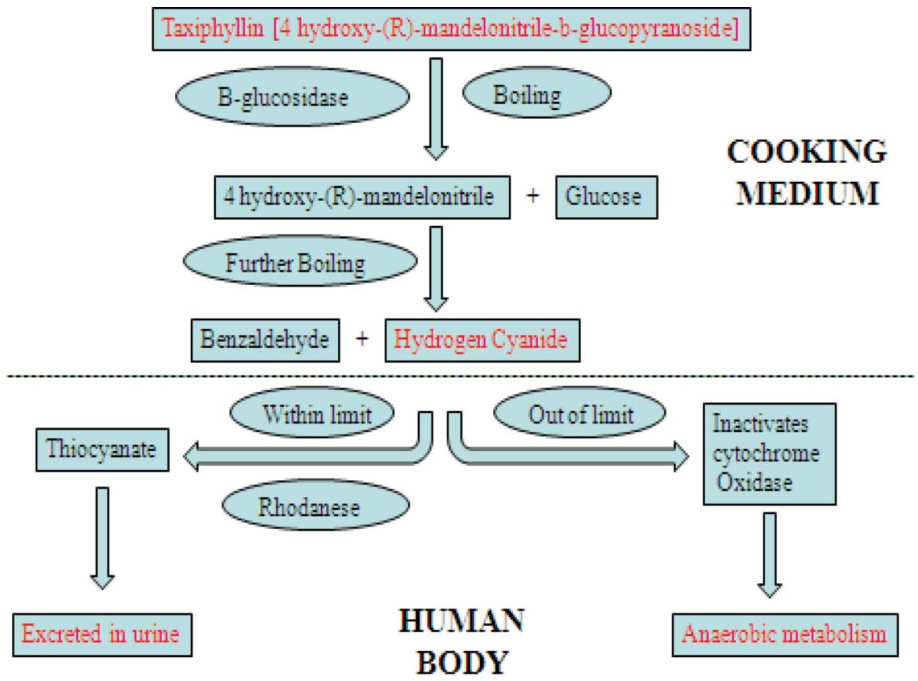
There is wide variation in the cyanide content between different varieties and species of bamboo shoots. In the early years, some Asian species like *D. giganteus* Munro and *D. hamiltonii* Nees et Arnott have been reported to contain 90–100 mg HCN/100 g fresh weight (Schwarzmaier, 1977). Later on, Ferreira et al. (1990) reported that bamboo shoots contain as much as 1000 mg/kg of hydrogen cyanide in the apical part. On the contrary, World Health Organization (1993) report stated that the concentration of cyanide in the immature shoot tip of bamboo was 8000 mg/kg of hydrogen cyanide. A sample of *Dendrocalamus giganteus* contained, on average, 894 mg/kg of hydrogen cyanide (Ferreira et al., 1995). In a study conducted by IIT Delhi, the shoots of *D. Strictus* and *B. vulgaris* (harvested from planted forest) were found to contain 386 ppm and 200 ppm of cyanogenic glycosides, respectively (Satya et al., 2009). Bamboo shoots were found to contain 1600 ppm total HCN in the tip and 110 ppm in the base by the acid hydrolysis and picrate method (Haque and Bradbury, 2002). In another study, the cyanide content was found less as compared to the previous study but was found different among the base, middle, and tip portions. The highest concentration was found at the tip portion of the bamboo shoot (120 mg/kg), followed by the middle (12 mg/kg) and the base portions (1.1 mg/kg) (RAS, 2007). Fresh bamboo shoots contain high cyanogenic glycoside (551 mg/kg), followed by thiocyanate (24 mg/kg) and glucosinolate (9.57 mg/kg; Chandra et al., 2004a).

Recommended Level and Fate of HCN

The acute lethal dose of HCN for humans is 0.5–3.5 mg/kg body weight and for animals is 0.66–15 mg/kg body weight (Jones, 1998). But FAO/WHO Codex Alimantarius has defined a safe limit for human consumption, which is 10 mg HCN equivalent per kg dry weight (FAO/WHO, 1991). However, when the dose is relatively small, humans are able to detoxify HCN by the enzyme rhodanese forming thiocyanate, which is excreted in the urine. Chronic cyanide poisoning sets in due to lack of nutrients like riboflavin, protein, vitamin B_{12}, sodium, and methionine. The detoxification requires sulfur amino acids like cysteine and methionine in the diet (FSANZ, 2004). Endogenic hydrolysis may release 0.05–0.3% hydrocyanic acid (Bhargava et al., 1996). Another report stated that enzymatic hydrolysis yielded 0.03% of hydrocyanic acid and about 0.23% benzoic acid (Raizada and Chatterji, 1956). The fate of taxiphyllin in the cooking medium and human body is depicted in Figure 2, Singhal et al., 2009.

Side Effects of Cyanide Poisoning

Chronic sub-lethal dietary cyanide has reportedly caused some reproductive effects including lower birth rate, increased number of neonatal deaths, thyroid dysfunction, and behavioral defects (FSANZ, 2004). Chronic consumption can lead to hypothyroidism by inhibiting thyroid peroxidase (TPO) activity (Chandra et al., 2004a). Inhibition of TPO activity was highest in bamboo shoots. Boiled extracts showed maximum inhibition followed by cooked and raw extracts (Chandra et al., 2004b). Acute cyanide intoxication include drop in blood pressure, rapid



Source: Singhal et al, 2009

Figure 2 Fate of taxiphyllin in cooking medium and human body. (Figure available in color online).

pulse, dizziness, headache, stomach pain, diarrhea, twitching, and convulsions. Death may result when the individual is unable to detoxify cyanide above the safe limits (FSANZ, 2004). However, the golden bamboo lemur (*Hapalemur aureus*) eats about 500 g of bamboo (*Cephalostachyum* ef *uiguieri*) per day, which is 12 times the lethal dose of cyanide without showing any adverse effects at all (Glander et al., 1989).

Processing Methods

The toxic compound can easily be removed by various processing methods (boiling, canning, soaking, drying, and fermentation) before consumption.

Slicing

For bamboo shoots, slicing liberates hydrogen cyanide that is removed by boiling (FSANZ, 2003)

Soaking

Soaking bamboo slices overnight involves enzymatic hydrolysis of taxiphyllin by ß-glucosidase to yield glucose and 4-hydroxy(R)mandelonitrile, which is further hydrolyzed to HCN and benzaldehyde by the activity of hydroxynitrile lyase enzyme (Bhardwaj et al., 2007). Changing water several times before cooking or presoaking for a long time in water containing 2% salt may also help in further reduction of the cyanogenic glycoside (Bhargava et al., 1996).

Boiling/Canning

Traditionally, boiling bamboo shoot in an open vessel for three to four hours can reduce the toxicity through the non-enzymatic hydrolysis of taxiphyllin. Bamboo shoots were cooked (one part bamboo shoots, four parts water) for 20, 100, and 180 minutes at 98°C/ambient pressure, 110°C/14.5 × 104 kPa, and 122°C/21.12 × 104 kPa. The shoots were then cooled in water, canned, and sterilized. The maximum removal of HCN was about 97% leaving a residue level of about 27 mg/kg HCN (1000 mg/kg in fresh shoots) in the canned sterilized product. The optimum conditions that resulted in this reduction of HCN were 98–102°C for 148–180 minutes (Ferreira et al., 1995). Similarly, 91% reduction of cyanide content was observed following slicing and cooking bamboo shoot in boiling water for 15 minutes. The content decreased from 40 mg/kg to 3.7 mg/kg when boiled for 15 minutes and it further reduced to 1.9 mg/kg when boiled for half an hour. The content was not detected in shoots boiled for 60 minutes. Cyanide levels for canned and packaged bamboo shoots samples ranged from non-detected to 5.3 mg/kg (RAS, 2007).

Fermentation

Prolonged fermentation also reduces the taxiphyllin content by lowering the pH through microbial activity (Bhardwaj et al., 2007). In a similar study upon natural fermentation of shoots of *D. giganteus* and *B. Tulda* as the pH drops, the lactic acid bacteria indirectly degrades taxiphyllin into HCN and other components by accumulating acid (Singh and Singh, 1994).

Addition of Food Additives

Newer method adopted by younger generation, i.e., pressure cooking or addition of mono-sodium glutamate (MSG), results in incomplete hydrolysis of the toxin and may therefore prove to be hazardous (Bhardwaj et al., 2007).

Drying

Cyanide was not detected in any of the dried bamboo shoot samples tested (RAS, 2007).

If not processed by proper means, food borne botulism has been found to be associated with the consumption of home canned bamboo shoots (Swaddiwudhipong and Wongwatcharapaiboon, 2000). It indicates the need for further investigation on this crucial aspect in terms of process optimization to reduce cyanogenic toxicity along with preserving nutrients.

MEDICINAL PROPERTIES OF BAMBOO SHOOT

Bamboo shoot is not only eaten for its flavor and taste by the tribal communities but is also appreciated as an important plant by the nature for its medicinal role. Use of shoots by the tribal people in various forms to eradicate a disease is well known in Ayurveda since ancient times.

Traditional Knowledge Base

Various traditional practices and approaches using bamboo shoot as a base plant for medication still prevail in different communities.

In certain sections, a little dried and powdered meat of por (a kind of mole that lives under the culm of bamboos) mixed with crushed berries and fermented bamboo shoots of *Bambuonesa* sp. are boiled or cooked and taken by patients suffering from dysentery and diarrhea. Fermented bamboo shoot if mixed with crushed leaves of *Allium porrum* Linn and chilli is also used to cure influenza. The paste made can also be applied to treat fungal infection (Changkija, 1999). Decoction of tender shoots of *B. nutans* is applied on wounds and poisonous bites. The shoots are also boiled in water and the soup is taken in cases of stomach ulcer. Tender shoots of *B. tulda* are boiled in water and the soup is taken in cases of poxes and other skin diseases and the paste is applied on poisonous bites and injuries (Singh et al., 2003a; ICFRE, 2009). Not only the decoctions but also the blackish soot deposited on the culms of *Bambusa arundinacea* Willd is scrubbed off, mixed with lime (or even with finely powdered coke), and applied to cuts and wounds (Jain, 1965). Valkosen (2001) established that garlic fruits and bamboo shoots are effective in the treatment of pigs against *Ascaris suum.*

Many female Burmese migrant workers have been reported to use bamboo shoots or sticks with traditional Chinese medicine to penetrate their genital areas to abort the fetuses (Ruenkaew, 2009). A heavy dose of pepper with bamboo shoots is said to produce abortion (Chaveerach et al., 2006). Decoctions of tender shoots mixed with palms jaggery is used to cause abortions or to induce labor and expulsion of placenta after childbirth and to prevent excessive loss of blood (ICFRE, 2009).

The juice of the pressed bamboo shoots possesses protease activity that helps digestion of proteins. The boiled bamboo shoot or pickle is served as an appetizer (ICFRE, 2009).

Tabasheer or *banslochan* has been used in Ayurvedic medicine system since ancient times as a cooling tonic and aphrodisiac, and in asthma, cough, and other debilitating diseases. It is a siliceous secretion found in the culms of various species of bamboos. It occurs in fragments or masses, about an inch thick. It is the residue of the watery liquid occasionally found in hollow internodes. Its presence is generally detected by rattling noise on shaking the bamboo. *Tabasheer* may be chalky, translucent, or transparent with a specific gravity ranging from 2.16–2.19. It has a color of pumice and sometimes appears bluish white with no taste. It is mainly composed of silicic acid (upto 96.9%) with above 1% of organic matter. The residue obtained on ignition contains 99% silica with traces of iron, calcium, alum, and alkalies (Raizada and Chatterji, 1956). The juice (siliceous matter) of *D. strictus* has been reported to be used as an anti-inflammtory agent near joints. It is also used as astringent and eardrops, and in cooling and healing of cuts (Bhat et al., 2009).

Long ago, Raizada and Chatterji (1956) reported the antiseptic and larvicidal activity of bamboo shoots. The sap of bamboo shoots has been found to contain hydrocyanic acid lending to antiseptic and larvicidal properties. It needs further investigation to develop products of commercial value.

Pharmaceutical Investigation

Cholesterol, Diabetes, and Cancer Control

The top part of fresh bamboo shoots significantly reduced serum total lipids, very low density lipoprotein-cholesterol (VLDL-C), low density lipoprotein-cholesterol (LDL-C), and VLDL-triacylglycerol (VLDL-TG), and enhanced high density lipoprotein-cholesterol (HDL-C) values in rats as compared to the bottom part that was rich in lignin (Tsai, 1997). In a recent study, eight subjects with normal health status received a dietary fiber-free diet (control), a diet containing 25 g of cellulose, and a diet containing 360 g of bamboo shoots. It was found that the serum total cholesterol and low-density lipoprotein cholesterol decreased by 9.6% and 15.3%, respectively, with the bamboo shoot diet feeding compared with the dietary fiber-free diet. Fecal volume and bowel movement frequency significantly increased, indicating its role in lowering of cholesterol and prevention of diabetes (Park and Jhon, 2009).

Bamboo shoots at levels as low as 0.25% in the diet significantly decreased serum cholesterol by 23%. Daily fecal steroid excretion was not consistently increased by bamboo shoots. Feed efficiency and weight gain were reduced by feeding bamboo shoots at levels from 15% to 2.5% in the diet, but these effects disappeared at 1% or less. These experiments suggest that bamboo shoots can reduce serum cholesterol in rats by a mechanism that does not involve changes in steroid excretion (Hosig, 1992). A phytosterol-containing extract isolated from bamboo shoot is being used to reduce cholesterol levels in mammals and hence its use as a dietary supplement is acknowledged (Lachance and He, 1998). Interestingly, bamboo stem of the *Bambusa* sp. was also found to be used as a complementary and alternative medicine by the patients suffering from diabetes mellitus (Mehrotra et al., 2004).

Powdered bamboo of lower unbranched culm portions of three-year-old and older bamboo is used as an active ingredient in compositions for reducing the incidence of cancer of the colon and rectum (Kumon, 2002).

Reservoir of Acetylcholine

Acetylcholine in plants has been implicated in the regulation of differentiation, phyotochrome-mediated processes, and ion and water transport. The upper portion of the bamboo shoot *Phyllostachys bambusoides* has been reported to contain the highest acetylcholine (a well-known neurotransmitter in the cholinergic nervous systems of vertebrates and insects) content (2941 nmol/g). Given that the upper portion of bamboo shoots grows very rapidly, these findings are consistent with the notion that, in the plant kingdom, acetylcholine is involved in the regulation of differentiation, water homeostasis, and photosynthesis (Horiuchi et al., 2003).

Bamboo Vinegar

Bamboo vinegar (*Phyllostachys pubecsens*) is prepared by introducing dried bamboo into a kiln with a flame tunnel, heating the bamboo slowly to 600–900°C holding for four days, sealing the tunnel, cooling to room temperature, and withdrawing the charcoal. In this process of carbonization, the vapor is cooled and the resulting solution is recovered. After it is allowed to stand for six months, the solution is decanted to remove tar. The supernatant is distilled under reduced pressure and the resultant product is called bamboo vinegar solution. It is believed that bamboo vinegar can act as insecticide, bactericide, a deodorant for treating malodor from pest, and also as a folk medicine (Akakabe et al., 2006). Effects of levels of bamboo vinegar liquids (BVL) at 2.0 and 4.0% level showed increase in daily weight gains in pigs. The glucose and the cholesterol contents in the serum decreased significantly ($p < 0.05$) at 2.0% and 4.0% BVL. It was concluded that 2.0% BVL has a positive effect on the feeding performance, carcass grade, and the meat quality characteristics of pigs (Kook et al., 2005).

Phytosterols

Phytosterols are secondary plant products found in many plants and are the precursors of pharmaceutically important steroidal products including corticosteroids, sex hormones, and oral contraceptives (Jain et al., 1980; Martin, 1997). Phytosterol content in fresh samples of *B. vulgaris*, *B. balcoa*, and *B. pallida* ranged from 0.12% to 0.19% (dry weight). The total phytosterol level increased with the fermentation period from seven to 35 days (Srivastava and Sarangthem, 1994). The content further increased two-fold from 0.19% to 0.42% (dry weight) during Soibum fermentation of another species *D. hamiltonii* for 50 days (Sarangthem et al., 2003). The increase in the fermented sample is due to anaerobic digestion by microorganisms that cause degradation of the organic matter and result in enrichment of phytosterol (Srivastava, 1990). β-sito-sterol, stigmasterol, campesterol, and an unidentified phytosterol are the four phytosterols that have been isolated from fermented shoots (Sarangthem and Srivastava, 1997).

Purple Bamboo Salt

Bamboo salt had been developed traditionally by the monks in Buddhist temples. It is prepared by placing sun dried salt in a bamboo case, plugged with mud on both sides, and then heated one to nine times at more than 1000°C. The bamboo salt has higher contents of minerals and it turns out to be a healthy salt during heating because of the chemical and physical changes. It is used as a folk medicine for treating cancer patients in the Republic of Korea. It is known to have various therapeutic effects on diseases such as inflammations, viral diseases, diabetes, circulation organ disorders, cancer, etc. (Hwang et al., 2008). Bamboo salt contains about 85% to 98% of sodium chloride, about 1.5% to 10.0% of potassium, about 0.2% to 1.0% of phosphate, and about 0.005% to 0.3% of sulfate as the main component and at least five inorganic ionic components selected from magnesium, chrome, iron, silicon, aluminum, zinc, fluorine, cupper, barium, manganese, and nickel, along with magnesium oxide and/or magnesium silicate in the water-insoluble part (Ha et al., 1995).

In a recent study, methanol extracts of *doenjan* (Korean Fermented Soybean Paste) made with one-time heat-treated bamboo salt exerted more suppressive effects on chromosome aberration indicating its antimutagenic and anticlastogenic effect (Hwang et al., 2008). Purple bamboo salt (0.01–1 μg per site) significantly inhibited the ear swelling response induced by intradermal injection of compound 48/80 in mice. It also inhibited the histamine release from the rat peritoneal mast cells (RPMCs) by compound 48/80 at the dose level of 0.01–1 mg/ml. It also inhibited (0.01–1 g/kg) the passive cutaneous anaphylaxis (PCA) by oral administration. Results of the study suggest its beneficial role in the regulation of immediate-type of allergic reactions (Shin et al., 2004).

In a study, mouthrinse with bamboo salt toothpaste (LG Household and HealthCare) containing 0.3% xanthorrhizol showed the inhibitory effect at 1% of concentration as compared to Colgate Total Plax showing inhibition to oral microorganisms at 30% and Listerine at 50% (Park et al., 2002).

Antifungal and Antibacterial Property

Dendrocin, an antifungal protein, with a molecular weight of 20 kDa and an inhibitory action on mycelial growth in the fungi *Fusarium oxysporum*, *Botrytis cincerea*, and *Mycosphaerella arachidicola* was isolated from fresh bamboo shoots (Wang and Ng, 2003).

2,6-Dimethoxy-*p*-benzoquinonwe has been found to be the active antibacterial substance contained in the bark of *Phyllostachys heterocycla* var. Pubescens (Nishina et al., 1991).

CONCLUSIONS AND FUTURE PROSPECTS

Bamboo shoots no doubt form an important food source from the plant origin. Consumption in various forms (fermented, roasted, dried, canned) is evident in the East Asian countries but it has a great potential to be incorporated in several other dishes all over the world. Various edible species exist in different parts of the world, which are eaten in multiple forms and locally called by different names. Most of the studies that have been reviewed depict that bamboo shoots are very good reservoirs of nutrients. They were found rich in protein and fiber content and low in fat content. They were found to contain vitamins and minerals like selenium, an antioxidant, and potassium, a healthy heart mineral, in amounts that would sustain a healthy human body. Medicinal and pharmaceutical properties further make them unique. It became very evident from the review that presence of cyanogenic glycosides in bamboo shoots cannot be neglected and safe consumption should follow after proper processing of shoots without disturbing the nutrient reserve. Further R&D work by integrating traditional knowledge with current scientific studies would help in developing safe nutraceuticals and pharmaceutical formulations for human health. Simplification of technological system may open new avenues for rural industrialization.

ACKNOWLEDGMENTS

Financial support from Ministry of Rural Development, India, is greatly acknowledged.

REFERENCES

Agrahar-Murugkar, D. and Subbulakshmi, G. (2006). Preparation techniques and nutritive value of fermented foods from the Khasi tribes of Meghalaya. *Ecol. Food Nutr.* **45**(1):27–38.

Akakabe, Y., Tamura, Y., Iwamoto, S., Takabayashi, M., and Nyuugaku, T. (2006). Volatile organic compound with characteristic odour in bamboo vinegar. *Biosci. Biotechnol. Biochem.* **70**(11):2797–2799.

Arinana, Hinsui, J., Ignatius, B., Kronseder, K., Kärkkäinen, J., Pingoud, P., and Sandra, E. (2008). Non timber forest products in Northern Thailand. Available at: http://www.mm.helsinki.fi/MMEKO/VITRI/forrsa/RE_2_Course%20and%20workshop%20proceedings/report/Group5_Report.pdf (accessed July 4, 2009).

Bahadur, K. N., and Jain, S. S. (1981). Rare bamboos of India. *Indian J. Forestr.* **4**(4):280–286.

Bhardwaj, R., Singh, R. K., Wangchu, L., and Sureja, A. K. (2007). Bamboo shoot consumption: Traditional wisdom and cultural invasion. **In**: Biodiversity Utilization and Conservation, pp. 72–75. Arunachalam, A. and Arunachalam, K., Eds., Aavishkar, Jaipur (India).

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

Bhat, H. R., Jain, S. K., Parrota, J. A., and Singh, H. P. (2009). Impact of cultivation and gathering of medicinal plants on Biodiversity: Case studies from India (FAO Corporate Document Repository). Available at: http://www.fao.org/docrep/005/AA021E/AA021e16.htm (accessed July 4, 2009).

Bhatt, B. P., Singh, K., and Singh, A. (2005). Nutritional values of some commercial edible bamboo species of the north Eastern Himalayan Region, India. *J. Bamboo Rattan* **4**(2):111–124.

Bhatt, B. P., Singha, L. B., Sachan, M. S., and Singh, K. (2004). Commercial edible bamboo species of the North-Eastern Himalayan Region, India. Part I: Young shoot sales. *J. Bamboo Rattan* **3**(4):337–364.

Bhatt, B. P., Singha, L. B., Singh, K., and Sachan, M. S. (2003). Commercial edible bamboo species and their market potentiality in three Indian tribal states of North Eastern Himalayan Region. *J. Bamboo Rattan* **2**(2):111–133.

Chandra, A. K., Ghosh, D., Mukhopadhyay, S., and Tripathy, S. (2004a). Effect of bamboo shoot, *Bambusa arundinacea* (Retz.) Willd. on thyroid status under conditions of varying iodide intake in rats. *Indian J. Exp. Biol.* **42**(8):781–786.

Chandra, A. K., Mukhopadhyay, S., Lahari, D., and Tripathy, S. (2004b). Goitrogenic content of Indian cyanogenic plant foods and their in vitro anti-thyroidal activity. *Indian J. Med. Res.* **119**(5):180–185.

Changkija, S. (1999). Folk medicinal plants of the Nagas in India. *Asian Folklore Stud.* **58**:205–230.

Chaveerach, A., Mokkamul, P., Sudmoon, R., and Tanee, T. (2006) Ethnobotany of the genus *Piper* (Piperaceae) in Thailand. *Ethnobotany Res. Appl.* **4**:223–231.

Chen, R. Y., Liu, M. S., Chang, T. C., and Tsai, M. J. (1989). Post harvest handling and storage of bamboo shoots (*Bambusa oldhami* Munro). *Acta Hortic.* **258**:309–316.

Chinesefood-recipes.com. (2009). Chinese Food Recipes. Available at: http://www.chinesefood-recipes.com/food_articles/bamboo_shoots_medicinal_properties.php (accessed July 4, 2009).

Cho, Y. S., Yeum, K. J., Chen, C. Y., Beretta, G., Tang, G., Krinsky, N. I., Yoon, S., Lee-Kim, Y. C., Blumberg, J. B., and Russell, M. R. (2007). Phytonutrients affecting hydrophilic and lipophilic antioxidant activities in fruits, vegetables and legumes. *J. Sci. Food Agric.* **87**:1096–1107.

Choudhury, D., Sahu, J. K., and Sharma, G. D. (2010). Biochemistry of bitterness in bamboo shoots. *Assam University Journal of Science & Technology: Physical Sciences and Technology* **6**(2):105–111.

Christine, R. and Wetterwald, M. F. (1992). Bamboos. Timber Press, Portland, OR.

Conn, E. E. (1969). Cyanogenic glycosides. *Agric. Food Chem.* **17**:519–526.

CTAHR Fact Sheet. (1997). Bamboo for forest and garden. Ornamentals and Flowers Series No. 18:1–6. Available at: https://scholarspace.manoa.hawaii.edu/handle/10125/2877 (accessed July 4, 2009).

Devi, S. P., and Singh, H. T. (1986). Studies on the chemical and nutritional changes of bamboo shoots during fermentation. *J. Food Sci. Technol.* **23**:338–339.

Diver, S. (2001). Bamboo: A Multipurpose Agroforestry Crop, pp. 1–13. Appropriate Technology Transfer for Rural Areas, Butte, MT. www.attra.ncat.org.

Duke, J. A. and Atchley, A. A. (1986). CRC Handbook of Proximate Analysis Tables of Higher Plants. CRC Press, Boca Raton, FL.

Embaye, K. (2000). The indigenous bamboo forests of Ethiopia: An overview. *AMBIO* **29**(8):518–521.

FAO. (1990). Roots, Tubers, Plantains and Bananas in Human Nutrition. Food and Agricultural Organizations of the United Nations, Rome.

FAO/WHO. (1991). Joint FAO/WHO Food Standards Programme. Codex Alimentarius Commision XII, Supplement 4, FAO, Rome.

Feng'e, Y. (2002). Bamboo cookies? *INBAR News Mag.* **9**(1):11.

Ferreira, V. L. P., Moraes MAC-de Mantovani, D. M. B., and Paschoalino, J. E. (1992). Chemical composition, processing and evaluation of bamboo shoots. *Coletanea Inst. Technol. Aliment.* **22**:177–193.

Ferreira, V. L. P., Moraes, M. A. C., Sales, A. M., and Carvalho, C. R. L. (1990). Broto-de-bambu-Uma opcao alimentar II Processamento e aceitablilidade. *Coletanea Inst. Tecnol. Aliment.* **20**:129–143.

Ferreira, V. L. P., Yotusuyanagi, K., and Carvalho, C. R. L. (1995). Elimination of cynogenic compounds from bamboo shoots *Dendrocalamus giganteus* Munro. *Trop. Sci.* **35**:342–346.

FSANZ (Food Standards Australia New Zealand. (2003). Advice on the preparation of cassava and bamboo shoots. Draft Assessment Report, Proposal P257. Available at: http://www.foodstandards.govt.nz/_srcfiles/P257_DAR.pdf (accessed May 25, 2009).

FSANZ. (2004). Cyanogenic glycosides in cassava and bamboo shoots: A human health risk assessment. Technical report series No. 28. Available at: http://www.foodstandards.gov.au/_srcfiles/28_Cyanogenic_glycosides.pdf (accessed July 4, 2009).

Fu, J. (2001). Chinese Moso bamboo: It's importance. *Bamboo Mag. Am. Bamboo Soc.* **22**(5):5–7.

Fu, J. (2009). International network for bamboo and rattan. FAO Corporate Document Repository. Non-Wood News No. 10. Originated by Forestry Department. Available at: http://www.fao.org/docrep/005/y4640e/y4640e07.htm (accessed June 25, 2009).

Fuchigami, M. (1990). Differences between bamboo shoots and vegetables in thermal disintegration of tissues and polysaccharides fractionated by successive extraction. *J. Food Sci.* **55**(3):739–745.

Fung, M. L. (1997). Vegetarian and non-vegetarian. **In**: Chinese Cooking, P.A.D.V., Ed., P.A.D.V. Publication, New Delhi.

Giri, S. S. and Janmejay, L. S. (1994). Changes in soluble sugars and other constituents in bamboo shoots in *Soibum* fermentation. *J. Food Sci. Technol.* **31**(6):500–502.

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

Glander, K. E., Wright, P. C., Seigler, D. S., Randrianasolo, V., and Randrianasolo, B. (1989). Consumption of cyanogenic bamboo by a newly discovered species of bamboo lemur. *Am. J. Primatol.* **19**(2):119–124.

Gopalan, C. B., Ramasastri, V., and Balasubramanion, S. C. (1978). Nutritive Value of Indian Foods, p. 204. National Institute of Nutrition, ICMR, Hyderabad (India).

Greijmans, M., Boualay Oudomvilay, B., and Banzon, J. (2007). Houaphanh Bamboo Value Chain Analysis. Netherlands Development Organization. Available at: http://www.snvworld.org/en/Documents/Knowledge%20Publications/Laos-AGRI-Bamboo-valuechain-SNVassessment-2007.pdf (accessed June 25, 2009).

Ha, J. M., Jeong, K. L., Suh, S. S., Choi, K. Y., Kim, M. M. and Chang, S. Y. (1995). Process for preparation of bamboo-salt, bamboo-salt. European Patent EP0663207.

Haque, M. R. and Bradbury, J. H. (2002). Total cyanide determination of plants and foods using the picrate and acid hydrolysis methods. *Food Chem.* **77**:107–114.

Hasegawa, C., Sakamoto, Y., and Ichihara, K. (1959). On the relationship between homogentisic acid and the egumi taste of bamboo shoots and hange. *Seikagaku* **35**(5):246–251.

Horiuchi, Y., Kimura, R., Kato, N., Fujii, T., Seki, M., Endo, T., Kato, T., and Kawashima, K. (2003). Evolutional study on acetylcholine expression. *Life Sci.* **72**(15):1745–1756.

Hosig, K. W. (1992). Effects of dietary fiber on serum cholesterol, gastrointestinal function and fecal steroid excretion. Dissertation. Perdue University. Available at: http://docs.lib.purdue.edu/dissertations/AAI9313998 (accessed June 26, 2009).

Hwang, K. M., Jung, K. O., Song, C. H., and Park, K. Y. (2008). Increased antimutagenic and anticlastogenic effects of *Doenjang* (Korean fermented soybean paste) prepared with bamboo salt. *J. Med. Food* **11**(4):717–722.

ICFRE. (2009). Bamboo as Food and Medicine. Indian Council of Forestry Research and Education (ICFRE), Dehradun (India). Available at: http://www.icfre.org/UserFiles/File/rfri/Bamboo_%20food_%20medicine_221206.pdf (accessed May 24, 2009).

Ishii, T. and Hiroi, T. (1990). Linkage of phenolic acids to cell wall polysaccharides of bamboo shoot. *Carbohydr. Res.* **206**:297–310.

Jain, S. C., Kamal, R. and Rathor, A. K. (1980). A note on phytosterols in some species. *Indian Drugs* **17**:145.

Jain, S. K. (1965). Medicinal plant lore of the tribals of Bastar. *Econ. Bot.* **19**(3):236–250.

Jeyaram, K., Singh, Th. A., Romi, W., Devi, A. R., Singh, W. M., Dayanidhi, H., Singh, N. R., and Tamang, J. P. (2009). Traditional fermented foods of Manipur. *Indian J. Trad. Knowl.* **8**(1):115–121.

Jones, D. A. (1998). Why are so many food plants cyanogenic? *Phytochemistry* **47**(2):155–162.

Jun, M., Tohru, U., Jianzhang, L., and Takeshi, F. (2004). Identification and evaluation of antioxidant activities of bamboo extracts. *Forestr Stud. China* **6**(2):1–5.

Kennard, W. C., and Freyre, R. H. (1957). The edibility of shoots of some bamboos growing in Puerto Rico. *Econ. Bot.* **11**:235–243.

Kim, Y. N., Giraud, D. W., and Driskell, J. A. (2007). Tocopherol and carotenoid contents of selected Korean fruits and vegetables. *J. Food Composit. Anal.* **20**:458–465.

Knechtges, D. R. (1986). A literary feast: Food in early Chinese literature. *J. Am. Oriental. Soc.* **106**:49–63.

Kook, K., Jeong, J. H., and Kim, K. H. (2005). The effects of supplemental levels of bamboo vinegar liquids on growth performance, serum profile, carcass grade, and meat quality characteristics in finishing pigs. *J. Animal Sci. Technol.* **47**(5):721–730.

Kozukue, E. and Kozukue, N. (1981). Lipid content and fatty acid composition in bamboo shoots. *J. Food Sci.* **46**(3):751–755.

Kozukue, E., Kozukue, N., and Kurosaki, T. (1983). Organic acid, sugar and amino acid composition of bamboo shoots. *J. Food Sci.* **48**(3):935–938.

Kumbhare, V., and Bhargava, A. (2007). Effect of processing on nutritional value of central Indian bamboo shoots. Part I. *J. Food Sci. Technol.* **44**(1):29–31.

Kumbhare, V. R. (2003). Studies on Some Indian Bamboos for their Nutritional Values. Thesis. Tropical Forest Research Institute (TFRI), Jabalpur, India.

Kumon, S. (2002). Anticancer composition. European Patent EP0919240.

Lachance, P. A., and He, Y. H. (1998). Hypocholesterolemic compositions from bamboo shoots. U.S. Patent No. WO/1998/057545.

Lieberman, S. and Bruning, N. (1990). The Real Vitamin and Mineral Book: Going Beyond the RDA for Optimal Health. Avery Group, New York.

Martin, C. K. A. (1997). Advances in Applied Microbiology, Vol. 22, pp. 29–64. Perlman, D., Ed., Academic Press, New York.

Mauria, S. and Arora, R. K. (1988). Genetic resources of bamboos: An Indian perspective. *Indian Forester* 539–547.

Mc Dowell, L. R. (2003). Minerals in Animal and Human Nutrition. 2nd ed. Elsevier Health Sciences, Amsterdam.

Mehrotra, R., Baja, J. S., and Kumar, D. (2004). Use of complementary and alternative medicine by patients with diabetes mellitus. *Natl. Med. J. India* **17**(5):243–245.

Minerals (2009). . Available at: http://www.textbooksonline.tn.nic.in/Books/11/BioChem-EM/Chapter%209.pdf (accessed July 5, 2009).

Nirmala, C., David, E., and Sharma, M. L. (2007). Changes in nutrient components during ageing of emerging juvenile bamboo shoots. *Int. J. Food Sci. Nutr.* **58**(8):612–618.

Nirmala, C., Sharma, M. L., and David, E. (2008). A comparative study of nutrient components of freshly harvested, fermented and canned bamboo shoots of *Dendrocalamus giganteus* Munro. *Bamboo Sci. Cult. J. Am. Bamboo Soc.* **21**(1):33–39.

Nishina, A., Hasegawa, K., Uchibori, T., Seino H., and Osawat, T. (1991). 2, 6-Dimethoxy-*p*-benzoquinone as an antibacterial substance in the bark of *Phyllostachys heterocycla* var. Pubescens, a species of thick-stemmed bamboo. *J. Agric. Food Chem.* **39**:266–269.

NMBA (National Mission on Bamboo Applications). (2009). Recipes standardized by ERG, Bangalore. Available at: http://www.bambootech.org/subsubTOP.asp?subsubid=90&subid=29&sname=USAGE (accessed July 4, 2009).

Park, E. J. and Jhon, D. Y. (2009). Effects of bamboo shoot consumption on lipid profiles and bowel function in healthy young women. *Nutrition* **25**:723–728.

Park, H. K., Kim, M. M., Kim, S. N., Kim, H. D., Kim, Y. H., Rang, M. J., Ahn, H. J., and Hwang, J. K. (2002). Evaluation of xanthorrhizol as a natural antimicrobial agent for oral hygiene products. Available at: http://iadr.confex.com/iadr/2002SanDiego/techprogram/abstract_18700.htm (accessed June 25, 2009).

Porterfield, W. M. (1951). The principal Chinese vegetable foods and food plants of Chinatown markets. *Economic Botany* **5**(1):3–37.

Pubchem. (2009). Taxiphyllin: Substance summary. Available at: http://pubchem.ncbi.nlm.nih.gov/summary/summary.cgi?sid=4972#Source (accessed July 6, 2009).

Raizada, M. B. and Chatterji, R. N. (1956). World distribution of bamboos with special references to the Indian species and their more important uses. *Indian Forester* **82**(5):215–218.

Rajyalakshmi, P. and Geervani, P. (1994). Nutritive value of the foods cultivated and consumed by the tribals of South India. *Plant Foods for Human Nutrition* **46**:53–61.

RAS (Risk Assessment Studies). (2007). Natural Toxins in Food Plants. Report No. 27. Available at: http://www.cfs.gov.hk/english/programme/programme_rafs/programme_rafs_fc_01_17_report.html (accessed July 7, 2009).

Report ERG-BS (V-2). (2009). Process, Market and Business Opportunity Report: Bamboo Shoot. Engineering Resources Group, Bangalore (in association with CPF, FRESH and Delphi). Available at: www.bambootech.org/files/ERG%20report%20on%20shoots.pdf (accessed May 25, 2009).

Rubatzky, V. E. and Yamaguchi, M. (1997). World Vegetables: Principles, Production and Nutritive Values, pp. 658–660.Chapman & Hall, New York.

Ruenkaew, P. (2009). Towards the formation of a community: Thai migrants in Japan. **In**: Part III: Outcomes of Globalisation (The Papers of the 2001 API Fellows), pp. 36–55. Abad, R. G., Ed. The Nippon Foundation, Tokyo. Available at: http://www.api-fellowships.org/pdffiles/part%203.pdf (accessed June 25, 2009).

Sankaran, M., Singh, N. P. and Prakash, J. (2007). Genetic resources of underutilized horticultural crops in Tripura. **In**: Underutilized and Underexploited Horticultural Crops, pp. 1–20. Peter, K. V., Ed., New India Publishing Agency, New Delhi (India).

Sarangthem, K., Singh, T. N., and Thongam, W. (2003). Transformation of fermented bamboo (*Dendrocalamus hamiltonii*) shoots into phytosterols by microorganisms. *J. Food Sci. Technol.* **40**(6):622–625.

Sarangthem, K. and Srivastava, R. C. (1997). Enrichment of levels of phytosterols in fermenting samples of succulent shoots of *Dendrocalamus* species grown in Manipur. *Natl. Acad. Sci. Lett.* **20**(5&6):64–67.

Satya, S., Singhal, S., Prabhu, G., Bal, L. M., and Sudhakar, P. (2009). Exploring the nutraceutical potential and food safety aspect of bamboo shoot of some Indian species. Proceedings of the World Bamboo Congress, 16–19 September, Bangkok.

Schwarzmaier, U. (1976). Uber die cyanogenese von *Bambusa vulgaris* and *B. guadua*. *Chemische Berichte* **109**:3379–3389.

Schwarzmaier, U. (1977). Cyanogenesis of *Dendrocalamus*: Taxiphyllin. *Phytochemistry* **16**:1599–1600.

Scurlock, J. M. O., Dayton, D. C., and Hame, B. (2000). Bamboo: An overlooked biomass resource? *Biomass and Bioenergy* **19**(4):229–244.

Sharma, B. D., Hore, D. K., and Pandey, G. (1992) Genetic resources of bamboo in the north-eastern region of India. *Indian J. Forestry* **15**(1):44–51.

Sharma, Y. M. L. (1980). Bamboos in the Asia-Pacific region. **In**: Bamboo Research in Asia. Proceedings of a Workshop Held in Singapore, pp. 99–120. Lessard, G. and Chouniard, A., Eds., World Publications, Singapore.

Shin, H. Y., Na, H. J., Moon, P. D., Shin, T., Shin, T. Y., Kim, S. H., Hong, S. H., and Kim, H. M. (2004). Inhibition of mast cell-dependent immediate-type hypersensitivity reactions by purple bamboo salt. *J. Ethnopharmacol* **91**:153–157.

Shrestha, P., Gautam, R., Rana, R. B., and Sthapit, B. (2001). Home gardens in Nepal: Status and scope for research and development. **In**: Proceedings of the Second International Home Gardens Workshop, pp. 105–124. Watson, J. W. and Eyzaguirre, P. B., Eds., Federal Republic of Germany, Witzenhausen.

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

Singh, H. B., Singh, R. S., and Sandhu, J. S. (2003a). Herbal Medicine of Manipur: A Color Encyclopaedia. Daya Books, New Delhi (India).

Singh, R. K. P., Satapathy, K. K., and Singh, K. S. (2003b). Common fermented food products of Manipur. *Indian J. Hill Farm.* **16**(1&2):113–115.

Singh, S. G. and Singh, L. J. (1994). Release of HCN in Soibum fermentation. *J. Phytol. Res.* **7**(2):169–170.

Singhal, P., Bal, L. M., Satya, S., and Sudhakar, P. (2009). Bamboo shoot: Food safety and nutritional perspective. **In**: Abstract Proceedings of the National Seminar on Bamboo: Plantation, Management and Its Utilization, p. 66, AFRI, Jodhpur (India).

Sinha, M. K. (2007). Prospect of bamboo culture in Nagaland: A note. **In**: Issues on Natural Resource Management With Special Reference to North East India, pp. 79–87. De, U. K. and Kulirani, F., Eds., Daya Books, New Delhi (India).

Somnasang, P., Moreno, G., and Chusil, K. (1998). Indigenous knowledge of wild food hunting and gathering in North-East Thailand. *Food Nutr. Bull.* **19**(4):359–365.

Srivastava, R. C. (1990). Bamboo, new raw material for phytosterols. *Curr. Sci.* **59**(24&25):1333–1334.

Srivastava, R. C. and Sarangthem, K. (1994). Enrichment in the level of total phytosterols during fermentation of succulent shoots of *Bambusa* species grown in Manipur. *Vegetos.* **7**:7–12.

Steinkraus, K. H. (1995). Handbook of Indigenous Fermented Foods, 2nd ed. CRC Press, Boca Raton, FL.

Sue, T. (1995). Bamboo shoots = good food. *Temp. Bamboo Quart.* **2**(1–2):8–11.

Suwannapinunt, W. and Bunvong, T. (1990). Food compositions of some Thai bamboo shoots. *Thai J. Forestr.* **9**:67–72.

Swaddiwudhipong, W. and Wongwatcharapaiboon, P. (2000). Foodborne botulism outbreaks following consumption of home-canned bamboo shoots in Northern Thailand. *J. Med. Assoc. Thai.* **83**(9):1021–1025.

Tamang, B. and Tamang, J. P. (2009). Traditional knowledge of biopreservation of perishable vegetable and bamboo shoots in Northeast India as food resources. *Indian J. Trad. Knowl.* **8**(1):89–95.

Tamang, J. P. and Sarkar, P. K. (1988). Traditional fermented foods and beverages of Darjeeling and Sikkim: A review. *J. Sci. Food Agric.* **44**:375–385.

Tamang, J. P. and Sarkar, P. K. (1996). Microbiology of mesu, a traditional fermented bamboo shoot product. *Int. J Food Microbiol.* **29**(1):49–58.

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

Tjon Sie Fat, L. A. (1978). Konink. Nederl. Akad. *Wetensch.* **81**:347.

Tripathi, Y. C. (1998). Food and nutrition potential of bamboo. *MFP News* **8**(1):10–11.

Tsai, C. E. (1997). Effect of dietary fibers on serum and liver lipids. *Food Sci. Taiwan* **24**(6):706–712.

Tsaltas, T. T. (1969). Dietetic management of uremic patients I. Extraction of potassium from foods for uremic patients. *Am. J. Clin. Nutr.* **22**(4):490–493.

Valkosen. (2001). Efficacy of garlic fruits and bamboo shoots in deworming swine. **In**: Proceedings of the 26th Annual Conference of the Nigerian Society of Animal Production, pp. 50–51, NAPRI, Zaria, Nigeria.

Vatsala, V. V. A. (2003). Bamboos in India. NISCAIR, New Delhi.

Vetter, J. (2000). Plant cyanogenic glycosides. *Toxicon.* **38**:11–36.

Wang, H. X. and Ng, T. B. (2003). Dendrocin, a distinctive antifungal protein from bamboo shoots. *Biochem. Biophys. Res. Commun.* **307**(3):750–755.

World Health Organization. (1993). Toxicological Evaluation of Certain Food Additives and Naturally Occurring Toxicants. WHO Food Additive Series:30. World Health Organization, Geneva.

Yamaguchi, M. (1983). World Vegetables: Principles, Production and Nutritive Values. Avi Publishing, West Port, CT.

Yang, R. Y., Tsou, S. C. S., Lee, T. C., Hanson, P. M., and Lai, P. Y. (2005). Antioxidant capacities and daily antioxidant intake from vegetables consumed in Taiwan. **In**: *Symposium on Taiwan-America Agricultural Cooperative Projects*, pp. 69–77. National Taiwan University, Taipei, Taiwan.

Young, R. A. (1954). Flavour qualities of some edible oriental bamboos. *Econ. Bot.* **8**:377–386.

Yuming, Y., Kanglin, W., Shengji, P., and Jiming, H. (2004). Bamboo diversity and traditional uses in Yunnan, China. *Mt. Res. Dev.* **24**(2):157–165.