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Biochemistry of Bitterness in Bamboo Shoots

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Abstract

Bamboo is a natural resource in the world. The young and tender bamboo plant, called bamboo shoot, is utilized as one of the food items in many countries. Consumption of bamboo shoots in most of the countries is in dried, canned, boiled, fermented or medicinal forms. Bamboo shoots are low in fats and cholesterol contents, but very high in potassium, carbohydrates and dietary fibers. However, due to presence of hydro cyanine (HCN) develops bitterness in the bamboo shoots, which limits the interest of many people for this renewable and yet unexplored natural food item. The present article present the various qualities of bamboo shoot, biochemistry of bitterness in bamboo shoots and processing challenges in supporting and establishing bamboo shoot based R&D sectors.

Keywords: Bamboo Shoot, Bitterness, HCN, Superheated Steam Dying, Canning.

Introduction

Bamboo shoots are the young and tender culms of bamboo that are consumed for various food items after harvesting. Bamboo shoots form a traditional delicacy of many countries. The freshly harvested shoot is cream yellow in color, has a strong smell and is sweet in taste. However, all species of bamboo shoots available worldwide are not edible. The utilization pattern of the bamboo shoots in most of the countries indicates that it is consumed in forms of raw, dried, canned, boiled, fermented or medicinal. Bamboo shoots are very seasonal, short-lived and perishable in nature.

The total potential of bamboo worldwide is estimated at $10 billion. In the international market, China earns US$130 million every year from exports of edible bamboo shoot, with imports of US at around 44,000 tonnes accounting for 14.5% of the total world imports) and import of Australia is at 8,000 tonnes per annum (Cahill, 1999). It has been observed that every year US imports 30,000 tonnes of canned bamboo shoots from Taiwan, Thailand and China to be consumed as food items (Lewis, 1996). Taiwan consumes 80,000 tonnes of bamboo shoots annually constituting a value of US$ 50 million (Tai, 1985). In Singapore, mostly consumed are the canned shoots; however, frozen cooked shoots are also used (Pan, 1995). In Japan, the annual per capita consumption of bamboo is now 3 kg per person presently, compared to 1.2 kg per person in 1950s.

Bamboo Shoots Qualities

Bamboo shoots are presently among the most favorite food items among people all over the world, but there is hardly any organized bamboo shoot processing and marketing industry. Therefore, the product is being far off from standardization or globalization. In the following sub-sections, an attempt has been made to highlight the quality attributes i.e., physical, chemical, nutritional, sensory, and anti-microbial qualities of bamboo shoots and the subsequent qualities of the products derived or to be derived from them.

Bamboo shoots are generally 8-12 inches long, taper to one end and grow extraordinarily. However, their size and weight depend considerably upon the location, depth and nutrition of the soil, watering and drainage conditions, rainfall, temperature, pH and soil fertility. Broadly, the temperate climate bamboos are runners, which shoot in the spring, while the tropical and sub-tropical varieties are clumpers, which shoot in the late summer and fall. Bamboo shoots look like coiled springs and have an acerbic flavour.

Bamboo shoots are low in fats and cholesterol contents, but very high in potassium, carbohydrates and dietary fibers. Many nutritious and active materials such as vitamins, amino acids, and anti-oxidants such as flavones, phenols and steroids are present in the bamboo shoots. Bamboo shoots are valuable in pharmaceutical and food processing industries and can be processed into beverages, medicines, additives or health foods. In attendance, however, hardly any product has created their way into the markets. Table 1 represents the chemical composition of commonly edible bamboo shoots. The table shows that the water, protein, carbohydrate, mineral and hydrocyanic acid contents of bamboo shoots vary from 85.98-92.37%, 1.98-3.29%, 3.89-9.94%, 0.89-1.14% and 0.032-0.13%, respectively.

Table 2 shows that bamboo shoots are low in cholesterol and saturated fats contents (total fats 0.5%), are high in carbohydrate (5.70%), protein (3.9%), minerals (1.1%) and moisture (88.8%) (Satya et al., 2009). It is a good source of Vitamin *E* (*á*-Tocopherol), Vitamin *C*, *B6*, thiamin, riboflavin, niacin and dietary fibers like hemicelluloses, cellulose, pectin, lignin (Park and John, 2009). It has been reported that bamboo shoots can significantly decrease serum total and serum LDL cholesterol in rats and total liver lipids including liver cholesterol by 16.1 mg/dl. With 17 different types of amino acids, it contains over 10 kinds of mineral elements i.e., Cr, Zn, Mn, Mg, Ni, Co, Cu; Lysine, Germaclinium, many nutritious and active materials.

Bamboo shoots are soft and crispy and develop an acrid flavor, if not harvested as soon as they come out of the ground (Sue, 1995). They contain a potentially toxic glycoside of á-hydroxynitrile, called taxiphyllin. (Anonymous, 2004) which is turned on by the hydrolytic enzyme: â-glycosidase, upon disruption of the plant cell (Ermans et al., 1980; Nahrstedt, 1993). Taxiphyllin further breaks down to form cyanohydrins and sugar, which rapidly decomposes into hydrocyanic acid and an aldehyde or a ketone. In *D. giganteus*, it varies upto 894 mg/kg (Ferreira et al., 1995), in *M. bambusoides*, 0.14 mg/g, in *B. pallida*, 0.04 mg/g, respectively. The new shoots are almost free from acridity and are brilliant for human consumption. Homogentisic acid is, however, also responsible for the pungent taste of the shoots (Bhargava et al., 1996). But the taste also depends on the total sugar content, total amino acid content like aspartic acid (Asp), glutamic acid (Glu), glycine (Gly) and tannin contents; while the amino acids increase the deliciousness of bamboo shoots, tannins decrease the same by increasing the offensive taste (Xia-Bo, 2006).

With different flavones and glycosides, bamboo shoots have excellent anti-microbial qualities and can be extracted to make capsules and tablets. In the traditional system of Indian medicine, the silicious concretions found in the shoots are called 'banslochan'; and in the Indo-Persian and Tibettan system of medicine, it is called 'tabashir' or 'tawashir'; commonly in English, it is called 'bamboo manna'. Earlier obtained from *M. bambusoides*, it is known for its unique healing properties, but is very hard to get. Presently it is replaced by synthetic salicic acid.

Shoots of *B. arundinacia/B. bambos* contain choline, betain, nuclease, urease, cyanogens, glucosides and are used in the treatment of diarrhoea, thread worm and cough; shoots and dried pith of *D. strictus* contain silicious matter and have tonic and astringent action. The juice of pressed bamboo shoots possesses protease activity that helps in digestion of proteins. Boiled bamboo shoots are used as appetizers and the decoction of shoots are used for cleaning wounds and maggot infected sores, ulcers etc; mixed with palm-jaggery, it is known to induce parturition and abortion (RFRI, 2008). In Java, sap from inside the shoots of *B. vulgaris* is used for curing

jaundice (Burkill, 1935). Bamboo is filled with antimicrobial qualities and its shoots are used in preparation of steroidal drugs (Sarangthem, 2003).

HCN in Bamboo Shoots

Bamboo shoot is one of the common food items in many countries and its popularity is growing day-by-day, as main or supplementary foodstuff. A thriving economy exists around bamboo and bamboo shoot based food item in the international market in terms of food security and nutrition. There exists great opportunity especially in an organized food processing sector to take up plantation, harvesting, processing and marketing of bamboo and bamboo shoots- based food products. Bamboo shoots can be dried, marinated, or sautéed to prepare various food items. Although fresh shoots (of *D. giganteus*) are healthier and nutritionally richer, (Nirmala et al., 2008) the younger shoots, later fortified, can be utilized for various small scale cottage industries by processing them into a wide range of long-standing products. It should, however, be noted that, in selecting an appropriate process technology for the bamboo shoots, it is important to examine energy, environment as well as cost issues. Different technologies may be appropriate at different geographical locations and local socio-economic conditions. Due to increase in population, raised attention towards urbanization and industrialization and drastic climatic change, potential of this natural resource is declining day-by-day.

Cyanogenic glycosides are nitrogeneous phytoanticipins (Zagrobelny et al., 2004) and are used by various plants as effective defensive mechanism against predators (Thomsen and Brimer, 1997; Jones, 1998; Francisco and Pinotti, 2000). A mechanisms responsible for the formation of HCN has been formulated by Miller and Conn (1980), and it has been found that in most of the species it is the degradation of the cyanogenic glycosides (Conn, 1979) that produces HCN; and the enzyme responsible for this are found out to be â-cyanoalanine synthase (EC 4.4.1.9)which is found in a number of plant species (Blumenthal et al., 1968; Floss et al., 1965), apart from Rhodanese (thiosulphate-cyanide sulphur transferase EC 2.8.1.1) and Formamide hydrolyase (EC 4.2.1.66). The steps that catalyze the reaction through â-cyanoalanine synthase are (Miller et al., 1980):

$$\underset{\text{Cystein}}{HSCH_2CHNH_2CO_2H} + HCN \text{ '!} \underset{\text{cyanoalanine}}{NCCH_2CHNH_2CO_2H} + H_2S$$

$$S_20_3^{2-} + CN^{--} \text{ '!} SO_3^{2-} + SCN^-$$

$$HCN + H_20 \text{ '!} HCONH_2$$

Bamboo shoots contain 0.3 to 0.8% HCN (Poulton, 1983; Tripathi, 1998; Anonymous, 2004). Out of which, up to 0.16% of the total cyanide is contained in the tip, reducing to 0.01% in the base (Haque and Bradbury, 2002), with highest in leaves of young plants, but dropping rapidly after pollination. However, subsequent processing helps in fighting the cyanide concentration, though incomplete cooking result in glycoside hydrolysis and higher release of HCN, but the total amount of HCN in the shoots can be eliminated/ detoxified by boiling/cooking for two hours (Anonymous, 2004). Table 3 shows the HCN content of edible bamboo shoot species.

Cyanogenic glycosides were assessed by various authors and organizations (Simeonova and Fishbein, 2004; Gettler and Baine, 1938; Halstrom and Moiler, 1945, Satya et al., 2007; NMBA, 2009; JECFA, 1993; Speijers, 1993; ATSDR, 2006). Subsequent detoxification and potential toxicity of cyanoglycosides resulting in acute cyanide poisoning in human, bird, fish, wildlife and livestock has been documented (Conn, 1979a, b; Oke, 1979, 1980; Ballantyne, 1987a; Wilson, 1983; Yamamoto et al., 1989). The intermediate degradation of cyanogenic glycosides and their products – the cyanohydrins – are only addressed in some of the reviews and articles (WHO, 1993; EFSA 2004; Majak, 1992; Brimer and Rosling, 1993; Hernandez et al., 1995). Functionally, taxiphyllin in presence of â-glucosidase breaks down to form HCN and aldehyde or ketone. The HCN, so formed, inhibits cytochromoxidase which then stops the oxidative phosphorylation and utilization of intracellular oxygen ceases and there is cardiac arrest in human body (Conn, 1979).

Remedies for Bitterness

Cyanide content, naturally, is reported to decrease substantially following harvesting (Nirmala et al., 2007). Different indigenous methods of reducing

acidity/bitterness from fresh bamboo shoots has been reported and some of them include chopping of tender shoots into small pieces, partial drying of fresh shoots, boiling in water/salt water and draining or keeping shoots in hot water for 10 - 15 min or in water for a week at ambient temperature, etc.

Adi women of Arunachal Pradesh used banana leaves for semi-fermentation of shoots and pressed under stones near water stream for 3 - 4 months to reduce bitterness (Bhardwaj et al., 2005; Bal et al., 2005). Similarly, Bhatt et al., (2007) reported unique traditional processing of bamboo shoot fermentation to reduce the cyanide percentage. Ferreira, (1995) reported the optimum cooking conditions that resulted in 97% reduction of HCN were 98 - 102°C for 148 - 180 min. Subsequently, Tripathi (1998) mentioned that removal of HCN can be done by steaming bamboo shoot. Bhargava et al., (1996) reported removal of this during cooking shoots by changing water several times or by pre-soaking for a long time by subsequent changing 2% salt solution. Wongsakpairod (2000) reported superheated steam drying under low temperature removes HCN from bamboo shoot as Taxiphyllin decomposes at around 116°C.

Conclusion

In spite of the fact that, bamboo shoot has been an integral part of diet of the tribal community, scientific validation of traditional processing methods in terms of food quality and safety has not been attempted. The integration of traditional processes after scientific validation would go a long way in developing a suitable system for storage and preservation of this perishable commodity for rural entrepreneurship. Also, processing techniques to take care of the food safety aspect would enhance the export potential of this wonderful product. In this context, efficacy of discarded toxic extract as bio-pesticide needs to be explored. The use of hybrid technologies, such as solar-assisted heat pump dryer, solar dryer with thermal energy storage, microwave assisted drying may be more cost effective to get the desired quality products.

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Table 1: Chemical analysis of commonly edible bamboo shoots (NMBA, India)

Nutrients	Bamboo species						
	B. balcooa	*B. polymorpha*	*M. bambusoides*	*D. strictus*	*D. hamiltonii*	*D. Giganteus*	*B. pallida*
Water (%)	91.65	91.65	91.22	85.98	92.37	91.19	92.29
Minerals (%)	0.99	0.91	0.98	1.14	1.01	0.89	1.12
Phosphorus (mg/100g)	30.99	15.06	14.28	58.13	27.76	12.57	32.27
Calcium (mg/100g)	24.01	180.69	47.58	139.5	44.16	26.93	21.17
Iron (mg/100g)	1.02	1.53	0.879	2.917	1.65	1.06	1.11
Hydrocyanic acid (%)	0.071	0.032	0.056	0.13	0.070	0.044	0.106
Protein (%)	2.74	2.10	3.29	1.98	2.60	2.59	2.31
Niacin (mg/100g)	1.40	2.60	6.70	2.10	2.60	6.40	1.40
Carbohydrates (%)	3.90	4.86	3.93	9.94	4.00	4.78	3.83

Table 2. Nutrient analysis of processed bamboo shoots (Choudhury, Sahu and Sharma, 2010)

Constituents Quantity	per 100g
Dietary fibers 1.5 g	1.5 g
Lignin 46 mg	46 mg
Proteins	
Animal protein	
Plant Proteins	2145 mg
Amino acid	
Essential amino acids	751 mg
Non-essential amino acids	1008 mg
Carbohydrates	
Cellulose	0.85 g
Monosaccharide	307 mg
Polysaccharides	288 mg
Fatty acids	
Saturated fatty acids	0.05 g
Monounsaturated fatty acids	0.007 g
Polyunsaturated fatty acids	0.12 g
Short chain fatty acids	0 mg
Long chain fatty acids	181 mg
Minerals and trace elements	
Sodium	268 mg

Table 3. Detailed HCN content of commonly edible bamboo shoot species

Species	Region of the shoot	Concentration of HCN in edible parts of the shoot (mg/g)
Dendrocalamus hamiltonii	Tip	2.42
	Middle portion	0.86
	Base	0.15
Bambusa pallid	Tip	0.27
	Middle portion	0.17
	Base	0.13
B.tulda	Tip	0.17
	Middle portion	0.83
	Base	0.28
B.balcooa	Tip	2.15
	Middle portion	1.38
	Base	0.62
Melocanna bambusoides	Tip	1.81
	Middle portion	0.68
	Base	0.35

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