An Overview of the Potential Usage of Bamboo Plants in Medical Field

M. B. Noremylia, A. N. Aufa, Zarini Ismail, and Mohamad Zaki Hassan

Abstract Bamboo plants belong to the grasses family (Poaceae) and are one of the most important and valuable forest resources. This multipurpose plant contains a variety of different species. All different plant parts, such as roots, rhizomes, shoots, stems, leaves, and seeds, exhibit their own unique properties that can be used in biomedical applications. Bamboo plants have an important place in traditional Asian medicine, particularly in China and Japan. Since the 1960s, biomedical research on the toxicity and health benefits of various bamboo species and parts has been conducted worldwide. These studies have shown that bamboo has many health benefits and has been linked with the prevention of many diseases, including diabetes mellitus, hypercholesterolemia, hypertension, heart disease, and certain types of cancer. Besides that, bamboo also has antioxidant activity, antibacterial, anti-inflammatory, etc. Bamboos are known to have a diversity of constituents such as flavonoids, phenols, alkaloids, and coumarins, as determinant compounds for their bioactivity. These biodegradable materials could substitute several typical, non-biodegradable materials with comparable characteristics and performance as biomaterials. Since bamboo plant constituents are part of the physiological function of living flora, they are more compatible with the human body. This chapter reviews the potential usage of bamboo plants in medical-related fields.

Keywords Diabetes mellitus · Cholesterol · Hypertension and cardiovascular disease antioxidants · Anti-cancer · Pharmaceutical purposes · Pharmaceutical purposes · Antibacterial properties

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1 Effects of Bamboo Consumption on Diabetes Mellitus

Insulin sensitivity is one of the main causes that may lead to the risk of developing diabetes mellitus [1]. Diabetes mellitus is well known as a chronic and progressive disease that has a lasting effect on the organs and tissues of the host [2]. Bamboo has been recommended as a functional food that offers health benefits in controlling the metabolic disease of the host gut microbes [3]. As shown in Fig. 1, Bamboo shoots are a potential prebiotic, which plays a significant role in gut health as well as anti-diabetic activities. This was mainly attributed to the phenolic components in bamboo leaves, such as orientin, homoorientin, isoorientin, vitexin, homovitexin, and tricin. However, the presence of cyanogenic glycosides makes them not suitable to be eaten raw.

As for usage in diabetes mellitus, various studies focus on improving the insulin sensitivity of bamboo shoots in vivo. A study by Li et al. [5] found that the bamboo shoot fiber (BSF) obtained from *D. hamiltonii* and *D. latiforus* demonstrated that the BSF had lower glucose-stimulated insulin concentration. This is due to the higher level of Akt (an enzyme of serine/threonine protein kinase) in the mice's tissue associated with a higher protein expression level of PGC-1α. The result showed that the BSF eventually improved the insulin sensitivity in the mice by activating the

Fig. 1 Bamboo shoots [4]

PGC-1α. A similar study by Zheng et al. [6] tested the bamboo shoot in both in vivo and in vitro studies to identify their hypoglycaemic properties. They found that the bamboo shoot fiber was able to reduce the oral glucose tolerance of the mice after 4 weeks of administration. Nevertheless, they demonstrated that the soluble dietary fiber of bamboo significantly increases blood insulin levels.

Bamboo is well known for its high content of carbohydrates. Some studies focus on bamboo polysaccharides, also known as polycarbohydrates. A study by Zheng et al. [7] shows extracted crude polysaccharides from the bamboo shoot shell and administered them in vivo dose-dependent on induced diabetic mice. The dose given was at ~400 mg/kg and they found that the dose eventually decreased the blood glucose level as well as serum triglycerides and total cholesterol down to 48.7, 34.8, and 26.5%, respectively. There were also decreases in weight loss of the mice, indicating that the bamboo shoot polysaccharides were able to act as an anti-diabetic agent. Li et al. [8] studied the correlation between the bamboo shoot fiber in preventing obesity as well as diabetes by modulating the gut microbiomes. The dietary fiber of the bamboo shoot reduced the obesity of high-fat mice after 6 weeks of in vivo study.

2 Bamboo Effects on Cholesterol, Hypertension, and Cardiovascular Disease

Bamboo has also been known as a herbal medicine for the treatment of hypertension due to its biological and therapeutic antioxidant properties. In addition, young bamboo shoot ingestion is said to aid in digestive improvement, hypertension relief, cancer prevention, and cardiovascular disease prevention, according to ancient Chinese medical texts.

Bamboo leaf flavonoids (BLFs) can significantly decrease the serum triglyceride level, increase high-density lipoprotein content, regulate blood lipids and reduce the risk of atherosclerosis, and have also displayed strong anti-oxidative, anti-aging, and anti-fatigue activities. A study by Fan et al. [9] demonstrated that bamboo is very effective in retarding lipid oxidation as well as preventing biogenic amine formation in pork sausage when combined with tea polyphenols. One study found that bamboo reportedly decreased the total cholesterol level in healthy young women when compared with controls on a dietary fiber-free diet [10]. A study by Jiao et al. [11] showed that bamboo shavings extract might lower serum levels of total cholesterol and total triglycerides, which are the primary contributors directly causing pathological alterations in cardiovascular illnesses. This is a result of the triterpenoid-rich bamboo shaving extract's anti-hyperlipidemic and anti-hypertensive effects as well as the vasodilator effects of friedelin on phenylephrine-induced vasoconstriction in rat thoracic aortas. Bamboo shoots contain silica, which is crucial for preserving the suppleness, permeability, and structural integrity of the arteries and controlling blood pressure. It may help lower blood lipids and cholesterol. It also improves

potassium's ability to reduce hypertension and calcium's ability to help regulate heartbeat.

Bamboo contains a very high concentration of vitamin C. Vitamin C is an antioxidant, reportedly, reducing the risk of arteriosclerosis and some forms of cancer. It is capable of neutralizing reactive oxygen species in the aqueous phase before lipid peroxidation is initiated. Nirmala et al. [12] demonstrated that the fresh shoots of bamboo contain vitamin C up to 5.00 mg/100 g.

Cho et al. [13] investigated the effects of bamboo oil on lipid metabolism. They found that the total cholesterol and triglyceride concentrations in the blood decreased with the increase of bamboo oil concentrations. The total cholesterol decreased from 139.6 to 80.4 mg/dL with the increase of bamboo oil concentration up to 8.0%. It might be expected from the study that bamboo oil is believed to have possible protective or curative effects for fatty livers and arteriosclerosis induced by the high-cholesterol diet. Kang et al. [14] extracted bamboo leaves from *Sasa quelpaertensis* and administrated them to mice. The study findings not only decreased the body weight, adipose tissue weight, and serum cholesterol but also reduced the deposition of lipid droplets in the liver compared to untreated mice.

High levels of cholesterol in the blood are a crucial problem as it is one of the risk factors for various non-communicable diseases such as heart disease, hypertension, and stroke. Vitamin E is a well-known fat-soluble antioxidant and can only be obtained through diets. Vitamin E shows protective effects against coronary heart diseases due to inhibiting low-density lipoprotein (LDL) oxidation. A study by Nirmala et al. [12] and Yang et al. [15] found that the content of Vitamin E in bamboo ranges between 0.50 and 0.90%. Makatita et al. [16] found that bamboo can reduce blood cholesterol levels. The study demonstrated that blood cholesterol was reduced after consuming bamboo. They concluded that the bamboo shoot was able to be used as an alternative medicine in controlling blood cholesterol levels.

A study by Fu et al. [17] found that the compound in bamboo, orientin, can prevent apoptosis in the myocardium and cardiomyocytes of the heart in experimental animal studies. This occurred by preventing the activation of the mitochondrial apoptotic pathway, making it a potential source for cardio-protective effects. However, a study by Chuang et al. [18] demonstrated that the consumption of bamboo shoots might be associated with hyperuricemia, which is the increased uric acid content that may lead to cardiovascular disease.

Some studies focused on the bamboo culm extracts, where it was found that ethanolic from the bamboo culm showed ameliorated risk factors for cardiovascular diseases in mice treated with an of high-cholesterol diet. According to Lee et al. [19], the bamboo culm extracts significantly improved hepatic antioxidant enzyme activities while positively reducing hepatic lipid peroxidation and protein carbonylation.

3 Antioxidants

Free radicals produced in our body play an important role in the development of produced in our body and in developing many chronic diseases. Oxidative stress is a complex process characterized by the imbalanced production of free radicals and the ability of the body to eliminate reactive oxygen species through the use of antioxidants. The main antioxidants in bamboo leaves and shoots are flavonoids, phenols, and vitamins C and E [12, 20]. 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 tricin are also present. The flavonoid content was recorded to be 3.44% in different bamboo leaf species [21]. In the case of antioxidant protection, flavonoids stand as one of the most efficient molecules in combating oxidative stress and are used for the treatment of cardiovascular illness [22].

The antioxidant of bamboo leaves was certified to be a natural antioxidant due to the presence of bioactive compounds. It has been reported to possess strong antioxidant activity and inhibit the free radical-induced deterioration of macromolecules in vitro [23]. Besides, bamboo leaves oxidants have also been identified as having therapeutic potential due to their antioxidant effects [24]. A study by Gu et al. [25] found that the bamboo leaf inhibits antioxidants and anti-inflammatory abilities due to the senescence of HaCaT cells induced by AAPH in the 10–40 μg/mL of bamboo leaf. As illustrated in Fig. 2, the recovery of mitochondrial membrane potential increases demonstrating that the bamboo leaf contains the highest antioxidants where the mitochondria acts as an oxidative phosphorylation, which generates energy by utilizing the energy released during the oxidation of the food we eat.

Bamboo shoot is considered one of the health-promoting foods due to its high content of nutrients and bioactive compounds. It holds great promise as an additive for fortifying different food products. Bamboo shoot-fortified crispy salted snacks, commonly known as namkeen lead to a reduction in bioactive compounds with better qualities, as reported by Santosh et al. [26]. In a work by Singhal et al., they reported that the fermented bamboo shoot significantly increased in phenol and flavonoid content. Besides, the antioxidant capacity was also increased, indicating their potential to protect human health [27].

Vitamin C is well known as a potent antioxidant [28]. The content of vitamin C was evaluated by Rana et al. from fresh edible shoots of *Phyllostachys mannii* and the approximate content of vitamin C was found to be around 3.23 ± 0.05 mg/100 g FW [28]. However, the vitamin C from fermented bamboo shoots was decreased to 35.77% in a study reported by Singhal et al. [27]. Soesanto discovered that the highest content of Vitamin E is found in Apus bamboo shoots extract, 0.3284%. Furthermore, the Apus bamboo extract antioxidant activity is more active than other bamboo shoot species [29].

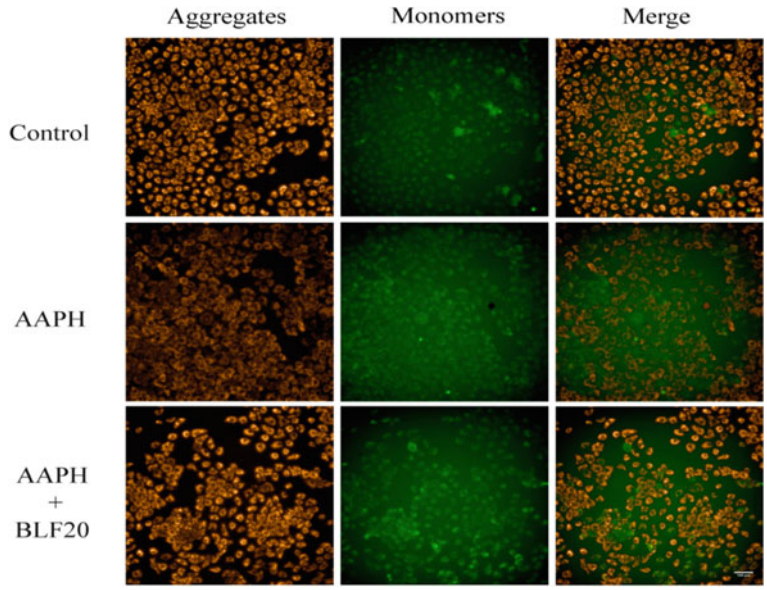

Fig. 2 Mitochondrial membrane potential of the bamboo leaf [25]

4 Anti-cancer

The consumption of bamboo shoots has been linked with the prevention of several chronic diseases, including certain types of cancer. Bamboo shoots contain several phytochemicals which have been proven to have potent anti-cancerous properties such as phytosterols, phenols, and dietary fibers [30].

Seki and Maeda found that the vigorous (multistep) extractions of bamboo leaves show more potent antitumor activity, in which they suppress tumor growth and prolong survival in mouse tumor models compared to the conventional extraction method [31]. In another work by Seki et al., similarly, they proved that Kumaiza bamboo extract had anti-cancer properties and might play an important role in cancer prevention [32]. Besides, Abdelhameed et al. clarified that methanol extract of the bamboo shoot skin *Phyllostachys heterocycle* stimulated apoptotic breast cancer cell death by 32.6-fold [33]. The bamboo salt soy sauce called Sarijang was utilized as a chemotherapeutic agent to control U937 human leukemia cells. The extract compounds triggered the apoptosis of U937 human leukemia cells through activating the intrinsic caspase pathway and the DR-mediated extrinsic pathway [34]. Kim et al. demonstrated that bamboo shavings (Bambusae Caulis in Taeniam, BCT) significantly reduced the metastatic activity of highly cancer cells by suppressing MMP-9 activity via inhibition of ROS-mediated NF-κB activation [35]. Additionally, bamboo-shaving polysaccharides (BSP) were identified as the most selective

polysaccharide inhibiting the growth of six gastric cancer cell lines while having no toxic effect on normal gastric mucosal cells. Similarly, BSP had a more potent killing effect on a subset of human stomach cancer cells than on liver or lung cancer cells [36].

5 Pharmaceutical Purposes

Bamboo salt and bamboo vinegar are some important bamboo-based pharmaceutical preparations that are now gaining importance. Some pharmaceutical products are cellulose, bioethanol, bio-methane, starch, charcoal, flavors, preservatives, and bamboo leaf tea [37].

Bamboo salt (BS) is a processed salt produced according to a traditional recipe using sun-dried salt. BS is known to have therapeutic effects in treating diseases, including viral diseases, dental plaque, diabetes, circulatory organ disorders, cancer, inflammatory disorders, allergic rhinitis, and cisplatin-induced ototoxicity [38]. Bamboo salt has been added to toothpaste, and according to the manufacturer, this toothpaste can prevent cavities, reduce plaque and gingivitis, soothe sensitive teeth, fight bad breath, whiten teeth, strengthen tooth enamel, prevent receding gum line and decrease mineral loss [39].

The vapor that comes off the heated bamboo can be condensed to produce a liquid known as bamboo vinegar [40]. Bamboo vinegar has been produced in Japan for many years and is used medicinally to treat eczema, atopic dermatitis, and other skin diseases [41].

6 Antibacterial Properties of Bamboo

Bamboo, a naturally multipurpose plant, grows quickly and can survive harsh climatic conditions due to its notable antibacterial characteristics. Several studies were done to determine the bioactive compound (s) responsible for the antibacterial properties of bamboo. Afrin et al. investigated the origin of the antibacterial property of Australian-grown bamboo (*Phyllostachys pubescens*) by extraction of matured bamboo culm powder in water, dimethyl sulphoxide, and dioxane [42]. Their antibacterial activity was tested against Gram-negative bacteria, *Escherichia coli*. They identified lignin as being the main source of the antibacterial compound in *Phyllostachys pubescens.* It is assumed that the antibacterial property of lignin arises from aromatic and phenolic functional groups in lignin. Several other studies also found that lignin is the primary source of antibacterial compounds in bamboo [43, 44]. The antibacterial performance of lignin depends on its extraction and purification methods [44]. Examples of extraction methods used include ethanol fractionation, acid precipitation, nanoparticle modification, etc.

In other studies, Thanaka et al. isolated and identified active compounds, stigmasterol, and dihydrobrassicasterol from Moso bamboo shoot skins (*Phyllostachys*

pubescens) [45]. These compounds potentially have antibacterial activity since they inhibited the growth of *Staphylococcus aureus* and *Escherichia coli*. Thus, in addition to its primary use for composting, the bamboo shoot skin can be more widely and effectively utilized. Moreover, other parts of the bamboo plant, such as leaves, also exhibit some antibacterial activity against some bacteria [46].

The antibacterial properties in natural bamboo provide the resistance of this plant to the harsh environment and self-defense against biotic and abiotic agents. So, lignin and other compounds that exhibit antibacterial activities can be advantageous factors if they can be fully exploited and retained in the final bamboo products. For example, Wang et al. retained the antibacterial trait of bamboo in a bamboo-derived product to improve resistance against microorganisms by introducing bamboo vinegar into the material [47]. Bamboo vinegar was derived from the pyrolysis of bamboo charcoal, such as acetic acid, phenolic compounds, and alcohol compounds, among others.

With the advancement of technologies, including in the textile industry, clothing manufactured from bamboo has entered the textile market. Products made from bamboo are often labeled "eco-friendly", "biodegradable", and "anti-microbial", irrespective of their method of manufacturing. However, these claims may not always portray the product's authenticity and true environmental impact [48]. There are often debates regarding the antibacterial property of bamboo textiles. Studies done by Zhou and Deng found that natural bamboo fibers do not possess any significant antibacterial effect [49], and even if they do, it is just due to a certain crude and particular microstructure of natural bamboo fibers [50]. Li and Dao investigated the antibacterial activity of bamboo and compared it with other textile fibers such as cotton, jute, flax, ramie, and bamboo viscose and reported that natural bamboo does not have the natural antibacterial property [51]. They also reported that the resistance of plant fibers might be related to their hygroscopicity, and some extraction methods could improve the ability of natural bamboo to resist microorganisms. At present bamboo-based, textiles have still not achieved their full potential, but cleaner production processes are appearing [48].

7 Effects of Bamboo Consumption on Gut Microbiota

The role of gut microbiota in health has grown tremendously in recent years. The microbiota, a collective term used for microorganisms that live in our body, plays a major role in health and disease by shaping the body's immune system and metabolism. Altered microbiota has been associated with certain conditions such as obesity and diabetes mellitus. Dietary fiber plays an important role in maintaining body weight and the overall health status of a person. Adults should consume more than 25 g of dietary fiber per day, according to the WHO [52]. Dietary fiber is a carbohydrate polymer-resistant to digestion and absorption in the human intestine, whether natural or synthetic, soluble or insoluble, fermented or nonfermented, viscous or nonviscous [53]. The fermentation of dietary fiber will produce short-chain fatty acids (SCFAs) such as acetate, propionate, butyrate, and others. Many studies have shown

that SCFAs play an important role in maintaining the stability of the gastrointestinal environment; promoting colon epithelial cell proliferation, regulating inflammatory response, and inhibiting intestinal pathogenic bacterial colonization [54].

Several studies have investigated the effects of fiber from different parts of bamboo, such as bamboo shoots and culms, on the gut microbial communities. For example, Ge et al. investigated the digestive microbial communities and the production of SCFAs by in vitro human fecal fermentation [55]. They found that the insoluble fiber from bamboo promotes the production of SCFAs after 24 h of fermentation. Additionally, bamboo fiber that has been extracted by alkaline hydrogen peroxide could alter the microbial composition and diversity by increasing the relative abundance of *Bacteroides* and decreasing the ratio value of *Firmicutes* to *Bacteroidetes* [55]. Similarly, Huang et al. performed an in vitro human fecal fermentation study [56]. However, they studied the fermentation of a compound called O-acetyl-arabinoxylan obtained from bamboo shavings. The study showed O-acetyl-arabinoxylan remarkably modulates the microbial composition in the human colon, by increasing the growth of potential beneficial genera (i.e., *bifidobacterium*, *lactobacillus*, *bacteroides*, etc.) and decreasing the growth of potentially harmful genera.

Increasing evidence suggests that the development of obesity might be associated with gut microbiota, which can influence the host metabolism, digestion of nutrients, energy utilization, and storage. In an experimental animal study, researchers demonstrated that certain gut microbiota could alter the development of obese mice. Chen et al. [56] demonstrated that bamboo shaving polysaccharide could act as an anti-obesity agent in experimental mice by increasing community richness and diversity and regulating gut microbiota composition. In other experimental animal studies, mice with high-fat diets were fed different types of fiber, including bamboo shoot fiber and several other commonly consumed fibers. The study showed that mice that consumed bamboo shoot fiber had a markedly increased relative abundance of beneficial bacterial *Bacteroidetes* and strong inhibition of *Verrucomicrobia*. They conclude that bamboo shoot fiber is a potential prebiotic that can modulate gut microbiota and improve metabolism [57].

8 Conclusion

Bamboo, a multipurpose plant, could be used as a cheap and widely available resource in numerous applications, including in the pharmaceutical and biomedical industries, if carefully exploited. Previous studies have demonstrated that bamboo has many health benefits and potential due to its high content of nutrients and bioactive compounds. Various different extraction techniques were shown to exert a significant influence on their effectiveness. As evidenced by the variety of bamboo species, many parts of the plants have been used medicinally. Most of the studies have oriented

toward “modern diseases”, such as heart diseases, obesity, and cancer. However, further extensive studies are needed to elucidate the effectiveness of bamboo for other diseases in the medical field.

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