Chapter

Medicinal Properties of Bamboos

Katarzyna B. Wróblewska, Danielle C.S. de Oliveira, Maria Tereza Grombone-Guaratini and Paulo Roberto H. Moreno

Abstract

Bamboos are described as one of the most important renewable, easily obtained, and valuable of all forest resources. These plants belong to the grasses' family (*Poaceae*), which covers about a quarter of the world's plant population, within the subfamily Bambusoideae. The estimated diversity of bamboos in the world is approximately 1400 species, distributed in 116 genera. Bamboo species have been used in Southeast Asia, as a base material to produce paper, furniture, boats, bicycles, textiles, musical instruments, and food, and their leaves have also been used as a wrapping material to prevent food deterioration since ancient times. These species accumulate biologically active components such as polyphenols and other secondary plant metabolites that might explain the use of bamboo leaves in Asian traditional medicine for the treatment of hypertension, arteriosclerosis, cardiovascular disease, and certain forms of cancer. Besides the usual secondary metabolites, bamboo extracts may contain biologically active peptides and polysaccharides that still need to be further studied for their activity and their synergistic with other metabolites. Most of the studies found in the literature are from Asian bamboo species, and the potential of the Southern American species is yet to be explored.

Keywords: bamboo, antioxidant, antimicrobial, polyphenols, triterpenes, traditional medicine

1. Introduction

Bamboos are described as one of the most important renewable, easily obtained, and valuable of all forest resources. Bamboo species have been known and used by human kind since the beginning of civilization; its use as building materials can be traced back to the pre-ceramic period 9500 years ago, while relics from bamboo mats and baskets were dated at 3300-2800 BC [1]. In Asian countries, their leaves are used as a food wrapping material to prevent food deterioration since ancient times, besides using the culms as a construction material. In this region, bamboo leaves are described in the traditional medicine for treating hypertension, arteriosclerosis, cardiovascular disease, and certain forms of cancer. These therapeutic properties are most likely mediated by their antioxidant capacity.

These plants form a large subfamily of the grasses (*Poaceae*: Bambusoideae), comprising about 1662 species distributed in 121 genera. Bamboos present a large range of functional forms found over numerous biogeographic regions, including dwarf herbaceous species in temperate climates and giant tropical woody species that can reach up to 20 m height [2]. These species can adapt and propagate in

inhospitable environments, such as humid and cold mountain tops as well as the ones dry and warm [3], naturally occurring in all continents except Europe [4]. Bamboos play an important role in South American forest diversity. Brazil is the country with the greatest number of native bamboo species in the New World [5]. This means that 89% of the genera and 65% of known bamboo species (36 genera and 254 species) are distributed among the Atlantic Forest, the Cerrado, and the Amazon [6].

Bamboos have a large ecological amplitude in response to canopy disturbances and can become super dominant species after opening in natural or anthropic origin. In addition, they have a very rapid growth from the stem base to the top of the plant [7]. Currently, bamboo species are considered as one of the most available forest resources. In tropical and subtropical areas, bamboos represent approximately 20–25% of the total biomass, which contributes to their status as one of the most important renewable resources [8]. Considered a rapid atmospheric carbon sink, bamboo has also physical and mechanical properties that make it suitable to be used in the development of products normally produced with native wood or from reforestation, such as construction components, furniture industry, cables for agricultural tools, panels, and plates, among others.

Bamboo species share some common characteristics of their phenolic composition with other grasses. They contain several glycosylated flavones whose aglycones are represented by apigenin, luteolin, and tricin [9–11]. This is also the case in, for example, durum wheat (*Triticum durum*) [12] and barley (*Hordeum vulgare*) [13]. Just as in other grass species, such as corn, wheat, and rice [14], most glycosides are conjugated via a *C*-linkage to the flavone aglycone. In China, their phenolic compounds are used to make a preparation, called antioxidant of bamboo leaves (AOB), to be applied as food antioxidant whose use is sanctioned by the local Health Ministry. The AOB is composed mainly by flavonoids, lactones, and phenolic acids. The main flavonoids found in AOB are the flavone *C*-glycosides such as orientin, homoorientin, vitexin, and isovitexin [15].

2. Biological activities of bamboo species

2.1 Antioxidant potential of bamboos

The production of reactive oxygen species (ROS) is a result of normal cell metabolism; however, once the oxidative processes start to be predominant over the antioxidant, the imbalance called "oxidative stress" can be harmful to human body [16]. Oxygen's reactivity, which is under normal conditions, permits the high-energy electron transfer allowing the formation of big quantities of adenosine-5-triphosphate (ATP) by the oxidative phosphorylation and jeopardizes the cells of living organisms by attacking molecules such as proteins, lipids, or DNA [17]. Free radicals created in this process cause various genetic changes causing cancer, cardiovascular and neurological diseases, nephropathy, rheumatoid arthritis, and other disorders [18]. Plants provide an abundant source of the substances with biological activity. In case of antioxidant protection, flavonoids stand for one of the most efficient molecules combating the oxidative stress.

There are two terms describing the antioxidant efficacy: "antioxidant activity" and "antioxidant capacity," and they have different meanings. The prior expresses the kinetics of a reaction between an antioxidant and the prooxidant or radical scavenging activity, and the latter one measures the thermodynamic conversion efficiency of the reaction. The analytical methods to evaluate antioxidant activity may be divided into electron transfer (ET)-based and hydrogen atom transfer

(HAT)-based methods. ET-based methods utilize the process of the reduction in the oxidative component by the antioxidant, which leads to the change in color that can be observed [19]. Within this group, we can specify: DPPH (2,2-di(4-*tert*-octylphenyl)-1-picrylhydrazyl) method, ABTS (2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid), FRAP (ferric reducing antioxidant power), and CUPRAC (cupric reducing antioxidant capacity). HAT-based assays include for instance oxygen radical absorbance capacity (ORAC) reaction, detectable by the fluorescence loss of fluorescein. More "functional" analyses count the number of lipid oxidation products like thiobarbituric acid-reactive substances (TBARS) or evaluate a desired health effect of the product [19, 20].

The majority researchers working with bamboo-derived products use DPPH, ABTS, and FRAP methods or the combination of those to evaluate the antioxidant effect of their samples, when ORAC is less common. Values are expressed in the percentage of the radical inhibition, IC_{50}, which is an inhibitory concentration (concentration needed to deactivate 50% of the radical formation) or Trolox equivalents. **Table 1** demonstrates the results grouped by the method and unit used by the authors, and **Table 2** shows IC_{50} against DPPH of the compounds isolated from the bamboo species.

The most popular method (also as per the number of results included in **Table 1**) is the certainty DPPH radical scavenging test. IC_{50} is a unit that is easy to compare because it gives an idea of the concentration, which is necessary to decrease the radical formation by 50%. The values obtained for different species of bamboo varied between 51 μg/mL for *Sasa borealis* (leaf butanolic fraction) [9] and 5300 μg/mL for *Phyllostachys nigra* (shoot water fraction) [24]. The highest antiradicalar activity was obtained in case of butanol, ethyl acetate, and ethanol fractions. Although leaf extracts seemed to be the part of the plant that provides reasonably good results, essential oils were efficient in much smaller concentrations. The essential oil from *Phyllostachys heterocycla* cv. pubescens had IC_{50} of only 2.85 μg/mL (value recalculated from μL/mL for comparison purposes if the density of an essential oil is approximately 0.9 g/mL) as reported by Jin et al. [21]. The worst in the group, but still with high activity, was an essential oil from *Phyllostachys vivax* f. *aureocaulis* N.X.Ma. (7.53 μg/mL [25]). The essential oils had their range of action like isolated compounds. For instance, isoorientin, isolated from the leaves of *Sasa borealis*, had IC_{50} determined as 9.5 μM [9], which gives 4.26 μg/mL, very close to the essential oil mentioned here.

Two from the chosen authors [10, 26] described the results for two Asian bamboo species: *Phyllostachys nigra* v. *henonis* and *Phyllostachys edulis* in the percentage of DPPH inhibition. The 20 μg/mL ethanol extract from the first species managed to suppress 40.9% of the radical formation, whereas the second one, depending on the fraction, was able to decrease it from 30.4 to 79.1% (chloroform and butanol fractions, respectively) in the concentration of 100 μg/mL. Both authors investigated in parallel the influence of the bamboo samples on lipid peroxidation. It was confirmed that the *P. nigra* scavenging effect reduced the rate of liposome peroxidation and human LDL (low-density lipoprotein) oxidation suppressing DNA modifications [10]. 3-*O*-caffeoyl-1-methylquinic acid (shown in **Table 2**), isolated from *P. edulis*, exhibited 36% of the inhibition of superoxide generation in human promyelocytic leukemia HL-60 cells [26].

The results expressed in IC_{50} for the DPPH and other methods such as ABTS, FRAP, and ORAC varied due to different mechanisms of action between prooxidant and antioxidant molecules. An ethyl acetate fraction from a Brazilian bamboo, *Merostachys pluriflora*, defined as the most active fraction from this species against DPPH (IC_{50} = 117.68 μg/mL), the second most active against ABTS cation radical (IC_{50} = 19.66 μg/mL) was also quite potent ferric reducing (IC_{50} = 51.88 μg/mL) and

Bamboo species	Sample	DPPH	ABTS	FRAP	ORAC	Ref.
Phyllostachys heterocycla cv. pubescens	Essential oil	2.85*				[21]
P. heterocycla cv. gracilis	Essential oil	4.44*				
P. heterocycla cv. heterocycla	Essential oil	3.82*				
P. kwangsiensis	Essential oil	4.93*				
Merostachys pluriflora Munro ex. C. G. Camus	Leaf ethanol	119.51	25.65	92.08	5.79	[22]
	Leaf hydromethanolic	137.37	16.30	85.73	6.18	
	Leaf ethyl acetate	117.68	19.66	51.88	2.73	
	Leaf dichloromethane	190.73	37.21	89.69	6.05	
	Culm ethanol	181.92	39.51	62.02	4.20	
	Culm hydromethanolic	413.80	47.22	108.50	9.33	
	Culm ethyl acetate	244.85	33.25	51.22	3.47	
	Culm dichloromethane	—	60.69	27.92	1.22	
	Culm hexane	296.94	94.77	145.80	9.10	
P. pubescens (Pradelle) Mazel ex J. Houz	Leaf ethanol		—			[23]
	Branch ethanol		350.60			
	Inner culm at 1 m height ethanol		373.80			
	Inner culm at 5 m height ethanol		88.50			
	Rhizome ethanol		171.50			
	Leaf water		306.70			
	Branch water		179.50			
	Inner culm at 1 m height water		231.90			
	Inner culm at 5 m height water		198.30			
	Rhizome water		266.70			
	Shoot methanol	3600.00				[24]
	Shoot chloroform	4000.00				
	Shoot ethyl acetate	800.00				
	Shoot butanolic	700.00				
	Shoot water	4700.00				
Pseudosasa amabilis McClure	Essential oil	5.29*				[25]
Pleioblastus gramineus (Bean) Nakai	Essential oil	6.50*				
P. vivax f. *aureocaulis* N.X.Ma.	Essential oil	7.53*				
Indocalamus latifolius (Keng) McClure	Essential oil	4.99*				

Bamboo species	Sample	DPPH	ABTS	FRAP	ORAC	Ref.
P. nigra (Lodd. ex Lindl.) Munro	Shoot methanol	3400.00				[24]
	Shoot Chloroform	2300.00				
	Shoot ethyl acetate	400.00				
	Shoot butanolic	800.00				
	Shoot water	5300.00				
Sasa borealis (Hack.) Makino and Shibata	Leaf butanolic	51.00				[9]

*ABTS—scavenging ABTS(2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) cation radical effect; DPPH—scavenging DPPH (2,2-di(4-tert-octylphenyl)-1-picrylhydrazyl)radical effect; FRAP—ferric reducing antioxidant power; all the values in the table are the—IC_{50} [μg/mL]—inhibitory concentration, concentration needed to diminish the production the radical/oxidized product by 50%; ORAC—oxygen radical absorbance capacity. *Values recalculated from μL/mL to μg/mL, assuming that the density of an essential oil is approximately 0.9 g/mL.*

Table 1.
Antioxidant activity of different bamboo species.

Bamboo species	Part of the plant	Isolated compound	DPPH (IC_{50})	Reference
Sasa borealis (Hack.) Makino and Shibata	Leaves	Isoorientin	9.5	[9]
		Isoorientin 2-O-α-L-rhamnoside	34.5	
		Apigenin 6-C-β-D-xylopyranosyl-8-C-β-D-glucopyranoside	161.5	
Phyllostachys edulis (Carrière) J. Houz.	Leaves	3-O-(3′-methylcaffeoyl) quinic acid	16.00	[26]
		5-O-caffeoyl-4-methylquinic acid	8.8	
		3-O-caffeoyl-1-methylquinic acid	6.9	

DPPH—scavenging DPPH (2,2-di(4-tert-octylphenyl)-1-picrylhydrazyl) radical effect; IC_{50}—inhibitory concentration, concentration needed to diminish the production of DPPH radical by 50% [μM].

Table 2.
Antioxidant activity of isolated compounds of bamboos.

oxygen radical scavenging (IC_{50} = 2.73 μg/mL) agent. On the other hand, dichloromethane culm fraction from the same plant, not so active against DPPH nor ABTS, reduced almost two times more the ferric cation in the FRAP method than the previous sample (IC_{50} = 27.92 μg/mL) and was an excellent scavenger of the oxygen radical in ORAC assay (IC_{50} = 1.22 μg/mL) [22]. No direct correlation between the results assessed by ABTS and ORAC was also found in another study, evaluating the antioxidant activity of different parts of *P. pubescens* [23].

Trolox equivalents received by two methods: DPPH and FRAP were also compared, and it was found that in case of *P. heterocycla* cv. pubescens, gracilis, Tao Kiang, and *P. aureosulcata*, leaf and shoots in both evaluations were very similar to the TE content. Additionally, the extract that was the richest in TE in DPPH assay (*P. heterocycla* leaf) had also the highest value of it in the FRAP method [27]. As per this author, the shoots of bamboo were the part of the plant with the poorest antioxidant activity.

In general, bamboos were classified as good antioxidants, which can be related to their high flavonoid and phenol contents [27]. The scavenging activity against superoxide anion and hydroxyl radical of some methanol and hot water extracts from a bamboo powder, used in Japan for different purposes, was higher than the

ones received for the control—α-tocoferol and ascorbic acid [28]. A polysaccharide-rich extract from *Bambusa rutila* had hydroxyl radical scavenging activity equal to vitamin C [29], where an isoorientin and its ester, derived from a Chinese product called antioxidant of bamboo leaves (AOB), had their IC_{50} lower than vitamin E [30]. The acylation of isoorientin was performed to improve its solubility in lipidic media, however, the process did not have a positive impact on the antioxidant activity of the substance. A nutritional formulation developed from bamboo vinegar (5%) and maltodextrin (30%) had better *in vitro* antioxidant effect that tested commercial beverages [31]. In other study, it was proved that bamboo oil from *P. bambusoides*, when incubated for 20 h, had its linoleic acid scavenging rate similar to that of ascorbic acid [32].

Few studies of the functional antioxidant activity with correlated health effect were described in the literature as well. The lignophenol derivatives obtained from a wood mixture containing bamboo *P. bambusoides* demonstrated neuroprotective activity in cells influenced by hydrogen peroxide-induced apoptosis [33]. A short-term assay established that both Asp-Tyr identified and isolated from *P. pubescens* shoot fractions diminished significantly the systolic blood pressure of spontaneously hypertensive rats [34]. An extract from *Sasa senanensis*, named Absolutely Hemicellulose Senanensis (AHSS), had determined its *in vivo* activity, and it was shown that it inhibited the production of lipid peroxide by intestinal ischemia and subsequent reperfusion (I/R) injury model in rats [35].

2.2 Antimicrobial properties

Quality and safety of various products can be affected by the presence of microorganisms; therefore, antimicrobial substances are widely used in cosmetic, food, and pharmaceutical industries. In cosmetics, preservatives protect the formulation during the production and the use by the consumers [36]. In the food industry, these additives can improve organoleptic characteristics of food, such as color, smell, and taste, in addition to the protection of food during production, storage, and consumption [37]. The growing microbial resistance to existing drugs has generated the need for the pharmaceutical industry to search for new molecules that can be used as preservatives, antibiotics, and disinfectants [38]. This factor associated with the toxicity of certain additives [39] and the consumer appeals for the reduction in synthetic substances [40], encourage the search for alternative solutions. The complexity and molecular diversity of natural products make them an interesting source of new molecules [41].

The antimicrobial capacity of bamboo species was evaluated through several methodologies, resulting in different units for the presentation of the results. In **Table 3**, results are shown as minimal inhibitory concentration (MIC), which is the lowest concentration that is able to completely inhibit microbial growth.

The lower the MIC values, the more potent the substance is. To be considered as promising antimicrobial agents, natural products must have MICs below 100 μg/mL [39]. Therefore, the essential oils of *Phyllostachys kwangsiensis*, *P. heterocycla* cv. gracilis, and *P. heterocycla* cv. *Heterocycla* are the most active extracts, with MIC values ranging from 22.23 to 45.24 μg/mL for *S. aureus* and 31.76 μg/mL for *E coli*. 2,6-Dimethoxy-*p*-benzoquinone presented lower values than the essential oils; however, it is an isolated compound and not an extract. It is possible to affirm that the essential oils evaluated have an intense antimicrobial activity because their MIC values are close to those of an isolated compound.

In **Table 4**, the species were evaluated using the disk diffusion method. Three different extracts of each species were compared. All of them presented similar inhibition zones, around 7 mm. The wider inhibition zones were presented by

Bamboo species	Product	Microorganism	MIC (μg/mL)	Ref.
P. heterocycla var. *pubescens* (Pradelle) Ohwi	2,6-Dimethoxy-*p*-benzoquinone	*Escherichia coli*	400	[42]
		Bacillus subtilis	200	
		Salmonella typhimurium	400	
		Sarcina lutea	400	
		Pseudomonas aeruginosa	800	
		Staphylococcus aureus	200	
		Candida albicans	800	[43]
		Saccharomyces cerevisiae	25	
			10	
			25	
			800	
		Aspergillus niger	800	
	Chloroform/methanol extract (bark)	*Escherichia coli*	10,000	[44]
		Bacillus subtilis	5000	
		Salmonella typhimurium	10,000	
		Sarcina lutea	10,000	
P. heterocycla var. *pubescens* (Pradelle) Ohwi	Chloroform/methanol extract (bark)	*Pseudomonas aeruginosa*	50,000	[44]
		Staphylococcus aureus	2000	
	Essential oil	*Escherichia coli*	31.76*	[21]
		Staphylococcus aureus	31.76*	
P. pubescens (Pradelle) Mazel ex J. Houz.	Ethanol extract (outer culm)	*Staphylococcus aureus*	400	[23]
P. pubescens (Pradelle) Mazel ex J. Houz.	Hot water extract (leaf)	*Staphylococcus aureus*	1200	[23]
	Hot water extract (branch)	*Staphylococcus aureus*	1400	
	Hot water extract (inner culm)	*Staphylococcus aureus*	>16,000	
P. kwangsiensis W.Y. Hsiung, Q.H. Dai and J.K. Liu	Essential oil	*Escherichia coli*	31.76*	[21]
		Staphylococcus aureus	22.23*	
P. heterocycla fo. gracilis (W.Y. Hsiung ex Houz.) T.P. Yi	Essential oil	*Escherichia coli*	31.76*	
		Staphylococcus aureus	22.23*	
P. heterocycla (Carrière) Mitford cv *heterocycla*	Essential oil	*Escherichia coli*	31.76*	
		Staphylococcus aureus	45.24*	

**Concentration calculated considering the density value 0.9.*

Table 3.
Antimicrobial activity of bamboo extracts—MIC.

Bamboo species	Product	Inhibition zone (mm)		Ref.
		E. coli	*S. aureus*	
B. blumeana var. luzonensis Hack.	Acetone extract	7.2	9.3	[44]
	Ethanol extract	7.6	7.2	
	Hot water extract	7.4	7.4	
B. blumeana Schult. and Schult. f.	Acetone extract	6.6	7.0	
	Ethanol extract	9.8	9.3	
	Hot water extract	7.3	7.3	
B. vulgaris Schrad.	Acetone extract	7.5	6.9	
	Ethanol extract	7.5	7.8	
	Hot water extract	7.2	10.7	

Table 4.
Antimicrobial activity of bamboo extracts—inhibition zone.

Symbol	Diameter (mm)	Classification
–	<10	No activity
+	10–15	Activity
++	15–20	Good activity
+++	>20	Very good activity

Table 5.
Interpretation of inhibition zones [47].

the ethanolic extract of *Bambusa blumeana* against *E. coli* (9.8 mm) and *Bambusa vulgaris* hot water extract (10.7 mm) against *S. aureus*. However, all the extracts can be considered inactive, comparing them with the inhibition zones in **Table 5**. It is important to say that during the measurement of the diameter of the inhibition zones, the diameter of the disk is considered.

The search for bioactive compounds is not limited only to the compounds produced by a plant species. Microorganisms hosted in plant tissues and organs have become a new source of useful metabolites for the pharmaceutical, agricultural, and food industries [45, 46]. Found in various parts of plants (roots, stems, leaves, and barks), endophytic fungi colonize various species [47], and the relationship between the endophytic fungi and the host plant may be advantageous since many of them improve the growth and protect the plant against pathogens [46].

Using the agar diffusion method, some authors evaluated the antimicrobial activity of fungal strains isolated from bamboos. The antimicrobial potential of the strains was evaluated against human pathogens, and in **Table 6**, it is possible to find the main results. Isolate 130 from *P. edulis* culms and isolate B38 from the same species presented similar results, with activity ranging from good to very good for most pathogens evaluated. Nevertheless, the isolate FB16 from *P. edulis* presented the best result, with very good activity against a larger number of microorganisms.

One of the studies also evaluated the activity of fermentation products of fungal strains of *P. edulis*, and the results can be seen in **Table 7**. The product FB16 is the most active, with the biggest zones of inhibition. This behavior agrees with the results presented by the isolated fungus, as shown in **Table 6**. It is important to note that although the fermentation product FB16 presented the best result among the samples, its zones of inhibition are smaller than those presented by the isolated fungus.

Bamboo species	Isolate no.	*S. aureus*	*B. subtilis*	*L. monocytogenes*	*S. bacteria*	*E. coli*	*P. vulgaris*	*C. albicans*	*R. rubra*	Ref.
P. edulis (Carrière) J. Houz. *(Culms)*	106	+	+	–	–	NT	NT	++	–	[45]
	120	+++	+++	+	–	NT	NT	+++	++	
	127	–	+	+	+	NT	NT	+	–	
	128	+	+	–	–	NT	NT	+	+	
	130	+++	+++	++	++	NT	NT	+++	+	
P. edulis (Carrière) J. Houz.*(Seeds)*	B09	+	+	–	–	NT	NT	++	–	[47]
	B34	–	+	+	+	NT	NT	+	–	
	B35	+	+	–	–	NT	NT	+	+	
	B38	+++	+++	++	++	NT	NT	+++	+	
	ZZZ816	+++	+++	+	–	NT	NT	+++	+	
P. heteroclada Oliv.	FB16	NT	+++	+++	+++	+++	++	+++	NT	[46]
	FB43	NT	–	++	++	+	+	–	NT	
	FB06	NT	++	++	–	+	–	+	NT	
	FB21	NT	–	++	++	+	+	++	NT	

NT—not tested.

Table 6.
Antimicrobial activity of fungal isolates.

Isolate no.	Inhibition zone (mm)						Ref.
	B. subtilis	*L. monocytogenes*	*S. bacteria*	*E. coli*	*P. vulgaris*	*C. albicans*	
FB16	13.2	11.8	10.29	12.46	8.8	16	[46]
FB43	—	10.6	8.95	7.6	7.52	—	
FB06	8.66	9.1	—	7.84	—	7.66	
FB21	—	8.7	8.64	7.52	7.77	8.69	

—: not active.

Table 7.
Antimicrobial activity of fermentation products of fungal isolates from Phyllostachys heteroclada.

Despite the search for new substances with the ability to inhibit microbial growth, the presence of microorganisms is not always harmful. In some cases, certain microorganisms may contribute to human health, such as the human intestinal microbiota. It is composed of more than 400 bacterial species, and bifidobacteria and lactobacilli are the main ones [48]. They help in the digestion and synthesize bioactive compounds, besides preventing diseases, avoiding the growth of pathogenic microorganisms [49]. Through the consumption of probiotics and prebiotics, it is possible to maintain the balance of these intestinal bacteria. Probiotics are supplements containing the microorganisms of interest. Nondigestible carbohydrates that undergo fermentation by intestinal microbes are called prebiotics [48, 49].

Prebiotic activity was evaluated in bamboo shoots, since they are a rich source of polysaccharides and oligosaccharides [50]. The polysaccharides isolated from the shoots of *Gigantochloa levis* were able to stimulate the growth of *Bifidobacterium animalis*, *Bifidobacterium longum*, and *Lactobacillus acidophilus*. At the same time, they were able to reduce the growth of Salmonella sp., pathogenic bacteria [50]. Heteropolysaccharides-protein complexes from *Phyllostachys praecox* shoots were isolated, and the fractions containing these substances increased the *Bifidobacterium adolescentis* and *Bifidobacterium bifidum* counts [50]. These results suggest that bamboo shoots can be a source of probiotics.

2.3 Miscellaneous activities

Chinese traditional medicine has described the use of different parts of bamboos, such as leaves and rhizomes, to treat many diseases. Nowadays, scientific studies have demonstrated that bamboo extracts have excellent biological efficacy regarding their antioxidant activity. Theoretically, this activity might also be related for the treatment of diverse pathologies, such as resistance to free-radical, cardiovascular protection against neurodegenerative diseases, anticancer, and many others.

Bamboo shavings are a sort of Chinese traditional medicine that can be obtained from different bamboo species by scraping off the coating from bamboo stems, cutting the stems into slices, and binding them together by drying in shadowy places. A triterpenoid-rich extract of bamboo shavings was obtained from *P. nigra* var. *henonis* by superfluid carbon dioxide extraction and tested for antitumor activity. The extract showed a significant inhibitory activity against P388 and A549 cancer cell lines. The extract also presented an effective inhibitory effect on the sarcoma-loaded mice S180 model. Friedelin, the main compound in the extract, was also active on inhibiting the proliferation of four cancer lines, A375, L929, Hela, and THP-1 [51].

Bamboo extracts used as dietary supplement demonstrated a protective effect on the development of induced breast cancer by 7,12-dimethylbenz[a]anthracene

(DMBA). A crude hydroethanolic extract from *P. edulis* was incorporated into a standard rodent diet at a concentration of 5 g/kg (0.5%), and it was able to delay the onset of mammary tumor by 1 week, decreasing the tumor incidence by 44% and tumor multiplicity by 67%. The biochemical analysis indicated that the activity might be related to an increased estrogen metabolism [52].

Bamboo vinegar, a natural liquid derived from the condensation produced during bamboo charcoal production, a pyrolyzate product, has been used in agriculture and used as a food additive. This liquid is composed mainly by water and acetic acid, but it also contains a variety of phenolic compounds. A vinegar preparation produced from *P. pubescens* reduced inducible nitric oxide synthase expression and nitric oxide levels and interleukin-6 secretion using lipopolysaccharide-activated macrophages. The mechanism proposed for the anti-inflammatory effect of the vinegar involved a decrease in reactive oxygen species production and protein kinase C-α/δ activation. The main component involved in the anti-inflammatory activity was creosol (2-methoxy-4-methylphenol) in *in vivo* tests [53]. Vinegars obtained from *P pubescens*, *P. nigra*, and *P. bambusoides* were tested for protective effect against N-methyl-D-aspartate (NMDA)-induced cell death in primary cultured cortical neurons. All the preparations were able to restore cell viability when compared to untreated cells in an NMDA-induced neuronal cell death assay. Additionally, vinegars of *P. pubescens* and *P. nigra* showed a reduction of apoptosis following the exposure to NMDA, indicating them as supplements for ischemic injury treatment [54].

Besides the usual secondary metabolites, aqueous bamboo extracts contain many amino acids and polysaccharides that have not been investigated for their biological activities. Hypertension is associated with cardiovascular diseases such as arteriosclerosis, stroke, and myocardial infarction. Angiotensin converting enzyme (ACE, EC 3.4.15.1) is a dipeptidyl carboxypeptidase involved in different blood pressure regulating mechanisms. A peptide enriched *P. pubescens* shoot aqueous extract could significantly reduce systolic blood pressure, improve oxidant stress status (GSH-Px, SOD, TAC and MDA), and increase NO level in serum and NO synthase activity in kidney. This extract also decreased total cholesterol, triglyceride, and low-density lipoprotein cholesterol content and MDA level of hyperlipidemic rats. These activities were higher for crude extract rather than for the synthetic peptide used. This indicates a synergism with the phenolic compounds still present in the crude extract, such as p-coumaric acid, ferulic acid, caffeic acid, homoorientin, and orientin [55]. The antihyperlipidemic effect of these metabolites has been demonstrated later. The lipid metabolism was affected by phenolics and triterpenoids present in the inner culm water found from *Dendrocalamus giganteus* Wall. ex Munro. The freeze-dried powder obtained from this water was composed mainly of protocatechuic acid, *p*-hydroxybenzoic acid, syringic acid, friedelan-3-one, lup-20(29)-en-3-one, lup-20(29)-en-3-ol, and α-amyrin. The powder reduced the contents of triglycerides, total cholesterol, and free fatty acids in model assay with steatosis human liver cell L02 [56].

Most of the bamboo applications are related to the paper, textile, and construction industries, due to its high fiber contents. For this reason, scientists have been isolating and characterizing bamboo hemicelluloses since the 1970s. Hemicelluloses are polysaccharides found in plant cell walls that are characterized by being neither cellulose nor pectin and by having β-(1 → 4)-linked backbones with an equatorial configuration. Some of these polysaccharides are known to have an immunomodulatory activity. Hemicelluloses isolated from *P. pubescens* shavings showed *in vitro* immunomodulatory activity and significantly stimulated mouse splenocyte proliferation. All the isolated compounds markedly enhanced the phagocytosis activity and nitric oxide production of the murine macrophage

RAW264 [57]. The total polysaccharide fraction of *Sasa veitchii* (Carrière) Rehder inhibited the production of interferon gamma (IFN-γ) by not only the toll like receptors (TLRs) but also the C-type lectin receptors (CLRs) dectin-1, and dectin-2 of BWMP also inhibited the autologous production of IFN-γ in the splenocyte culture mice splenocytes in the presence of immunostimulant fungal polysaccharides [58].

3. Conclusions

Although bamboo has been used for centuries by the Traditional Chinese Medicine, this is still a group of plant under investigated regarding its medicinal properties. In Asian countries, such as China, Korea, and Japan, among others, the most used species have already been studied regarding their biological properties and chemical composition. On the other hand, in Southern American countries, where a huge bamboo diversity is available, very little has been done to access its medicinal properties.

Several species have shown an important antioxidant potential demonstrating that they can be applied in the treatment of different diseases such as anti-inflammatory, antitumor, and several other ailments involving oxidative processes. Additionally, besides the usual secondary metabolites, bamboo extracts may contain biologically active peptides and polysaccharides. The combined effect of these macromolecules with polyphenols and other metabolites may lead to multiple biological effects, such as antifree radical, antiaging, antifatigue, antibacteria, antivirus, and as a functional dietary supplement, cosmetic ingredient, and food additive.

Acknowledgements

The authors wish to thank CAPES and CNPq for the scholarships granted.

Conflict of interest

The authors declare that there is no conflict of interest.

DOI: http://dx.doi.org/10.5772/intechopen.82005

Author details

Katarzyna B. Wróblewska[1], Danielle C.S. de Oliveira[1], Maria Tereza Grombone-Guaratini[2] and Paulo Roberto H. Moreno[1*]

1 Department of Fundamental Chemistry, Institute of Chemistry, University of São Paulo, São Paulo, Brazil

2 Botanical Institute of São Paulo, São Paulo, Brazil

*Address all correspondence to: prmoreno@iq.usp.br

References

[1] Liese, W. Bamboo: Past, Present and Future. American Bamboo Society. 1999; Newsletter, 20

[2] Canavan S, Richardson DM, Visser V, Roux JJLR, Vorontsova MS, Wilson JRU. The global distribution of bamboos: assessing correlates of introduction and invasion. Aob Plants. 2017;**9**:1-18. DOI: 10.1093/aobpla/plw078

[3] Filgueiras TS, Santos-Gonçalves AP. A checklist of the basal grasses and bamboos in Brazil (*Poaceae*). Bamboo Science and Culture. 2004;**18**:7-18

[4] Soderstrom TR, Calderón CE. A Commentary on the Bamboo (*Poaceae*: Bambusoideae). Biotropica. 1979;**11**:161-172

[5] Judziewicz EJ, Clark LG, Londoño X, Stern MJ. American bamboos. Washington, DC, Smithsonian Institution Press; 1999. 392

[6] *Poaceae* in Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. 2016. Available from: http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB193 [Accessed: 18-01-2016]

[7] González ME, Veblen TT, Donoso C, Valeria L. Tree regeneration responses in a lowland Notophagus-dominated forest after bamboo dieback in South-Central Chile. Plant Ecology. 2002;**161**:59-73. DOI: 10.1023/A:1020378822847

[8] Bansal A, Zoolagud SS. Bamboo composites: Material of the future. Journal of Bamboo and Rattan. 2002;**1**:119-130. DOI: 10.1163/156915902760181595

[9] Park H, Lim JH, Kim HJ, Choi HJ, Lee I. Antioxidant flavone glycosides from the leaves of *Sasa borealis*. Archives of Pharmacal Research. 2007;**30**(2):161-166

[10] Hu C, Zhang Y, Kitts DD. Evaluation of antioxidant and prooxidant activities of bamboo *Phyllostachys nigra* var. Henonis leaf extract in vitro. Journal of Agricultural and Food Chemistry. 2000;**48**:3170-3176. DOI: 10.1021/jf0001637

[11] Jiao J, Zhang Y, Liu C, Liu J, Wu X, Zhang Y. Separation and purification of tricin from an antioxidant product derived from bamboo leaves. Journal of Agricultural and Food Chemistry. 2007;**55**:10086-10092. DOI: 10.1021/jf0716533

[12] Cavaliere C, Foglia P, Pastorini E, Samperi R, Laganà A. Identification and mass spectrometric characterization of glycosylated flavonoids in Triticum durum plants by high-performance liquid chromatography with tandem mass spectrometry. Rapid Communications in Mass Spectrometry. 2005;**19**:3143-3158. DOI: 10.1002/rcm.2185

[13] Ferreres F, Andrade PB, Valentão P, Gil-Izquierdo A. Further knowledge on barley (*Hordeum vulgare* L.) leaves O-glycosyl-C-glycosyl flavones by liquid chromatography-UV diode-array detection-electrospray ionisation mass spectrometry. Journal of Chromatography A. 2008;**1182**:56-64. DOI: 10.1016/j.chroma.2007

[14] Brazier-Hicks M, Evans KM, Gershater MC, Puschmann H, Steel PG, Edwards R. The C-glycosylation of flavonoids in cereals. Journal of Biological Chemistry. 2009;**284**:17926-17934. DOI: 10.1074/jbc.M109.009258

[15] Zhang Y, Bao B, Lu B, Ren Y, Tie X, Zhang Y. Determination of flavone C glucosides in antioxidant of bamboo leaves (AOB) fortified foods by reversed-phase high-performance liquid chromatography with ultraviolet

diode array detection. Journal of Chromatography, A. 2005;**1065**:177-185

[16] Birben E, Sahiner UM, Sackesen C, Erzurum S, Kalayci O. Oxidative Stress and Antioxidant Defense. WAO Journal. 2012;**5**:9-19

[17] Burton GJ, Jauniaux E. Oxidative stress. Best Practice&Research Clinical Obstetrics Gynaecology. 2011;**25**(3):287-299. DOI: 10.1016/j.bpobgyn.2010.10.016

[18] Pham-huy LA, He H, Pham-huy C. Free radicals, antioxidants in disease and health. International Journal of Biomedical Sciences. 2008;**4**(2):89-96

[19] Apak R, Gorinstein S, Böhm V, Schaich KM, Özyürek M, Güçlü K. Methods of measurement and evaluation of natural antioxidant capacity/activity (IUPAC technical report). Pure and Applied Chemistry. 2013;**8**(5):957-998

[20] Pisoschi AM, Negulescu GP. Methods for total antioxidant activity determination: A review. Biochemistry and Analytical Biochemistry. 2011;**1**(1):1-10. DOI: 10.4172/2161-1009.1000106

[21] Jin YC, Yuan K, Zhang J. Chemical composition, and antioxidant and antimicrobial activities of essential oil of *Phyllostachys heterocycla* cv. *Pubescens* varieties from China. Molecules;**16**:4318-4327. DOI: 10.3390/molecules16054318

[22] Gagliano J, Grombone-guaratini MT, Furlan CM. Antioxidant potential and HPLC-DAD profile of phenolic compounds from leaves and culms of *Merostachys pluriflora*. South African Journal of Botany. 2018;**115**:24-30. DOI: 10.1016/j.sajb.2017.12.008

[23] Tanaka A, Zhu Q, Tan H, Horiba H, Ohnuki K, Mori Y, et al. Biological activities and phytochemical profiles of extracts from different parts of bamboo (*Phyllostachys pubescens*). Molecules. 2014;**19**:8238-8260. DOI: 10.3390/molecules19068238

[24] Park E-J, Jhon D-Y. The antioxidant, angiotensin converting enzyme inhibition activity, and phenolic compounds of bamboo shoot extracts. LWT—Food Science and Technology. 2010;**43**(4):655-659. DOI: 10.1016/j.lwt.2009.11.005

[25] Hu CJ, Liao HB, Yuan K, Hu JH, Lin XC. Chemical composition and antioxidant activity of essential oil of bamboo leaves from four species in China. Asian Journal of Chemistry. 2011;**23**(6):2543-2547

[26] Kweon MH, Hwang HJ, Sung HC. Identification and antioxidant activity of novel chlorogenic acid derivatives from bamboo (*Phyllostachys edulis*). Journal of Agricultural and Food Chemistry. 2001;**49**(10):4646-4655. DOI: 10.1021/jf010514x

[27] Li YX, Cheng FR, Jin YC, Yuan K. Studies on the active components and antioxidant activity of the extracts from different parts of bamboo. Asian Journal of Chemistry. 2013;**25**(11):6354-6360. DOI: 10.14233/ajchem.2013.14584

[28] Nagai T, Suzuki N, Tanoue Y, Kai N, Nagashima T. Antioxidant activities of the extracts from bamboo powder as underutilized resource. Journal of Food, Agriculture and Environment. 2009;**7**(2):228-232

[29] Gao YN, Tian CR, Zhao LL. Extraction, purification and antioxidant activity of polysaccharides from bamboo leaves. Journal of Forestry Research. 2012;**23**(1):139-143. DOI: 10.1007/s11676-012-0223-y

[30] Xu J, Qian J, Li S. Enzymatic acylation of isoorientin isolated from antioxidant of bamboo leaves with palmitic acid and antiradical activity

of the acylated derivatives. European Food Research and Technology. 2014: 661-667. DOI: 10.1007/s00217-014-2262-4

[31] Echavarría ACC, Yepes FJ, Torres HP. Determinación del potencial antioxidant en extractos de vinagre *Guadua angustifolia* Kunth para aplicaciones alimenticias. Determination of the antioxidant potential in *Guadua angustifolia* Kunth vinegar extracts for food applications. Revista Cubana de Plantas Medicinales. 2012;**17**(4):330-342

[32] Choi D, Cho K, Na M, Choi H, Kim Y, Lim DH, et al. Effect of bamboo oil on antioxidative activity and nitrite scavenging activity. Journal of Industrial and Engineering Chemistry. 2008;**14**:765-770. DOI: 10.1016/j.jiec.2008.06.005

[33] Akao Y, Seki N, Nakagawa Y, Yi H, Matsumoto K, Ito Y, et al. A highly bioactive lignophenol derivative from bamboo lignin exhibits a potent activity to suppress apoptosis induced by oxidative stress in human neuroblastoma SH-SY5Y cells. Bioorganic and Medicinal Chemistry. 2004;**12**(18):4791-4801. DOI: 10.1016/j.bmc.2004.07.022

[34] Liu L, Liu L, Lu B, Chen M, Zhang Y. Evaluation of bamboo shoot peptide preparation with angiotensin converting enzyme inhibitory and antioxidant abilities from byproducts of canned bamboo shoots. Journal of Agricultural and Food Chemistry. 2013;**61**:5226-5533. DOI: 10.1021/jf305064h

[35] Kurokawa T, Itagaki S, Yamaji T, Nakata C, Noda T, Hirano T, et al. Antioxidant activity of a novel extract from bamboo grass (AHSS) against ischemia-reperfusion injury in rat small intestine. Biological and Pharmaceutical Bulletin. 2006;**29**(11):2301-2303. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17077533

[36] Kokura S, Handa O, Takagi T, Ishikawa T, Naito Y, Yoshikawa T. Silver nanoparticles as a safe preservative for use in cosmetics. Nanomedicine: Nanotechnology, Biology, and Medicine. 2010;**6**:570-574. DOI: 10.1016/j.nano.2009.12.002

[37] Zhang J, Gong J, Ding Y, Lu B, Wu X, Zhang Y. Antibacterial activity of water-phase extracts from bamboo shavings against food spoilage microorganisms. African Journal of Biotechnology. 2010;**9**:7710-7717

[38] Gallón AIM, Torres EC, Cabrera CG. Actividad antiséptica de vinagre de *Guadua angustifolia* Kunth. Revista Cubana de Plantas Medicinales. 2011;**16**:244-252

[39] Moreno PRH, Costa-Issa FI, Rajca-Ferreira AK, Pereira MAA, Kaneko TM. Native Brazilian plants against nosocomial infections: A critical review on their potential and the antimicrobial methodology. Current Topics in Medicinal Chemistry. 2013;**13**:3040-3078

[40] Tanaka A, Shimizu K, Kondo R. Antibacterial compounds from shoot skins of moso bamboo (*Phyllostachys pubescens*). Journal of Wood Science. 2013;**59**:155-159. DOI: 10.1007/s10086-012-1310-6

[41] Cragg GM, Newman DJ. Natural products: A continuing source of novel drug leads. Biochimica et Biophysica Acta. 2013;**1830**:3670-3695. DOI: 10.1016/j.bbagen.2013.02.008

[42] Nishina A, Hasegawa KI, Uchibori T, Seino H, Osawa T. 2,6-Dimethoxy-*p*-benzoquinone as an antibacterial substance in the bark of *Phyllostachys heterocycla* var. pubescens, a species

of thick-stemmed bamboo. Journal of Agricultural and Food Chemistry. 1991;**39**:266-269

[43] Nishina A, Uchibori T. Antimicrobial of 2,6-Dimethoxy-*p*-benzoquinone, isolated from Thick-stemmed bamboo, and its analogs. Agricultural and Biological Chemistry. 1991;**55**:2395-2398

[44] Valentino MJG, Ganado LS, Ganado MR, Undan JR. Phytochemical screening and bio assay of the anti-microbial activity of three species of bamboo in Nueva Ecija, Philippines. Advances in Environmental Biology. 2015;**9**:389-396

[45] Shen X, Zheng D, Gao J, Hou C. Isolation and evaluation of endophytic fungi with antimicrobial ability from *Phyllostachys edulis*. Bangladesh Journal of Pharmacology. 2012;**7**:249-257. DOI: 10.3329/bjp.v7i4.12068

[46] Zhou YK, Shen XY, Hou CL. Diversity and antimicrobial activity of culturable fungi from fishscale bamboo (*Phyllostachys heteroclada*) in China. World Journal of Microbiology and Biotechnology. 2017;**33**:104:1-7. DOI : 10.1007/s11274-017-2267-9

[47] Shen XY, Cheng YL, Cai CJ, Fan L, Gao J, Hou CL. Diversity and antimicrobial activity of culturable endophytic fungi isolated from Moso bamboo seeds. PLoS ONE. 2014;**9**:1-7. DOI:10.1371/journal.pone.0095838

[48] Azmi AFMN, Mustafa S, Hashim DM, MAnap YA. Prebiotic activity of polysaccharides extracted from Gigantochloa Levis (Buluh beting) shoots. Molecules. 2012;**17**:1635-1651. DOI: 10.3390/molecules17021635

[49] Singh SP, Jadaun JS, Narnoliya LK, Pandey A. Prebiotic oligosaccharides: Special focus on fructooligosaccharides, its biosynthesis and bioactivity. Applied Biochemistry and Biotechnology. 2017;**183**:613-635. DOI: 10.1007/s12010-017-2605-2

[50] He S, Wang X, Zhang Y, Wang J, Sun H, Wang J, et al. Isolation and prebiotic activity of water-soluble polysaccharides fractions from the bamboo shoots (*Phyllostachys praecox*). Carbohydrate Polymers. 2016;**151**:295-304. DOI: 10.1016/j.carbpol.2016.05.072

[51] Lu B, Liu L, Zhen X, Wu X, Zhang Y. Anti-tumor activity of triterpenoid rich extract from bamboo shavings (Caulis bamfusae in Taeniam). African Journal of Biotechnology. 2010;**9**:6430-6436

[52] Lin Y, Collier AC, Liu W, Berry MJ, Panee J. The inhibitory effect of bamboo extract on the development of 7,12-dimethylbenz[a]anthracene (DMBA)-induced breast cancer. Phytotherapy Research. 2008;**22**: 1440-1445. DOI: 10.1002/ptr.2439

[53] Ho CL, Lin CY, Ka SM, Chen A, Tasi YL, Liu ML, Chiu YC, Hua KF. Bamboo vinegar decreases inflammatory mediator expression and NLRP3 inflammasome activation by inhibiting reactive oxygen species generation and protein kinase C-α/δ activation. PLoS ONE. 2013;**8**:1-12. DOI:10.1371/journal.pone.0075738

[54] Hong EJ, Jung EM, Lee GS, Kim JY, Na KJ, Park MJ, et al. Protective effects of the pyrolyzates derived from bamboo against neuronal damage and hematoaggregation. Journal of Ethnopharmacology. 2010;**128**:594-599. DOI: 10.1016/j.jep.2010.01.045

[55] Liu L, Liu L, Lu B, Xia D, Zhang Y. Evaluation of antihypertensive and antihyperlipidemic effects of bamboo shoot angiotensin converting enzyme inhibitory peptide in vivo. Journal of Agricultural and Food Chemistry.

2012;**60**:11351-11358. DOI: 10.1021/jf303471f

[56] Du P, Huang XJ, Wang TD, Huang SJ, Shan Y, Yu J, et al. Lipid metabolism effects of freeze-dried powder of bamboo juice on liver cell line L02 with steatosis. Advance Journal of Food Science and Technology. 2015;**9**:854-859. DOI: 10.19026/ajfst.9.1642

[57] Huang JQ, Qi RT, Pang MR, Liu C, Li GY, Zhang Y. Isolation, chemical characterization, and immunomodulatory activity of naturally acetylated hemicelluloses from bamboo shavings. Journal of Zhejiang University Science B. 2017;**18**:138-151. DOI: 10.1631/jzus.B1500274

[58] Sato W, Takeshita K, Tsuboi M, Kanamori M, Ishibashi K, Miura NN, et al. Specificity of the Immunomodulating Activity of *Sasa veitchii* (Japanese Folk Medicine Kumazasa) to Fungal Polysaccharides. International Journal of Medicinal Mushrooms. 2015;**17**:415-426