Effects of processing and preservation on phenols and phytosterols content in bamboo shoots

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Abstract

Phenols and phytosterols have tremendous impact on the health care system and may provide medical health benefits including the prevention or treatment of diseases and physiological disorders. The health benefits of the juvenile bamboo shoots are attributed to the presence of these bioactive compounds. Modern research has revealed that bamboo shoots play specific pharmacological effects in human health as anti-inflammatory, anti-allergic, antioxidants, antibacterial, antifungal, hepato-protective, neuroprotective and antiaging. Fresh bamboo shoots are delicious, crispy and healthy, with high phenolic and phytosterol content. However, processing procedures, such as soaking, boiling and drying may affect the levels of these bioactive compounds and subsequent overall health related activities. Here, the effects of various processing methods like soaking, boiling and drying were examined on the content of phenols and phytosterols in the shoots of four bamboo species. It was observed that different processing methods had significant effects on phenolic and phytosterols content in the bamboo shoots.

Keywords: Bamboo shoots, phenols, phytosterols

Introduction

Bamboo shoots carry the potential of value added economic activity at the entrepreneurial and community level through cultivation, processing and packaging. Its use in food and medicine goes far back in history and in the present time also, the importance of bamboo shoots as food has not gone down. In fact in 21st century bamboo shoots have come in a totally new avatar like health and functional food or nutraceuticals (Nirmala *et al*., 2014). Worldwide bamboo shoots have become a multibillion dollar business. China, the biggest supplier of bamboo shoots to the world market, earns US$130 million annually from exports of edible bamboo shoots (Cahill *et al*., 1990). About 200 species of bamboo can provide edible and palatable bamboo shoots, though Moso bamboo (*Phyllostachys edulis*) is the most preferred species for shoots in the international market (Assocham, 2007). Day by day bamboo is gaining popularity worldwide as healthy and nutritious food as it is free from residual toxicity, low in fat and rich in edible fiber and mineral elements mainly potassium, calcium, manganese, zinc, chromium, copper, iron and lower amount of phosphorus and selenium (Shi and Yang, 1992; Nirmala *et al*., 2007). Presence of high quality vitamins such as vitamin A, vitamin B1, vitamin B3, vitamin B6 and vitamin E (Shi and Yang, 1992), carbohydrates, proteins and minerals in bamboo shoots and their easy availability to common man may also help in solving nutritional deficiency of rural poor (Tripathi, 1998). Fresh bamboo shoots are delicious, crispy and healthy, with high fibre content. After cooking the shoots are still crisp, because cooking does not destroy their texture. Freshly harvested bamboo shoots need to be processed before cooking to remove cyanogenic glycoside, an anti-nutrient present in fresh bamboo shoots. Recent studies have demonstrated that bamboo shoots both fresh and fermented, are a good source of phenols and phytosterols that are the precursors of many pharmaceutically active substances found in plants (Srivastava 1990; Sarangthem and Singh 2003) and act as nutraceuticals (Miettinen 2003; Nirmala *et al*., 2014). Phenolic compounds, including their subcategory flavonoids, have antioxidant properties. This activity of phenolic compounds is mainly because of their redox properties which allow them to act as reducing agents, hydrogen donors, singlet oxygen quenchers and metal chelators (Rice-Evans *et al*., 1997). Phytosterols are very effective therapeutic strategy for lowering LDL cholesterol concentrations. They also inhibit the production of carcinogens, cancer cell growth, invasion and metastasis, and promote apoptosis in cancer cells (Meric *et al*., 2009; Woyengo *et al*., 2009). However, young bamboo shoots are generally consumed after processing and long term preservation due to presence of high content of cynogenic glycoside (antinutrient) and very short shelf life of shoots. Processing and preservation is expected to affect content, activity and bioavailability of various nutrient and bioactive compounds including phenols and phytosterols in the bamboo shoots. Keeping above into consideration, a study has been carried out to find the impacts of various processing methods on the phenolic and phytosterol contents of processed and preserved bamboo shoots.

Phenols in bamboo shoots

Phenols are today among the most talked about classes of phytochemicals present in plants because they are multifunctional and can act as free radical terminators, metal chelators, and singlet oxygen quenchers (Kris-Etherton *et al*., 2002). Bamboo shoot is rich in phenolic components which possess various bioactivities (Nirmala *et al*., 2014). It was determined that the antioxidant capacity was highly correlated with the total phenolic contents (Velioglu *et al*., 1998). Antioxidant properties are very significant in terms of food and nutraceuticals, but have been given less attention in case of bamboo shoots.

Antioxidant properties of bamboo shoots were first studied 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 (Singhal *et al*., 2013). Park and Jhon (2010), investigated the functional properties of shoots of two bamboo species *P. pubescens* and *P. nigra* and found a significant relationship between antioxidant activity and phenolic content. This study also found the dose dependent inhibitory activity of shoots on angiotensin-converting enzyme. Eight phenolic compounds, protocatechuic acid, p-hydroxybenzoic acid, catechin, caffeic acid, chlorogenic acid, syringic acid, p-coumaric acid, and ferulic acid, were identified in bamboos by high-performance liquid chromatography. The most important compounds were protocatechuic acid, p-hydroxybenzoic acid, and syringic acid (Park and Jhon, 2010). Phenolic acids present in the tender shoots have mild anti-inflammatory properties and are potent antioxidants that prevent cancer and blood vesselinjury that can start atherosclerosis (Belitz and Grosch 1999). In one of the studies, it was found that bamboo shoot contributed 46% of the daily antioxidant activity intake among different vegetables consumed in China (Yang *et al.*, 2005). These features make phenols a potentially interesting material for the development of functional foods (Blando *et al*., 2004). The phenolic content of fresh and processed shoots of four bamboo species, *Bambusa nutans, Dendrocalamus giganteus D. hamiltonii* and *D. latiflorus* has been analyzed using the Folin– Ciocalteau method using gallic acid as the standard (Singleton and Rossi, 1965). In fresh bamboo shoots, the phenolic content ranged from a minimum of 336.56 mg per 100 g in *D. giganteus* to a maximum of 612.24 mg per 100 g in *D. latiflorus* (Table 1). However, when the fresh shoots were subjected to various processing techniques such as boiling, drying and soaking in brine solution, different effects were seen on the phenolic content. The phenolic content decreased in all treatments except in dried shoots, increase might be due to the availability of precursors of phenolic molecules by non-enzymatic interconversion between phenolic molecules. The maximum decrease was observed in 10% brine solution. Zhang *et al*. (2011) also studied changes in amount of phenolic compounds in fresh, boiled, steamed, and stir fried bamboo shoots. The total phenolic content in both boiled and stir-fried samples reduced slightly compared to fresh shoots. The change in phenolic content in bamboo shoots is not only due to processing techniques, but several other factors are also responsible for decrease or increase in phenolic content, such as growing conditions, environmental factors, harvest season (Ni *et al*., 2013), age of shoot, part of shoot used, storage time and temperature.

Table 1: Phenols in fresh and processed bamboo shoots (mg per 100 g, fresh weight, dry weight)

Species	Fresh shoots	Processed shoots			
		Brine treatment		Boiled	Oven dried
		5%	10%		
B. nutans	489.83 ± 5.08	291.34 ± 1.60	89.53 ± 0.23	180.21 ± 2.38	1930.66 ± 2.49
D. giganteus	336.56 ± 9.3	157.41 ±2.10	124.26 ± 4.10	164.62 ± 2.10	1927.29 ± 1.63
D. hamiltonii	586.36 ± 4.3	192.77 ± 0.90	98.68 ± 0.31	354.11 ± 1.59	1934.54 ± 1.65
D. latiflorus	612.24 ± 1.8	383.27 ± 2.20	109.29 ± 0.10	482.43 ± 7.50	1950.67 ± 2.58

Mean values ± standard deviation of determinations for triplicate samples.

B = *Bambusa* D = *Dendrocalamus*

Phytosterols in bamboo shoots

Phytosterols are secondary plant products; have chemical structure resembling that of cholesterol. They possess several beneficial effects including anti-inflammatory (Park *et al*., 2001; Bouic *et al*., 2001), serum cholesterol lowering (Pollak, 1953; Miettinen *et al*., 2000; Blair, 2000), anti-ulcer (De Jong *et al*., 2003) and anti-cancer (Awad and Fink 2000; Moreau *et al*., 2002; Lin *et al*., 2004; Choi *et al*., 2007; Bradford and Awad 2008; Woyengo *et al*., 2009). Phytosterols have received particular attention because of their capability to lower serum cholesterol levels in humans (Marangoni and Poli 2010), result in reducing the risk of heart disease significantly. Use of foods containing phytosterols is a relatively recent development in nutrition (Gilbert *et al*., 2005). More than 200 different types of phytosterols have been reported in plants; the most abundant are B-sitosterol, campesterol, stigmasterol, and avenosterol (Jones 1999; Law 2000; Katan *et al*., 2003; St-Onge and Jones 2003; Abumweis and Jones 2008). Phytosterols are absorbed only in trace amounts but inhibit the absorption of intestinal cholesterol including recirculating endogenous biliary cholesterol, a key step in cholesterol elimination. Bamboo shoots are a good source of phytosterols (Sarangthem and Singh, 2003; Lu *et al*., 2009; Nirmala *et al*., 2014) and have beneficial effects such as lowering cholesterol levels and improving bowel functions (Park and Jhon, 2009). Lu *et al*., (2009) have also confirmed that bamboo shoots contain high sterol content (321 mg/100 g dry wt.). Predominant sterols in bamboo shoots have been identified as β-sitosterol, campesterol, and stigmasterol (He and Lachance 1998; Lachance and He 1998). The phytosterol content in bamboo shoots increased with the fermentation (Srivastava and Sarangthem, 1994). β-sitosterol, stigmasterol and campesterol have been isolated from fermented shoots (Sarangthem and Srivastava, 1997). A recent study have also shown that the total phytosterol content in bamboo shoot residue increased from 523 mg to 1,168 mg per 100 g after solid-state fermentation at 33 °C for 5 days using an isolated *Aspergillus niger* CTBU. The main compositions of phytosterols in fresh and fermented bamboo shoot residue were estimated using high performance liquid chromatography and it was observed that beta-sitosterol, stigmasterol, and cholesterol account for 80.1, 15.2, and 2.9 % of total phytosterols in fresh shoots residue, and account for 79.9, 17.2, and 3.1 % of total phytosterols in fermented shoot residues (Zheng *et al*., 2014). The phytosterol content in shoots of four bamboo species, *Pleioblastus amarus, P. praecox, Phyllostachys pubescens* and *Dendrocalamus latiflorus*, were evaluated using ultra- performance liquid chromatography with atmospheric pressure chemical ionization mass spectrometry (Lu *et al*., 2009). The major sterols present were β-sitosterol (24.6%), campesterol (2.2%), stigmasterol (1.2%), ergosterol (0.2%), cholesterol (0.6%), and stigmastanol (<0.1%) (Lu *et al*., 2010). Bamboo shoot oil is a phytosterols rich extract from the shoots of *P. pubescens* obtained by supercritical carbon dioxide extraction and its protective effects on nonbacterial prostatitis were also investigated (Lu *et al*., 2011). It was determined that bamboo shoot could significantly inhibit absolute weight, prostate index, total acid phosphatase, prostatic acid phosphatase, white blood cell, and expression levels of thirty up-regulated genes. The pronounced hypolipidemic effects of bamboo shoot oil might be attributed to its ability to inhibit cholesterol absorption and increase cholesterol excretion. Phytosterols as functional ingredients in bamboo shoots appear to be a practical and safe option for lowering cholesterol levels (Nirmala *et al*., 2014). Phytosterol content of juvenile shoots of four bamboo species (*Bambusa nutans, Dendrocalamus giganteus D. hamiltonii* and *D. latiflorus*) was also evaluated using the method given by Srivastava, (1990). The total phytosterol content of fresh shoots of *Bambusa nutans, Dendrocalamus giganteus D. hamiltonii* and *D. latiflorus* is shown in Table 2.

Table 2: Phytosterol content in fresh and processed bamboo shoots (mg per 100 g, dry weight)

Species	Fresh shoots	Processed shoots		
		Brine treatment		Water soaked
		5%	10%	
B. nutans	164.2 ± 0.30	171 ± 0.60	81.77 ± 1.20	97.24 ± 2.50
D. giganteus	136.23 ± 2.40	139.33 ± 1.50	67.66 ± 2.20	89.56 ± 0.70
D. hamiltonii	198.27 ± 2.30	322.34 ± 3.10	79.33 ± 1.80	108 ± 5.60
D. latiflorus	146.33 ± 3.10	175.23 ± 0.90	57.00 ± 2.10	76.00 ± 3.90

Mean values ± standard deviation of determinations for triplicate samples.

The range of total phytosterol content of fresh shoots varied between136.23 to 198.27 mg per 100 g, dry weight. The total phytosterol content increased significantly in 5% brine solution, values ranged from a minimum of 139.33 mg per 100 g in *D. giganteus* to a maximum of 322.34 mg per 100 g, dry weight in *D. hamiltonii.* In contrast, it decreased in 10% brine solution and water soaked shoots. Maximum decrease was observed in 10% brine solution. The preservation time of bamboo shoots in plain water has not much affected the total content of phenol and phytosterol, though the results are not consistent and need more study (Table 3). Age and part of the shoot is an important factor with respect to content of bioactive compounds and further studies taking uniform shoot age and shoot part is being conducted.

Table-3: Phenols (mg/100 g, fresh weight) and phytosterols (mg/100 g, dry weight) in water soaked shoots of *Dendrocalamus hamiltonii* at different time intervals

Time	Phenolic content	Phytosterol content
Fresh	586.36 ± 4.30	198.27 ± 2.80
First week	558.21 ± 1.14	139.66 ± 1.50
Second week	535.52 ± 2.39	179.74 ± 0.80
Third week	464.29 ± 1.90	108.00 ± 3.40
Fourth week	349.46 ± 12.30	213.15 ± 0.10
Fifth week	286.43 ± 7.13	112.32 ± 1.60
Sixth week	388.10 ± 0.90	190.41 ± 0.70
Seventh week	454.87 ± 6.08	158.00 ± 1.90
Eighth week	583.65 ± 1.59	150.66 ± 2.50
Ninth week	361.25 ± 2.54	152.11 ± 4.10
Tenth week	469.47 ± 2.71	192.00 ± 0.60

Mean values ± standard deviation of determinations for triplicate samples.

According to the results of our study, dried bamboo shoots were the best source of phenolic compounds and 5% brine treated shoots were the best source of phytosterols. Moreover, the shoots have more phenolic and phytosterol content compared to commonly consumed vegetables and fruits (Table 4). Since bamboo shoots are not only rich in nutrients but also an excellent source of phenols and phytosterols, they can be used as an ingredient in functional foods (Nirmala and Bisht, 2012).

Table-4: Comparative account of total phenolic content (mg/100 g, fresh weight) and phytosterol content (mg/100 g, dry weight) of bamboo shoots and some common food items

Species	Phenols	Phytosterols	Reference
Bamboo			
Dendrocalamus latiflorus	612.24 ± 1.80	146.33 ± 3.10	Present study
Dendrocalamus hamiltonii	586.36 ± 4.30	198.27 ± 2.30	
Bambusa nutans	489.83 ± 5.08	164.20 ± 0.30	
Dendrocalamus giganteus	336.56 ± 9.30	136.25 ±2.40	
Vegetables			
Broccoli (*Brassica oleracea* var. italica)	87.50 ± 8.10	18.3 ± 1.30	Kaur and Kapoor, 2002; Jimenez-Escrig *et al*., 2006
Beet root (*Beta vulgaris*)	323.0 ± 11.70	171.00 ± 70	Kaur and Kapoor, 2002; Piironen *et al*., 2003
Carrot (*Daucus carota*)	55.0 ± 0.90	18.6 ± 1.5	Kaur and Kapoor, 2002; Jimenez-Escrig *et al*., 2006
Cauliflower (*Brassica oleracea* var. botrytis)	96.0 ± 0.90	44.3 ± 1.2	Kaur and Kapoor, 2002 Jimenez-Escrig *et al*., 2006;
Cabbage *(Brassica oleracea* var. capitata)	92.5 ± 2.40	27.4 ± 1.9	Kaur and Kapoor, 2002 Jimenez-Escrig *et al*., 2006;
Beans (*Phaseaolus vulgaris*)	97.0 ± 1.10	18.8 ± 0.8	Weirauch *et al*., 1978 Jimenez-Escrig *et al*., 2006;
Fruits			
Apple (*Pyrus malus*)	296.3 ± 6.40	16.0 ± 0.9	Sun *et al*., 2002; Jimenez-Escrig *et al*., 2006
Banana (*Musa paradisiaca*)	90.4 ± 3.20	20.1 ± 1.2	Sun *et al*., 2002; Jimenez-Escrig *et al*., 2006
Cherry (*Prunus avium*)	105.4 ± 27.0	20.1 ± 1.4	Karakaya *et al*., 2001; Jimenez-Escrig *et al*., 2006
Legumes			
Chickpea *(Cicer arietinum*)	2.20	121.2 ± 4.7	Han and Baik, 2008; Jimenez-Escrig *et al*., 2006
Lentils (*Lens culinaris*)	12.00	117.3 ± 5.6	Han and Baik, 2008; Jimenez-Escrig *et al*., 2006
Nuts			
Almond (*Prunus amygdalus*)	239	148.6 ± 4.5	Kornsteiner *et al*., 2006; Jimenez-Escrig *et al*., 2006
Peanut (*Arachis hypogaea*)	420	143.6 ± 4.1	Kornsteiner *et al*., 2006; Jimenez-Escrig *et al*., 2006
Beverages			
Coffee (Instant)	146-151	_	Schulz *et al*., 1999

Black Tea	80.5-134.9	_	Khokhar and Magnusdottir, 2002
Green Tea	65.8-106.2	_	Khokhar and Magnusdottir, 2002
Red wine	242	_	Baroni *et al*., 2012

Conclusion

Bamboo shoots are the best source of phenols and phytosterols. The phenolic and phytosterol content was measured in fresh and processed shoots of four bamboo species (*Bambusa nutans, Dendrocalamus giganteus D. hamiltonii* and *D. latiflorus*). All the four species studied were having very high content of these bioactive compounds than reported in many other vegetables, fruits and nuts. The level of phenol and phytosterol content in shoots varied from species to species and are also affected by many other factors like climatic conditions, age of shoot, etc. Preservation of shoots in plain water has not much affected the level of phenol and phytosterol content, but in brine solution both the bioactive compounds have shown decrease, maximum being in 10 per cent solution. A large number of studies in a variety of *in vitro* and *in vivo* system show that phenols and phytosterols have many biological effects that potentially might contribute to prevention of coronary heart diseases and cancer. Long term preservation of shoots by drying or keeping in water is best to retain the original level of phenol and phytosterol content as well as crunchiness in bamboo shoots. More different types of processing methods such as drying and fermentation needs to be done in order to know the status of these bioactive compounds so that they can be used in food and pharmaceutical industries.

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