



Antioxidant and nutraceutical potential of bamboo: an overview

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Abstract

The mention of the traditional use of bamboo in Asian medicine dates back to the 6th century. Today people are switching over the use of herbal medicine instead of the synthetic drugs and bamboo, the 'Green gold' has voluminous nutraceutical properties and thus forms a core ingredient for research in many laboratory. Scientists from round the globe are exploring bamboo for establishing its pharmacological mechanism and also record the individual constituents responsible for it. This review summarizes published information on the historical uses, nutritional composition of various parts together with the antioxidative potential and the possible role and mechanism of action of these phytochemical components with regards to the antimicrobial, anti-diabetic, anti-cancer, anti-inflammatory, anti-obesity, anti-fatigue, anti-lipidemic effect along with effects on the cardiovascular diseases of this 'Green gold'.

Keywords: Anti-cancer, anti-diabetic, anti-inflammatory, antioxidants, bamboo, nutraceutical, phytochemical

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1. Introduction

Bamboo is the name given altogether 1575 species¹ of perennial evergreen plants that belongs to the subfamily Bambusoideae of the true grass family Poaceae². Bamboo is naturally distributed throughout the globe. Major species of bamboo is found in Asia Pacific and South America but much less in Africa³. India is a home for about 136 indigenous and exotic species that grow naturally and/or under cultivation⁴. Northeastern states like Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Sikkim along with the state of West Bengal (North Bengal, Himalaya) houses over 50% of the total bamboo species recorded in India⁵. Popular among the common people as "Poor man's timber" since ancient times, because of its innumerable applications has attained the status of "Green Gold of forests"^{6,7}. Today bamboo constitutes one of the most important renewable natural resources of India. The use of bamboo is not only restricted as structural and building materials but with the advent of time has become an important component of the rural industries⁸. From ancient time bamboo has been an important ingredient of traditional Asian Medicines in general and Chinese medicine in particular. Modern scientific approaches are now used to validate the traditional uses and researchers

from round the globe have been successful in isolating active chemical constituents from different parts of this green gold. They also provide an insight into the potential health benefits of bamboo parts. The present paper explores the bioactive components recorded in different bamboo species worldwide along with its nutraceutical potential.

2. Historical uses of bamboo

Popularly known as "Poor man's timber", bamboo has been closely associated with Asia as an important resource. Today bamboo is globally recognized as an important asset in eradication of poverty, economic and environmental development and thus leading to change its image to "Green Gold". Throughout the globe bamboo meets the basic requirements of the common people. Bamboo is closely associated with indigenous culture and knowledge not only in Asia but also in Africa and Latin America. There are over 1500 documented uses of bamboo worldwide⁹. In fact bamboo is valuable from top to rhizomes. Bamboo has multifarious uses and serves as a superior material for constructions, utensils, weapons, fuel, fodder, food, firewood, furniture, mats, chop sticks, tooth picks, handicrafts, musical instruments and many more¹⁰. It is extensively used in the paper and pulp industries. With the development of science and technology, the uses of bamboo have also developed. Today bamboo is used in making hard boards, flooring, corrugated sheets etc.¹¹ and thus can serve as a replacement of wood. Apart from this the shoots of bamboo are used as delicacy because of their high nutritive values^{12,13}. The shoots are used in many exquisite culinary preparations like pickle, vegetables, soup, salads, vinegar and several other forms in different countries¹⁴.

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3. Proximate Physicochemical composition/ Nutritional values of different parts of bamboo

3.1 Leaf: Studies conducted on bamboo leaf have shown that leaf is highly nutritive and contains important raw materials like crude protein, crude fiber, ash and other minerals. Leaves were found to be rich in calcium, magnesium, copper, and manganese; moderate in zinc, while poor in phosphorous, potassium and sodium¹⁵.

3.2 Seeds: Bamboo seeds are rich in various nutrients. The seeds have a good profile of minerals like calcium, phosphorous, iron. These are good source of vitamin B₁, nicotinic acid, riboflavin, carotene. Seeds are rich in carbohydrates (73.4%), crude protein (12%), fiber (2.6%), ash (1.1%) and moisture (10%)¹⁶.

3.3 Shoots: The shoots are rich in proteins, saccharides, amino acids, minerals, low in fat, inorganic salts and the water content may be as high as 90% (table I). Shoots are rich in dietary fiber and low in calories¹⁷.

However, the quantification of many components such as vitamins, minerals, and other pharmacological properties has to be evaluated in detail.

Table I: Nutritive value of bamboo shoots (modified from Chongtham *et al.*¹⁷ and Hu⁷⁴)

Constituents	Amount
Moisture	90 g
Protein	2.65 g
Fat	0.49 g
Saccharine	2.50 g
Soluble saccharine	1.53 g
Coarse fiber	0.58 g
Ash	0.88 g
Phosphorous	60 mg
Iron	0.8 mg
Calcium	12.8 mg

4. Bamboo and human health

The use of bamboo as traditional medicine by the Chinese dates back to some 2500 years. They used the bamboo leaves, branches, shoots, seeds, roots and juice to treat phlegm, cooling fever, laryngitis, rhinorrhagia (nose bleed) and vomiting. Thus it can safely be asserted that each part of bamboo is not only a treasure but also a medicine (figure 1).

The use of bamboo is endless and because of this it is an indispensable resource for the rural people.

4.1 Antioxidant potential of bamboo

In the process of economic development, with the increase in income, human society tends to care more about their health. Therefore, demand for healthy herbal organic foods developed from various plants has also increased. Production of more efficient and productive food items by the researchers are on demand. One such plant with multiple qualities is bamboo.

Bamboo has been used over centuries by the humans both in daily life and for medicinal purpose in China and other Asian countries. The earliest scientific evidence of use of bamboo in

traditional medicine dates back to 1963¹⁸. This marked the beginning of the use of bamboo as medicine which was followed by series of research carried out by different workers since then¹⁹⁻³¹. Bamboo has attracted attention world over due to its high antioxidant content and therapeutic effects on inflammation, fatigue, cancer, hyperlipidemia, diabetes, aging and hypertension.

Free radicals might occur either by the accidents of chemistry or due to specific metabolic purpose in the body. The free radicals produced by either way have different reactivity with some leading to damage to biomolecules such as DNA, lipids and proteins³². Antioxidants can react with free radicals during the oxidation process by acting as a reactive species scavenger and liberating catalysts, so antioxidants can be used to reduce the oxidative process³³ but they are not 100% effective. Mere large doses of diet-derived antioxidant was thought to be important to stay healthier for long time, but with the passage of time and development of science and technology the supply of 'pro-oxidants' is thought to be a better option³⁴. Bioactive compounds like ascorbic acid, carotenoids, tocopherols and phenols are antioxidants.

The bamboo leaf extract (BLE) is thought to be good source of natural antioxidants and also have great pharmaceutical potential³⁵⁻⁴³. BLE is mainly composed of flavonoids, lactones and phenolic acid. The flavonoids are represented mainly by the flavones C- glycosides which include homoorientin, isovitexin, orientin and vitexin. Apart from this quercetin, luteolin, rutin, caffeic acid, *p*-coumaric acid, chlorogenic acid and tricetin are also present⁴⁴ (table II). The flavonoid content was recorded to be 3.44% in different bamboo leaves species¹⁵.

4.2 Antimicrobial activity of bamboo

Plants are rich sources of various phytoconstituents which possess different medicinal properties against different microbes and bamboo is no exception. In 2010, Singh *et al.*⁴⁵ studied the antimicrobial activity of the aqueous and ethanolic leaf extracts of *Bamboosa arundinaceae* against *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aureginosa* and *Bacillus* sp. The ethanolic extract was found to be more effective in inhibiting the microbes compared to aqueous extract against the standard penicillin. Later, Tanaka and his co-researchers⁴⁶ studied the antibacterial activity of *Phyllostachys pubescens* shoot skin (untreated and dichloromethane extract) against *Staphylococcus aureus*. They found that both the extracts could inhibit the growth of *S. aureus* and thus possess antibacterial activity. In 2012, Mulyono *et al.*⁴⁷ evaluated the antibacterial activity of *Dendrocalamus asper* against *E. coli*. They found that of the three different extract types (ethanolic, methanolic and methanol-ethanolic) ethanolic and methanol-ethanolic proved to be potential source of antimicrobial drugs. Recently in 2013, Mulyono and his team⁴⁸ also studied the antibacterial activity of *Gigantochloa apus* against the diarrheagenic *E. coli*. As per their results, they noted that *E. coli* was sensitive to both the ethanolic and methanolic extracts but in a concentration dependant manner.

4.3 Validated nutraceutical potential of bamboo

4.3.1 Anti-diabetic effect:

Diabetes Mellitus (DM) is prevalent among almost 200 million

people worldwide, which is thought to increase exponentially to 300 million in the next two decades, type 2 being common⁴⁹.

In the study conducted by Ding and his coworkers⁵⁰ with moso bamboo leaves on 50 diabetic rats, they evaluated that different doses of polysaccharide were found to possess good hypoglycemic effect. Hyun and Hyeon-Skoog⁵¹ in their experiment with *Sasa borealis* leaf extract found that when substituted for meat in patty the leaf extract significantly lowered plasma glucose indicating anti diabetic activity of BLE. The anti diabetic activity of *Sasa borealis* leaf extract was also studied by Choi and his co workers⁵². The inhibitory effect of the leaves of *Pseudosasa japonica* was evaluated on high fat diet induced obesity and diabetes in C57BL/6J mice. All the mice had access to high fat diet for a week and then switched over to either the bamboo extract diet or control diet. The mice were regularly monitored for their daily intake of food and weight gained. Though the food intake of mice assigned to bamboo extract was found to be slightly higher than the control, but the weight gain was however restricted in mice on bamboo extract compared to control⁵³. In 2011, Senthilkumar and others⁵⁴ made an attempt to scientifically prove the anti-diabetic activity of the petroleum extract of the leaf of *Bambusa vulgaris* in streptozotocin induced diabetic rats. They found that oral administration of the extract for a period of 15 days was effective in significantly reducing the

blood glucose level in a dose dependant manner when compared to the standard drug glibenclamide. Nam and his team⁵⁵, recently in 2013, reestablished the exact mechanism by which the leaves of *Sasa borealis* exhibit the anti-diabetic activity. In their experiment they found administration of *S. borealis* extract in STZ-induced diabetic mice increased insulin signaling together with phosphorylation of AMP-activated protein kinase (AMPK) in HepG2 cells. In addition to this the extract also increased glucose uptake and suppressed the expression of gluconeogenic genes. They thus inferred that *S. borealis* extract exerted the anti-diabetic effect through the activation of AMPK and improvement of insulin signaling.

4.3.2 Bamboo in cardiovascular diseases:

With modernization and industrialization the number of death and disability due to chronic heart diseases such as cardiovascular disease, diabetes etc has surpassed the death and disability due to nutritional deficiencies and infectious diseases⁵⁶. Fu and his co researchers⁵⁷ experimentally proved that when the high cholesterol mice were treated with different concentrations of BLE, there was great reduction in the serum cholesterol. *Phyllostachys pubescens* leaves proved to have protective effect against palmitic acid induced lipo apoptosis⁵³. Experiments conducted on rats showed that flavonoids rich bamboo beer could significantly lower the blood triglycerides and cholesterol. Apart from this the beer could elevate HDL-cholesterol and reduce LDL- cholesterol in a dose dependant



Figure I: Principal therapeutic effect of bamboo

manner⁵⁸. The cardioprotective potential of flavone C-glucosides i.e. Orientin obtained from the leaves of *Phyllostachys nigra* has been proved by Fu and his co workers⁵⁹. They also stated that it could also inhibit apoptosis by blocking the mitochondrial apoptotic pathway.

4.3.3 Anti-cancerous effect:

The leaves of *Sasa senanensis* (popularly known as Kumaizasa) have been used in Eastern Asia as a potential source of natural drug since hundreds of years. The alkaline extract prepared from the leaves (in hot water at 100°C) of *S. senanensis* is popularly known as "Sasa health". Tsunoda et al.²¹ from their experiment on mammary tumor strain of SHN virgin mice proved that oral administration of Sasa health for 12 days could significantly inhibit both the development and growth of mammary tumor in experimental models. In 2008, Seki and his team³⁰ also made an attempt to prove the anti-tumor activity of Sasa health. They used three different temperatures (100°C, 121°C and 196°C) to prepare the Sasa health to evaluate the anti-tumor potential in three mouse tumor models (S-180, C38 and Meth-A). Oral administration of the extract a concentration of 0.05% or more was found to be effective in suppressing tumor growth in mouse models S-180 and C38. The extract also accelerated immunostimulating activity, which in turn activated the macrophages and human natural killer (NK) cells in tumor models and thus suppress the tumor. Panee⁵³ conducted experiment to test the effect of leaves of *Pseudosasa japonica* on the development of DMBA (7,12-Dimethylbenz[a]anthracene) induce breast cancer in SD (Sprague-Dawley) rats. He found that oral administration of bamboo extract for 3 weeks prior to DMBA injection could delay the onset of breast cancer by one week as compared to the control. Moreover, the bamboo extract also showed the potential of decreasing the incidence of occurrence of tumor by 44% and restricting the growth rate of the tumor by 67% after 11 weeks of DMBA treatment. In 2010, Seki and Maeda (2010), Seki et al. (2010) and Lu et al. (2010) studied the anti cancer/tumor activity of *Kumaizasa* bamboo, *Sasa senanensis* and *Caulis bamfusae*. In their study, Seki and Maeda (2010) tested the cancer preventive effect of aqueous extract of *Kumaizasa* bamboo both prior to tumor implantation and also after inducing of carcinogenesis using DMBA in experimental mouse. They found that the *Kumaizasa* bamboo was effective against both the cases and could significantly suppress the incidence of tumor growth and enhanced survival rate on one hand and the extract at the rate of 0.03% fed for two weeks could significantly suppress the cancer. In the same year, the anti tumor activity of *Sasa senanensis* leaf extract was experimented using three different mouse tumor models viz. S-180, C38 and Meth-A by Seki and his team⁶⁰. Oral administration of the extract at a concentration of 0.05% or more was found to significantly reduce the tumor growth in mouse models S-180 and C38 and also prolonged the survival rate compared to the control. Lu and his co-researchers⁶¹ were successful in establishing that the savings of *Caulis bamfusae* had the potential to inhibit the growth of cancer cell lines (P388 and A549) and also notably inhibit the tumor growth on sarcoma-loaded mice model S180 compared to standard cyclophosphamide. Apart from this they also isolated a compound named friedelin and proved its efficacy as anti tumor compound against cancer lines, A375, L929, HeLa and THP-1. Recently in 2013, the ethanolic leaf extract of *Sasa*

quelpaertensis has also been reported to exert potent cytotoxicity activity against human colon cancer HCT116 cells by Kim et al.⁶².

4.3.4 Anti-fatigue effect:

Leaf extract of *Phyllostachys nigra* var *henonis* have been reported to enhance the anti-fatigue capacity in mice⁶³. You and his coworkers⁶⁴ found that oral administration of 80% ethanol extract of *Pseudosasa japonica* leaf for 18 days could drastically increase the swimming time in experimental mice up to one and half folds and simultaneously reduce the blood lactate and elevate the removal of lactate suggesting its potential to reduce fatigue compared to the control group. In 2006, an attempt was also made to study the anti-fatigue activity of *Bambusa tuldoidea* using BALB/c mice models by Zhang and his team⁶⁵. They found that the extract at an appropriate concentration not only could prolong the weight-loaded swimming and climbing time but also exerted active effect on the serum urea nitrogen, hepatic glycogen and blood lactic acid level in BALB/c mice thus personified its anti-fatigue activity.

4.3.5 Anti-inflammatory effect:

In 2003, Muniappan and Sundararaj⁶⁶ validated that the methanol extract of *Bambusa arundinacea* was effective against both carrageenin induced and immunologically induced paw oedema in albino rats compared to standard drugs. They also proved that the extract in combination with phenylbutazone (a non-steroidal anti-inflammatory agent) was more effective in comparison to when used individually. They thus concluded that the natural product together with modern medicine can result in the development of the most suited anti-inflammatory drug.

Hwang and his co-researchers⁶⁷, provided scientific evidence to the traditional use of *Sasa quelpaertensis* leaves for the treatment of inflammation related diseases. They documented the hot water extract of *S. quelpaertensis* could ameliorate inflammation related diseases by suppressing nitric oxide production in pathological event.

Methanol extract of the leaves of *Bambusa vulgaris* have been shown to possess anti-inflammatory activity against the various anti-inflammatory tests performed which includes formaldehyde induced rat paw edema, acetic acid induced vascular permeability test, carrageenan induced peritonitis and cotton pellet granuloma in albino rats⁶⁸.

4.3.6 Anti-obesity effect:

Obesity, characterized by the deposition of excessive fats in the adipocytes is considered to be a major obstacle in efforts to improve human health⁶⁹.

Yang et al.⁷⁰ studied the effect of *Sasa borealis* leaf extract (SBE) on inflammatory cytokines and insulin resistance in high fat diet (HFD) induced obese mice. They found that the *S. borealis* leaf extract was effective at just 5% when administered for 12 weeks. After 12 weeks treatment they recorded that the body weight and the adipose tissue deposition were decreased significantly compared to untreated HFD mice. They also found decrease in glucose, insulin, IAUC, HOMA-IR, TNF- α , IL-6 and leptin levels. These results justified that SBE contains anti-obesity compounds. It was in 2012 that Kang and his

researchers⁷¹ made an attempt to explore the anti-obesity effect of *Sasa quelpaertensis* leaf extract (SQE) in high fat diet (HFD) induced obese mice and mature adipocytes. They noted that the administration of SQE for 70 days to HFD mice not only decreased the body weight, adipose tissue weight, serum cholesterol and triglycerides but also reduced the serum levels of several enzymes along with deposition of lipid droplets in the liver when compared to untreated mice. They finally concluded that the anti obesity effect of SQE is mediated by the activation of AMPK in adipose tissue.

4.3.7 Anti-hyperlipidemic effect:

Alterations in lipid profile are one of the most common complications in diabetes mellitus and affects 40% of all diabetic patients⁷². The study was carried out by Ding and his team⁷³ to elucidate the anti-hyperlipidemic effect of polysaccharides from Moso bamboo leaves (PMBL). Mice were fed with high fat food to induce hyperlipidemia and then treated with PMBL in a dose dependant manner. The result revealed significant decrease in total cholesterol, tri-glyceride and low- density lipoprotein in serum together with decrease in crude fat in liver concluding PMBL exhibited could improve hepatic function in mice and possesses antihyperlipidemic

Table II: List of chemical compounds and their structure isolated from different bamboo species

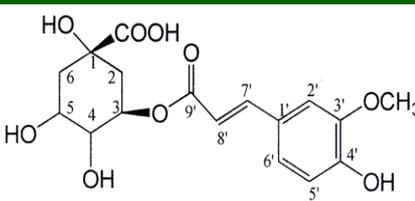
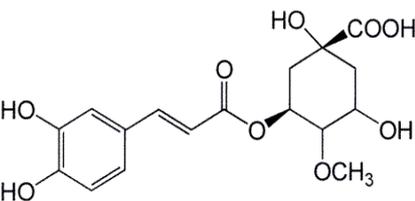
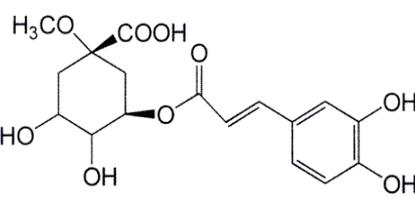
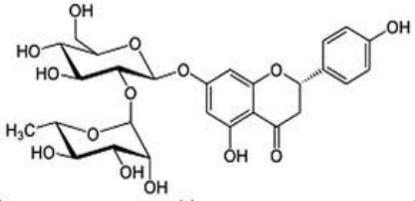
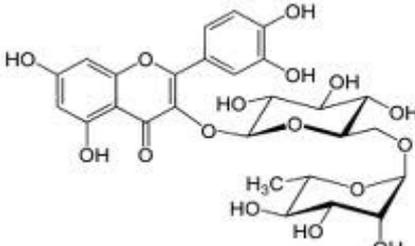
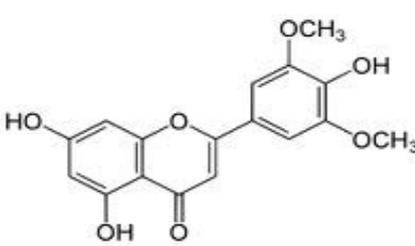
Plant name	Chemical compound	Chemical structure	References
<i>Phyllostachys edulis</i>	3-O-(3'-methylcaffeoyl) quinic acid		Kweon et al. ²³
	5-O-caffeoyl-4-methylquinic acid		
	3-O-caffeoyl-1-methylquinic acid		
<i>Phyllostachys nigra</i> var. <i>henonis</i>	naringin-7-rhamnoglucoside		Lu et al. ²⁷
	Rutin		
	Tricin		

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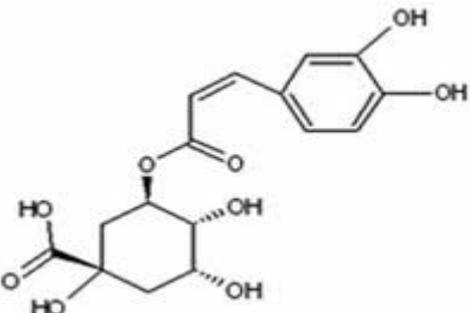
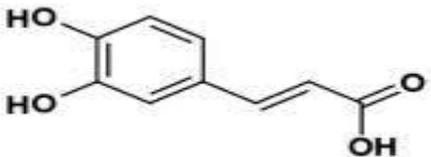
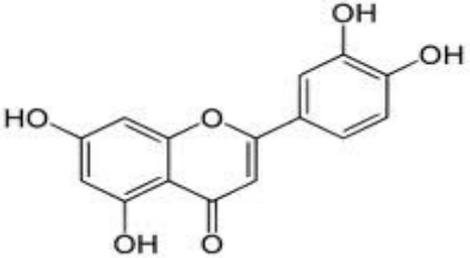
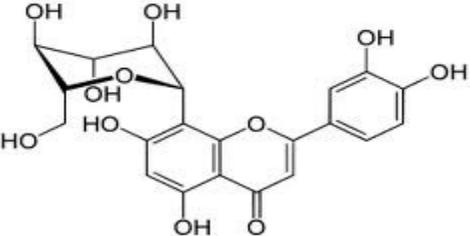
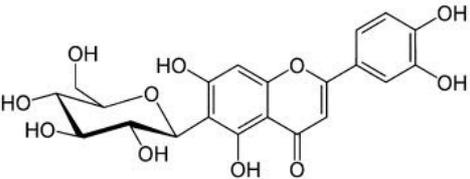
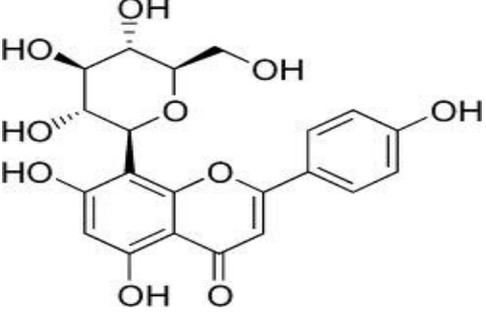
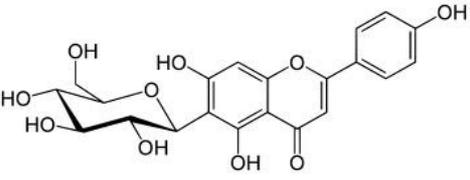
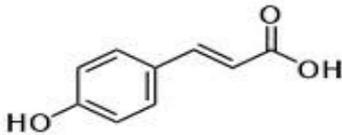
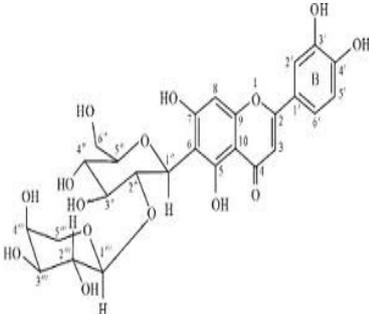
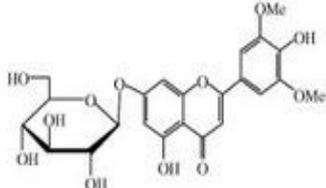
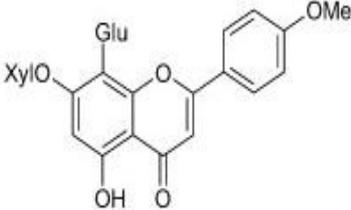
Plant name	Chemical compound	Chemical structure	References
<i>Phyllostachys nigra</i> var. <i>he-nonis</i>	Chlorogenic acid		
	Caffeic acid		
	Luteolin		
<i>Phyllostachys nigra</i> var. <i>he-nonis</i>	Orientin		Lu et al. ²⁷ ; Zhang et al. ^{75,76}
	Homoorientin		
	Vitexin		
	Isovitexin		

Table II continued to next page

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Plant name	Chemical compound	Chemical structure	References
<i>Phyllostachys nigra</i> var. <i>henonis</i>	p-coumaric acid		Zhang et al. ⁷⁶
<i>Sasa borealis</i>	isoorientin 2''-O-c~-L-rhamnoside		Park et al. ²⁹
	tricin 7-O-13-D-glucopyranoside		
	apigenin 6-C-13-D-xylopyranosyl-8-C-13-D-glucopyranoside		

activity.

4.3.8 Antihyperglycemic Activity

Middha and Usha (2012) reported *invitro* anti-diabetic study of bamboo species⁷⁷.

Conclusion

Leaves of different species of bamboo have been in use since long time not only as medicine but also as fodder. A number of studies have been done on animal models to judge the potentiality of bamboo leaf extract not only as food additive but also as medicine. The scientific validation and experiments clearly reveals that bamboo leaf is not only safe as food additive but also exhibit potential as raw materials to the pharmaceutical and nutraceutical industries. But a lot needs to be explored because the reports available are confined to some selected species of bamboo of the thousands that exists in nature.

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Conflict of interest

The authors declare no conflict of interest.

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