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Antioxidant and pharmaceutical potential of bamboo leaves

Poonam Singhal*, Santosh Satya and P. Sudhakar
Centre for Rural Development and Technology
Indian Institute of Technology, Delhi, India

ABSTRACT

Bamboos (Poaceae: Bambusoideae: Bambuseae) form a unique group of giant arborescent grasses. Bamboo leaves form an important diet of pandas and are much valued as fodder. Literature on the nutritional value of bamboo leaves is scarce. Anti-oxidant of bamboo leaves (AOB) is used as a novel food anti-oxidant in many food items for which the safety has also been evaluated by a few researchers. Bamboo leaves have been found to contain flavonoids. With this background, this paper reviews the different compounds present in the leaves of different species of bamboo. Several studies have shown positive correlation between consumption of bamboo extract and prevention of diseases like cancer, diabetes, heart problems, aging, fatigue etc. Bamboo leaves being rich in flavonoids have been found to have a great pharmaceutical potential which has not been fully explored.

Keywords: bamboo leaves, flavonoids, antioxidant, pharmaceutical

Abbreviations: FAO: Food and Agriculture Organization, OM: Organic Matter, CP: Crude Protein, EE: Ether extract, CF: Crude Fat, NFE: Nitrogen Free Extract, NDF: Neutral Detergent Fiber, ADF: Acid Detergent fiber, NBT/XO: Nitroblue Tetrazolium Chloride/Xanthine Oxidase, ROS: Reactive Oxygen Species, MSH: Melanocyte Stimulating Hormone, DPPH: 2,2-Diphenyl-1-Picrylhydrazyl, AOB: Antioxidant of bamboo leaves, BLE: Bamboo Leaf Extract, NADPH: nicotinamide adenine dinucleotide phosphate.

INTRODUCTION

Non-timber forest products (NTFPs) are products of biological origin other than wood derived from forests. NTFP's have long been an important component of the livelihood strategies of forest-dwelling people including tribal. Several million households world-wide depend heavily on NTFP for sustenance as well as for meeting family nutritional needs. As per FAO estimates, approximately 80 percent of the population of the developing world use NTFP for health care and fulfilling nutritional needs. In addition to providing subsistence and income, commercial value of NTFP has been increasing. Important products traded from the tropics include rattan, brazil nuts, gum arabic, lac, bamboo and spices (Arinana *et al.* 2009).

Bamboos are group of giant arborescent grasses and 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 world-wide. In India 125 species are found spreading over an area of 9.57 million hectare (Sharma 1980). India has the richest bamboo resources after China. The North Eastern states are endowed with more than 50% of the Indian bamboo genetic resources. Besides its several uses to human life, it prevents soil erosion and conserves soil moisture and thus can prove to be of immense significance in environmental protection. Along with its wide usage in the structural and building materials, it also forms an essential component in cottage and rural industry (Sharma *et al.* 1992). It constitutes one of the most important renewable natural resources of India. Recently, some biologically active components in bamboo leaves and their potential health benefits have been reported in

*Corresponding author: Poonam Singhal
Indian Institute of Technology, Delhi,
Centre for Rural Development and Technology
Hauz Khas, New Delhi-110016, India
Email Id: singhalpoonam6@gmail.com

literature. This paper gives an overview of the investigated bio-activities and pharmaceutical potential of bamboo leaves.

Uses and nutritional composition

Bamboo leaves are much valued as fodder for ruminants particularly when there is scarcity of pasture. In some district bamboo foliage forms the favorite food of elephants & giant pandas (Raizada and Chatterji 1956). Bamboo fodder had been reported to promote high milk production as well as high ghee content. All species of bamboos and species given as fodder were considered to have positive effects on animals, particularly young calves (Thapa *et al.* 1997).

Leaves of 27 species of bamboo plants analyzed for their nutrient content were found to be rich in crude protein (9-19%) and low in crude fiber (18-34%). Seventy percent of the total ash content was silica and other insoluble mineral matters. Leaves were poor in P, K and Na, normal to rich in Zn and Ca and rich in Ca, Mg, Cu and Mn contents. Cu content was very high (17ppm) in *B. arundinacea* leaves (Singh 1999). Seven species of bamboo leaves of Tripura studied for their nutritional composition were found to contain 83.89±0.51, 12.42±0.51, 1.39±0.06, 25.28±0.59, 44.79±0.50, 16.11±0.52, 73.01±0.46, 41.61±1.11, 31.40±0.84, 32.15±0.74 and 5.59±0.32% of OM, CP, EE, CF, NFE, total ash, NDF, ADF, hemicellulose, cellulose and acid detergent lignin, respectively. They were also found to be deficient in P but rich in Ca, Fe & Mn. (Datt *et al.* 2006).

In another study, conducted in the south of Hubei Province of China, on the nutritional status of bamboo leaves *(Phyllostachys pubescens)* concentrations of N, P, K, Ca, Mg and S were found to be 24.3, 1.34, 5.44, 4.08, 1.41, 112.2 mg/kg dry matter basis respectively. The concentration of micronutrients namely Fe, Mn, Cu, Zn, B and Mo was 144.3, 269.5, 4.2, 27.1, 5.6 and 9.6 mg/kg dry matter basis respectively. As the bamboo yield increases macronutrients, except Mn, Cu and Zn, and micronutrient concentration also increased (Chen *et al.* 2004).

CP, CF, Ca and P content in 2 species of Bamboo, namely *D. strictus and B. arundinacea* was found to be 14.2-15.1, 23.5-25.6, 1.1-1.6, 0.2-0.3% in *D. strictus* and 18.6, 24.1, 0.6 and 0.2% for *B. arundinacea* respectively (Gulati *et al.* 1984)

Antioxidant of bamboo leaves (AOB)

The antioxidant of bamboo leaves, abbreviated to AOB, is a pale brown powder extracted from bamboo leaves of the *Phyllostachys* Sieb. et Zucc. genus, represented by *Phyllostachys nigra* var. henonis. The main functional components in AOB are flavonoids, lactones and phenolic acids. As Flavone *C*-glucosides are a group of representative flavonoids in AOB. The chemical structures of four flavone *C*-glucosides, including orientin, homoorientin, vitexin and isovitexin found in AOB, are shown in Fig. 1. Other polyphenols present in AOB are naringenin-7-rhamnoglucoside, quercetin, luteolin, rutin, tricin, caffeic acid, chlorogenic acid and *p*-coumaric acid (Zhang *et al.* 2002b). AOB is used as a food antioxidant, which not only blocks the chain reaction of spontaneous oxidization of lipids, but also chelates transition metals, acting as a primary and secondary antioxidant simultaneously. On the basis of initial research, AOB was approved by the Food Additive Standardization Committee of People's Republic of China on December 28, 2003 as a novel food anti-oxidant, which can be used in edible oil, meat products, aquatic products and other foods with maximum dosage of 0.50 g/kg, and has been listed in the state standard GB-2760 (Hygienic Standards for Food Additives in Use) since April, 2004 (Hu *et al.* 2000; Lu *et al.* 2005; Lu *et al.* 2006). Studies done in fried bread sticks (Zhang and Zhang 2007), potato crisps and french fries (Zhang *et al.* 2007b) revealed the efficiency of using AOB to reduce acrylamide content by 82.9%, 74.1% and 76.1% in fried bread sticks, potato crisps & french fries respectively.

Table 1: Characteristics of antioxidant of bamboo leaves (*Phyllostachys nigra* var henonis)

Parameters	Specification
Total flavonoids	32.4%
Total lactone	15.6%
Phenolic acids	7.9%
Ash	1.24%
Protein	2.3%
Total heavy metals	<0.001
Moisture	4.9%

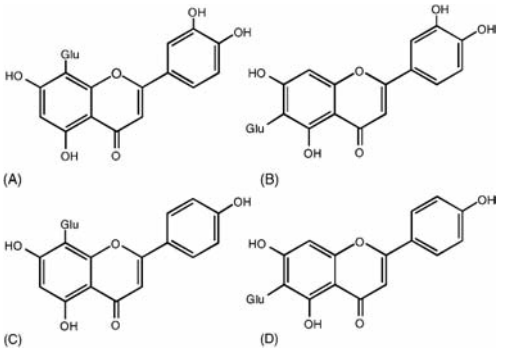

Figure 1: Chemical structure of the studied flavone C-glucosides in antioxidant of bamboo leaves (AOB): (A) orientin; (B) homoorientin; (C) vitexin; (D) isovitexin.

Safety evaluation of AOB

Animal models

For safely using AOB in food systems safety evaluation studies were conducted on animal models. The safety of AOB was examined by evaluating acute oral toxicity using Kun-Ming mice and Sprague-Dawley rats. A 90-day oral toxicity study showed that the maximum tolerated dose (MTD) of AOB was >10 g/kg body weight in both rats and in mice and there was no evidence for mutagenic effects. Administration at levels of 1.43, 2.87 and 4.30 g/kg per day to the rats for 90 days did not induce significant hematological, clinic, chemical and histopathological changes (Lu *et al.* 2005). Moreover when tested for teratogenicity, mortality did not occur. Weight gain during gestation, food consumption, and food efficiency were similar in all groups; reproductive performance was not affected and examination of the fetuses for external, visceral, and skeletal alterations did not reveal any fetotoxic, embryotoxic, or teratogenic effects of AOB. These safety studies suggested a no-observed-adverse-effect level (NOAEL) of 4.30 g/kg per day indicating safe use as food additive (Lu *et al.* 2006).

Sensory evaluation studies

AOB has recently been used in many food systems to reduce the carcinogenic agents formed during thermal processing of the food product. AOB with a total flavanoid content of 32% at an antioxidant ratio of 0.1 and 0.5% reduced acrylamide formation in fried chickens wings by 57.8 & 59% without affecting the original flavor & odour (Zhang *et al.* 2007a).

Secondary metabolites in Bamboo leaves and their antioxidative role

Secondary metabolites including flavanoids and polyphenols are widely distributed in medicinal plants, fruit juices, teas and health beverages, resulting in high human consumption (Walle 2004). Flavonoids generally occur in plants as glycosylated derivatives, and they contribute to the brilliant shades of blue, scarlet, and orange colours in leaves, flowers, and fruits. In recent years the health effects of flavonoids present in human diet have attracted much attention. Several studies suggested that they act as antioxidants (Burns *et al.* 2000; Kaneko and Baba 1999), and epidemiological studies indicate an inverse association between the intake of flavonoids and the risk of cardiovascular diseases (Hertog et al 1995; Knekt et al 1996; Yochum *et al.* 1999) and different types of cancer (Marchand et al 2000).

Flavonoid content was found to be on average 3.44% in different bamboo leaves species. Bamboo leaf flavonoids content varied in different parts of bamboo and was found highest up to 3.35% in shady spot of leaves (Li 2009). In another study the total flavonoid (TF) of bamboo leaf varied in the range of 0.67%-1.71% (on dry basis of leaf) (Zhang *et al.* 2002a).

Four flavone *C*-glycosides, i.e. orientin (49 mg), homoorientin (142 mg), vitexin (15 mg) and isovitexin (62 mg) were isolated from an ethanol aqueous extract of AOB by AB-8 resin-based column chromatography and preparative high-performance liquid chromatography (HPLC) (Zhang *et al.* 2008). These four flavone *C*-glucosides were determined for the first time in several food systems fortified by the antioxidant of bamboo leaves (AOB), such as high temperature sterilized milk, sunflower seed oil and extruded rice cake. The total amounts of these four flavone C-glucosides were 12.56 μg/100 mL, 881.08 μg/100mL and 1420.83 μg/100 g dry weight in AOB-fortified sterilized milk, sunflower seed oil and extruded rice cake, respectively (Zhang *et al.* 2005).

Phloroglucinol (PG), hydrocaffeic acid (HCA) & phloretic acid (PA) were identified as metabolites of these flavone *C*-glucosides. The fate of metabolism of flavone *C*-glucosides studied in rats revealed its poor absorption in the GI Tract, but prolonged retention time in

the colon suggested its ability to exert antioxidant activity and scavenge free radicals. More than 50% recovery of flavone *C*-glucosides was determined 12h after ingestion. Faeces contained 21.23±1.92 % of these four analytes (Zhang *et al.* 2007c)

Six phenolic acids viz., chlorogenic, ferulic, coumeric, protocatechuic, vanillic and coffeic acids were identified in the fallen leaf water extract of *Bambusa arundinacea* according to another study (Eyini *et al.* 1989).

Sasa borealis is a considered as a medicinal plant and a major source of bamboo leaves in Korea. Butanol extract of S. borealis leaves were found to have two antioxidative flavonoid *C*-glycoside derivatives, isoorientin (2) and isoorientin 2-O-α-L-rhamnoside (4) along with tricin 7-0-ß-D-glucopyranoside (1) and apigenin 6-C-ß-D-xylopyranosyl-8-C-ß-D-glucopyranoside (3). Flavanoids (2) and (4) showed potent free radical scavenging activity in DPPH assay with IC_{50} values of 9.5 and 34.5 μM, respectively, and strong cytoprotective effects against oxidative damage in HepG2 cells, at significantly low concentrations of 1.1 μM isoorientin and 0.8 μM isoorientin 2-O-α-L-rhamnoside (Park *et al.* 2007). Ethanol extracts of 17 species of bamboo leaves belonging to 6 genera were found to contain flavonoids and phenolic acids and had strong antioxidative and free radical scavenging activity. The extraction rate, total flavonoid and total phenol content were 16.08±3.59% 1.97±0.57% and 4.21±1.05% of dry leaves respectively and IC_{50} on $O^{\cdot 2-}$ and ·OH scavenging were 4.93±2.36 μg/ml and 1.48±0.91 mg/ml (on dry weight basis) (Zhang and Ding 1996). Tricin (5,7,4'-trihydroxy-3',5'-dimethoxyflavone) occuring in its glycosidic form in rice bran and other grass species such as wheat, barley, and maize is considered safe for cancer prevention (Jiao *et al.* 2007). Tricin (3.09 g) was prepared from 174 g of a crude column chromatography fraction obtained from 5 L of AOB (Jiao *et al.* 2007).

Three chlorogenic acid derivatives, one known and two novel, namely, 3-*O*-(3'-methylcaffeoyl) quinic acid (1), 5-*O*-caffeoyl-4-methylquinic acid (2), and 3-O-caffeoyl-1- methylquinic acid (3) were isolated from bamboo (*Phyllostachys pubescens*). The butanol extract of the bamboo leaves was found to have a significant antioxidant activity. Compounds 2 (IC_{50} = 8.8 and 19.2 μM) and 3 (IC_{50} = 6.9 and 14.6 μM) showed ~2–4 times higher antioxidant activity than did chlorogenic acid (IC_{50} = 12.3 and 28.3 μM), caffeic acid (IC_{50} =13.7 and 25.5 μM) and ferulic acid (IC_{50} = 36.5 and 56.9 μM). Compound 1 yielded the weakest antioxidant activity (IC50 = 16.0 and 29.8 μM). All three compounds exhibited stronger superoxide anion ($O_2^{\cdot -}$) |scavenging activities (IC_{50} = 1, 4.3 μM; 2, 2.8 μM; and 3, 1.2 μM) than ascorbic acid (IC_{50} = 56.0 μM), α-tocopherol (IC_{50} > 100 μM), and other test compounds (Kweon *et al.* 2001). Solvent-extracted bamboo leaf extract (BLE) of the species (*Phyllostachys nigra* var. henonis) containing chlorogenic acid, caffeic acid, and luteolin 7-glucoside exhibited a concentration-dependent scavenging activity of DPPH radical, suppressed the rate of propagation of liposome peroxidation, prevented human low-density lipoprotein oxidation, mediated by Cu^{2+} and finally protected supercoiled DNA strand against scission. Prooxidant activity of BLE was seen in a Cu^{2+}-induced peroxidation of structured phosphatidylcholine liposome, indicating catalytic peroxidation due to a relatively high reducing power of BLE (Hu *et al.* 2000).

The antioxidant capacities of essential oils from leaves of the 15 bamboo species was evaluated using the DPPH assay. The antioxidant capacity of essential oil obtained from *Bambusa multiplex* (IC_{50}=3.605 mg/mL) was greater than that from *Brachystachym densiflorum* (IC_{50}=12.128 mg/mL).The IC_{50} value of *Dendrocalamopsis oldhami* was 4.464 mg/mL. A positive correlation between antioxidant capacity and the concentration of essential oils is indicative for their antioxidative activity (Yue-jun *et al.* 2010).

The bamboo leaf extract of *Phyllostachys praecox* could scavenge the DPPH free radical with an IC_{50} value of 7.02 mg /l of the leaf extract and could significantly protect DNA from damage when the concentration is higher than 400 mg/L (Liu *et al.* 2009). Bamboo leaf extract had a strong antioxidative activity and was found to be as good as that of vitamin C (Yao *et al.* 2000). Bamboo extracts (*Phyllostachys nigra* var. henonis) had dose-dependently antioxidant activity in DPPH, NBT/XO and intracellular ROS assay. Bamboo extracts of *Phyllostachys* species inhibited xanthine oxidase (XO) directly. Bamboo extracts inhibited not

only purified tyrosinase activity but also inhibited melanin production in B16 melanoma cells stimulated by 1 ?M ?-MSH. Bamboo extracts may thus be useful for the development as whitening agents reducing cytotoxicity (Song *et al.* 2007)

Absolutely Hemicellulose Senanensis (AHSS), a novel extract from Sasa senanensis showed antioxidative activity and inhibited the intestinal rat ischemia and subsequent reperfusion I/R induced production of lipid peroxide. Thus, AHSS could be an important source of ingredients for use in functional foods and other applications in protecting against oxidation as in cancer, heart diseases, stroke etc. (Kurokawa *et al.* 2006).

Pharmaceutical potential

Bamboo leaves and cancer

Bamboo leaves of different Sasa species have been widely used in food and medicine in Eastern Asia for hundreds of years. Of special interest are Kumai-zasa (*Sasa senanensis* Rehder) leaves used to prepare an alkaline extract known as Sasa Health. Chronic treatment for 12 days with Sasa Health, in drinking water at the concentration of 0.044%-0.088% Fe-Chlorophyllin Na resulted in the significant inhibition of both development and growth of spontaneous mammary tumours in a high mammary tumour strain of SHN virgin mice. Results indicated that Sasa Health could be a promising agent for the protection and therapy of breast and other types of tumours (Tsunoda *et al.* 1998). In another study the efficacy of Sasa Health (in hot water at 100, 121 and 196ºC) was tested in mouse tumor models (S-180, C38 and Meth-A) for anti-tumor activity. Oral administration of the extracts at concentrations of 0.05% or higher significantly suppressed tumor growth in S-180 and C38 tumor models. Overall survival was significantly prolonged in the treatment group than that of control. The extracts resolved into three major fractions (F-I, F-II and F-III) out of which Fraction F-I consists of 1,3-beta-glucan and stimulated both macrophages and NK cells suggesting that it may be the primary immunopotentiating factor in suppressing cancer. Fraction F-III has potent free radical scavenging effects and may play an important role in cancer prevention. (Seki *et al.* 2008).

Two cohorts of Her2/NeuN female mice of different age (eleven-week-old and twenty-four-week-old) chronically treated with Sasa Health in drinking water showed both a delay in the development of tumors and reduced tumor multiplicity. Sasa Health also induced inhibition of mammary duct branching and side bud development in association with reduced angiogenesis indicating that it contains phytochemicals which retard spontaneous mammary tumorigenesis (Ren *et al.* 2004). Methanol extract of bamboo leaves induced rapid apoptosis in the human leukemia CMK-7 cell line. The active compounds are 201-hydroxypurpurin-7 delta-lactone ethyl methyl diester (1) and the corresponding methyl phytyl diester (2). The apoptosis by compound 1 (0.3 to 0.1 μM for CMK-7 cells) was enhanced when the culture was briefly irradiated with a fluorescent lamp suggesting it to be a promising compound as photosensitizers for photodynamic therapy in cancer treatment. Compound 2 was a weaker inducer of apoptosis than compound 1. The apoptosis occurred after light irradiation (Kim *et al.* 2003).

Plasmic malondialdehyde (MDA) content was found to decrease whereas superoxide dismutase (SOD) activity increased in rats consuming BLE (bamboo leaf extract) indicating its free-radical scavenging activity in mice bearing carcinoma (Li *et al.* 2010). Possibility of bamboo in the treatment of leukemia became clear when treatment of human myeloid leukemia HL-60 cells with 50-400 μg/mL acetone fraction of bamboo leaf for 72 hr significantly inhibited cell proliferation and induced a little increase in cell differentiation and nitroblue tetrazolium reduction assay. Synergistic induction of HL-60 cell differentiation was also observed when the acetone fraction of bamboo leaf was combined with either 5 nM 1,25-dihydroxyvitamin D (1,25-(OH)(2)D(3)) or 50 nM all-trans retinoic acid (RA). These results suggest that the acetone fraction of bamboo leaf enhanced leukemia cell differentiation and suggest a possibility of bamboo in the treatment of leukemia (Kim *et al.* 2007)

Bamboo and diabetes

Diabetes mellitus (DM), a global public health problem, is now emerging as an epidemic world over. According to a widely accepted estimation, the prevalence of diabetes for all

age-groups was 2.8% in 2000 and the number of diabetic patients is expected to reach 4.4% i.e. 366 million by the year 2030 (Wild *et al.* 2004). Diabetes is a metabolic disease which affects not only the glucose metabolism but also lipid and protein metabolism. There are mainly two types of diabetes – Type 1 and Type 2. In Type 1 or Insulin Dependent diabetes, the hormone insulin is not produced in the absence of pancreatic ß-cells while Type 2 diabetes mellitus (T2DM) is characterized by a progressive impairment of insulin secretion by pancreatic ß-cells and by a relative decreased sensitivity of target tissues to the action of this hormone (Kaushik *et al.* 2010).

When 50 diabetic mice were given different doses of polysaccharide from hairy bamboo, moso bamboo leaves (PMBL), it was found to possess a good hypoglycemic effect and it reduced significantly water and food intake and alleviate the weight loss of diabetic mice (Ding et al 2007). Patty prepared with 2.5% of the water extract of bamboo leaf (*Sasa borealis*) substituted for the meat in ten healthy adult women significantly lowered plasma glucose concentrations indicating bamboo leaf or powder may improve blood glucose (Hyun and Hyeon-Sook 2009). *Sasa borealis* water-extract (SBwE) modulated the high glucose–triggered mitogen-activated protein kinase–dependent upregulation of heat-shock proteins. Moreover SBwE suppressed these detrimental effects caused by PKC-dependent peroxynitrite formation via activation of NADPH oxidase and induction of nitric oxide synthase and heat-shock protein family that may be essential mechanisms responsible for increased apoptotic oxidative stress in diabetic vascular complications (Choi *et al.* 2008). A flavone, luteolin 6-C-(6"-O-trans-caffeoylglucoside) isolated from black bamboo leaves (*Phyllostachys nigra*) was found to show a strong aldose reductase, advanced glycation endproducts inhibition and showed antioxidative activity and thus can be thought as a new natural drug for diabetic complications (Jung *et al.* 2007)

Bamboo leaves and cardiovascular disease

With industrialization, the major causes of death and disability, in the more advanced societies, have shifted from a predominance of nutritional deficiencies and infectious diseases, to those classified as degenerative (chronic diseases such as cardiovascular disease (CVD), cancer, and diabetes). This shift has been termed "the epidemiologic transition" (Yusuf *et al.* 2001).

Reduction in blood viscosity, plasma viscosity and increase in the speed of electrophoresis time in blood adhesion model occurred in sixty rats when given different doses of Bamboo Leaf extract BLE (15 mg/kg, 30 mg/kg and 60 mg/kg). BLE at different concentrations of 22.5 mg/kg, 45 mg/kg, and 90 mg/kg could significantly reduce serum cholesterol of the high cholesterol's mice (Fu *et al.* 2005a). Extract from bamboo *Phyllostachys pubescens* showed protective effect against palmitic acid (PA)-induced lipoapoptosis (Panee *et al.* 2008). Tests done on rats showed that Bamboo beer, produced by fortifying BLE, rich in flavanoids lowered concentration of blood triglyceride and cholesterol significantly. Furthermore, it also elevated HDL-cholesterol and decreased LDL-cholesterol depending on dosage level (Zhang *et al.* 2000).

Orientin (0.5, 1.0 and 2.0 mg /kg) from bamboo leaves (*Phyllostachys nigra*), exerts a potent cardioprotective effect on ischemia/reperfusion (I/R), and hypoxia/reoxygenation (H/R) treated myocardium and cardiomyocytes, and inhibits apoptosis by preventing activation of the mitochondrial apoptotic pathway (cytochrome c - caspase-3 pathway) (Fu *et al.* 2006). Orientin, also relaxed phenylephrine-induced contractions with an IC50 value of 2.28 μM in the endothelium intact and with an IC_{50} value around 7.27 μM in the endothelium removed aortic rings of rabbit. Furthermore, Orientin inhibited norepinephrine (NE), $CaCl_2$ and KCl-induced vasoconstriction, concentration dependently in, and also reduced both the initial fast release and the sustained phases of phenylephrine-induced contractions. Orientin also increased cyclic guanosine 3,5-cyclic monophosphate (cGMP) levels without changing in adenosine-3',5'-cyclic phosphoric acid (cAMP) in rabbit aorta. The inhibition of both intracellular Ca^{2+} release and extracellular Ca^{2+} influx may be one of the main vasorelaxant mechanisms of Orientin (Fu *et al.* 2005b).

Bamboo and aging

A number of evaluations done on bamboo-leaf-flavonoids (comparable to the tea polyphenols and the *Ginkgo biloba* extract) was found to be

anti-free radicals, anti-oxidative, and anti-radiation and anti-inflammatory. It significantly accelerated the proliferation of two kinds of rat skin cells and inhibited the pigment synthesis at a concentration of 0.005% to 0.05%. Hence bamboo-leaf-flavonoids have potential as anti-aging product to protect skin in cosmetics (Zhang et al 2004). Bamboo leaf-extract of *Phyllostachys nigra* var. henonis showed anti-aging effect by inhibiting the post-oxidation of lipid and scavenge post-oxidated products of aged mice (Zhang and Tang 1997).

Bamboo leaves and fatigue

Administration of an 80% ethanol extract (PJE) of the leaves of *Pseudosasa japonica,* one of the major bamboo species in Korea, lead to a 1.5-fold increase in swimming time of mice, compared to the control group. The blood lactate level, an important indicator of fatigue was significantly lower (28%, $P<0.05$) in PJE group than in the control group suggesting that PJE possesses stimulatory effects that can enhance exercise endurance and reduce fatigue (Yanghee *et al.* 2006). Effect of the bamboo leaf-extract of the species *Phyllostachys nigra* var. henonis showed that it could enhance the capacity of anti-fatigue and resistance to nonspecific irritation in mice (Zhang and Tang 1997).

Bamboo leaves and Anti-inflammatory activity

Inflammation is a protective reaction against a variety of exogenous (microbial, chemical, physical) or endogenous (immunological, neurological) disturbances, which is characterized by the accumulation and activation of leukocytes in the affected tissue (Baggiolini and Dahinde 1994).

Methanol extract of the leaves of *Bambusa arundinacea* have been shown to possess anti-inflammatory effect on carrageen induced as well as immunologically induced paw oedema and antiulcer activity in albino rats (Muniappan and Sundararaj 2003).

Conclusion and Future Scope

Bamboo being the fastest growing grass has a potential to become man's favorite plant in view of its contribution to the environment, construction, food and fodder sectors. Bamboo leaves contribute as a source of fodder for ruminants in scarcity of pasture. Toxicity tests on animal models and sensory evaluation studies done on AOB indicate its safe use within specified limits as a food additive. Mainly four flavonoids namely orientin, homoorientin, vitexin and isovitexin have been isolated from bamboo leaves.

A number of studies done by various investigators on the antioxidant potential of alcoholic extract of bamboo leaves reflect its huge potential in scavenging free radicals, although a lot needs to be explored through scientific validation and experimentation. Bioactivity of bamboo leaves and their potential health benefits have been widely studied by various researchers. Studies showing positive correlation between flavonoids present in bamboo leaves and prevention of cancer, diabetes, heart diseases etc. are still scarce. Bamboo leaves thus exhibit a great potential as a raw material to the nutraceutical and pharmaceutical industry for future investigations.

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