About JMPR

The Journal of Medicinal Plant Research is published weekly (one volume per year) by Academic Journals.

The Journal of Medicinal Plants Research (JMPR) is an open access journal that provides rapid publication (weekly) of articles in all areas of Medicinal Plants research, Ethnopharmacology, Fitoterapia, Phytomedicine etc. The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JMPR are peerreviewed. Electronic submission of manuscripts is strongly encouraged, provided that the text, tables, and figures are included in a single Microsoft Word file (preferably in Arial font).

Submission of Manuscript

Submit manuscripts as e-mail attachment to the Editorial Office at: jmpr@academicjournals.org. A manuscript number will be mailed to the corresponding author shortly after submission.

The Journal of Medicinal Plant Research will only accept manuscripts submitted as e-mail attachments.

Please read the Instructions for Authors before submitting your manuscript. The manuscript files should be given the last name of the first author.
<table>
<thead>
<tr>
<th>Editors</th>
</tr>
</thead>
</table>
| **Prof. Akah Peter Achunike**  
*Editor-in-chief*  
Department of Pharmacology & Toxicology  
University of Nigeria, Nsukka  
Nigeria |
| **Associate Editors** |
| **Dr. Ugur Cakicioglu**  
*Elazig Directorate of National Education*  
Turkey. |
| **Dr. Jianxin Chen**  
*Information Center,*  
Beijing University of Chinese Medicine,  
Beijing, China  
100029,  
China. |
| **Dr. Hassan Sher**  
*Department of Botany and Microbiology,*  
College of Science,  
King Saud University, Riyadh  
Kingdom of Saudi Arabia. |
| **Dr. Jin Tao**  
*Professor and Dong-Wu Scholar,*  
Department of Neurobiology,  
Medical College of Soochow University,  
199 Ren-Ai Road, Dushu Lake Campus,  
Suzhou Industrial Park,  
Suzhou 215123,  
P.R.China. |
| **Prof. Parveen Bansal**  
*Department of Biochemistry*  
Postgraduate Institute of Medical Education and Research  
Chandigarh  
India. |
| **Dr. Ravichandran Veerasamy**  
AIMST University  
Faculty of Pharmacy, AIMST University, Semeling - 08100,  
Kedah, Malaysia. |
| **Dr. Sayeed Ahmad**  
*Herbal Medicine Laboratory,* Department of Pharmacognosy and Phytochemistry,  
Faculty of Pharmacy, Jamia Hamdard (Hamdard University), Hamdard Nagar, New Delhi, 110062,  
India. |
| **Dr. Cheng Tan**  
*Department of Dermatology,* first Affiliated Hospital of Nanjing Univeristy of Traditional Chinese Medicine.  
155 Hanzhong Road, Nanjing, Jiangsu Province,  
China. 210029 |
| **Dr. Naseem Ahmad**  
*Young Scientist (DST, FAST TRACK Scheme)*  
Plant Biotechnology Laboratory  
Department of Botany  
Aligarh Muslim University  
Aligarh- 202 002,(UP)  
India. |
| **Dr. Isiaka A. Ogunwande**  
*Dept. Of Chemistry,*  
Lagos State University, Ojo, Lagos,  
Nigeria. |
Editorial Board

Prof Hatil Hashim EL-Kamali  
Omdurman Islamic University, Botany Department, Sudan.

Prof. Dr. Muradiye Nacak  
Department of Pharmacology, Faculty of Medicine, Gaziantep University, Turkey.

Dr. Arash Kheradmand  
Lorestan University, Iran.

Prof Dr Cemşit Karakurt  
Pediatrics and Pediatric Cardiology  
Inonu University Faculty of Medicine, Turkey.

Dr. Sadiq Azam  
Department of Biotechnology, Abdul Wali Khan University Mardan, Pakistan.

Samuel Adelani Babarinde  
Department of Crop and Environmental Protection, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Kongyun Wu  
Department of Biology and Environment Engineering, Guiyang College, China.

Prof Dr Cemşit Karakurt  
Pediatrics and Pediatric Cardiology  
Inonu University Faculty of Medicine, Turkey.

Prof Swati Sen Mandi  
Division of plant Biology, Bose Institute, India.

Dr. Wafaa Ibrahim Rasheed  
Professor of Medical Biochemistry National Research Center  
Cairo, Egypt.

Prof Swati Sen Mandi  
Division of plant Biology, Bose Institute, India.

Dr. Ujjwal Kumar De  
Indian Vetreinary Research Institute, Izatnagar, Bareilly, UP-243122  
Veterinary Medicine, India.
## ARTICLES

### Research Articles

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effects of the stem barks aqueous extract of <em>Anthocleista schweinfurthii</em> Gilg (Loganiaceae) on acute and chronic gastric ulcers rats models</td>
<td>674</td>
</tr>
<tr>
<td>Christophe Mezui, Frida Longo, Paul Tan, Celine Nkenfou, Ntsayo Fokou and Hamani Salou</td>
<td></td>
</tr>
<tr>
<td>Potential medicinal application and toxicity evaluation of extracts from bamboo plants</td>
<td>681</td>
</tr>
<tr>
<td>Jun Panee</td>
<td></td>
</tr>
</tbody>
</table>

---

*Journal of Medicinal Plants Research*

Table of Contents: Volume 9  Number 23,  17  June, 2015
Effects of the stem barks aqueous extract of *Anthocleista schweinfurthii* Gilg (Loganiaceae) on acute and chronic gastric ulcers rats models

Christophe Mezui¹*, Frida Longo¹, Paul Tan², Celine Nkenfou¹, Ntsayo Fokou¹ and Hamani Salou¹

¹Department of Biological Sciences, Higher Training Teachers’ College, University of Yaounde I, P.O. Box 047, Yaoundé, Cameroon.

²Department of Animal Biology and Physiology, Faculty of Sciences, University of Yaounde I, P.O. Box 812, Yaounde, Cameroon.

Received 8 February, 2015; Accepted 17 March, 2015

*Anthocleista schweinfurthii* is used in the traditional management of gastro-duodenal ulcers; this led us to evaluate the gastro-cytoprotective and healing effects of this plant. Anti-ulcer activity of the stem barks aqueous extract of *A. schweinfurthii* (EAS) was evaluated using five methods: HCl/ethanol; indomethacin-HCl/ethanol; absolute ethanol; pylorus-ligated (acute gastric lesions); and acetic acid-induced chronic ulcers in rats. The parameters assessed were mucus production, gastric ulcer index, pH, acid concentration and volume of gastric contents. Sucralfate, cimetidine and ranitidine were used as the reference anti-ulcer drugs. In all cases, oral administration of EAS (250 and 500 mg/kg), dose-dependently, prevented gastric lesion formation (p<0.001). Generally, this cytoprotective action was accompanied by significant increases in gastric mucus production. Intraperitoneal indomethacin (30 mg/kg) significantly reduced mucus production but did not reduce the cytoprotective effect. In pylorus ligation, the extract did not reduce acidity and volume of gastric juice compared to controls. All doses of the extract showed a highly significant (p<0.001) reduction of ulceration with a healing rate over 90%. This study indicates that *A. schweinfurthii* possesses significant anti-ulcer activity and these results are substantiated by the histopathological examination of the ulcerated stomachs.

**Key words:** Gastric, ulcer, cytoprotection, *Anthocleista schweinfurthii*, Loganiaceae.

**INTRODUCTION**

*Anthocleista schweinfurthii* Gilg (Loganiaceae or Gentianaceae) is a tree plant found in tropical Africa and in Madagascar (Bach et al., 1967). In Gabon, *A. schweinfurthii* is used in ethno medicine to treat lactation disorders. In Congo Brazzaville, the stem bark decoction of *A. schweinfurthii* is used to treat fever, stomach ache, ovary infection and sterility in women. In Tanzania, the decoction of *A. schweinfurthii* is used to treat malaria, skin lesions and the juice of the leaves, roots or stem bark is used as cicatrizing agent (Kherharo, 1974). *A. schweinfurthii* is used in the traditional management of gastro-duodenal ulcers; this led us to evaluate the gastro-cytoprotective and healing effects of this plant. Anti-ulcer activity of the stem barks aqueous extract of *A. schweinfurthii* (EAS) was evaluated using five methods: HCl/ethanol; indomethacin-HCl/ethanol; absolute ethanol; pylorus-ligated (acute gastric lesions); and acetic acid-induced chronic ulcers in rats. The parameters assessed were mucus production, gastric ulcer index, pH, acid concentration and volume of gastric contents. Sucralfate, cimetidine and ranitidine were used as the reference anti-ulcer drugs. In all cases, oral administration of EAS (250 and 500 mg/kg), dose-dependently, prevented gastric lesion formation (p<0.001). Generally, this cytoprotective action was accompanied by significant increases in gastric mucus production. Intraperitoneal indomethacin (30 mg/kg) significantly reduced mucus production but did not reduce the cytoprotective effect. In pylorus ligation, the extract did not reduce acidity and volume of gastric juice compared to controls. All doses of the extract showed a highly significant (p<0.001) reduction of ulceration with a healing rate over 90%. This study indicates that *A. schweinfurthii* possesses significant anti-ulcer activity and these results are substantiated by the histopathological examination of the ulcerated stomachs.

**Key words:** Gastric, ulcer, cytoprotection, *Anthocleista schweinfurthii*, Loganiaceae.
**schweinfurthii** contains substances that promote vasoconstriction and increase cardiac contraction (Ngombe et al., 2010). The STRC/OAU-Cameroon Government-sponsored ethnobotanical survey did not cite **A. schweinfurthii** for its antiulcer use, but the bark of a sister species, **Anthocleista djalonensis**, is used to treat abdominal pain in Nigeria (Olowokudejo et al., 2008). However, led by reports of the use of **A. schweinfurthii** in the traditional treatment of gastric ulcers in Congo (Kherharo et al., 1974), we have tested the anti-ulcer properties of the aqueous stem bark extract of **A. schweinfurthii** using experimental rat models.

**MATERIALS AND METHODS**

**Plant**

The stem barks of **A. schweinfurthii** Gilg (Loganiaceae) were collected in December, 2010 in Yaounde Center region of Cameroon. Botanical identification was done by Pr Jean Michel Onana, botanist, director of the National Herbarium of Cameroon, by comparison with existing herbarium specimen n° HNC 53944. The stem barks of **A. schweinfurthii** were dried at room temperature in the laboratory. The dried stem barks of the plant were powdered and were extracted in distilled water by boiling 700 g in 5 L of distilled water for 30 min. The filtrate was lyophilized and the resulting brownish solid (50 g) was used for the pharmacological tests.

**Animal**

Male Wistar rats (180±20 g) were used for the experiments. The animals were raised in the animal house of the Higher Teachers Training College, University of Yaounde. They were fed a standard laboratory diet (SPC Ltd, Bafoussam, Cameroon) and were given fresh water *ad libitum*. Before the experiments, they were starved for 48 h in wire mesh bottom cages to prevent coprophagy but allowed free access to water. Prior authorization for the use of laboratory animals in this study has been obtained from Cameroonian National Ethics Committee (Reg. N. FWA-IRB 00001954). The use, handling and care of animals were done in adherence to the European convention (Strasbourg, 18.III.1986) for the protection of vertebrate animals used for experimental and other purposes (ETS-123), with particular attention to Part III, articles 7, 8 and 9.

**Assays**

**Anti-ulcerogenic tests**

**HCl/Ethanol-induced gastric lesions**: Gastric mucosal lesions were induced by the method describe by Hara and Okabe (1985). The test rats were administered the plant extract (250 and 500 mg/kg) per os while the controls received distilled water (1 ml). Those of the 4th group received by oral route 60 mg/kg of sucralfate (Ulcac®, Laboratoire Advents 46, quai de la Rapée-75012, Paris, France) (a reference drug). 1 h later, all the animals received the necrotizing HCl/ethanol (1 ml) solution by oral route. After 1 h, under light ether anesthesia, the abdomen of each rat was opened and the stomach removed. The ulcers produced in the glandular region of each stomach were measured and scored as earlier described. The scores were attributed with respect to the ulcerated surface (US) (mm²): score 0 (US=0); score 1 (0<US≤0.5); score 2 (0.5<US≤2.5); score 3 (2.5<US≤5); score 4 (5<US≤10); score 5 (10<US≤15); score 6 (15<US≤20); score 7 (20<US≤25); score 8 (25<US≤30); score 9 (30<US≤35) and score 10 (35<US).

**HCl/Ethanol-induced gastric lesions** in rats pre-treated with indomethacin: Indomethacin (Mark Sharp & Dohme, U.K.) was given to the rats (30 mg/kg) by intra peritoneal route. This was followed 1 h later by the HCl/ethanol ulcer procedure as described earlier (Sun et al., 1992).

**Absolute ethanol-induced gastric lesions**: Absolute ethanol-induced lesions were provoked using the HCl/ethanol-induced gastric lesions method, but instead the absolute ethanol was used. The rats received orally the plant extract or the vehicle followed 1 h later by ethanol. They were also killed using ether and the lesions formed were observed and scored (Robert et al., 1979).

**Pylorus-ligated gastric secretion and ulceration**: The method described by Shay et al. (1945) was used to study the ability of extract to reduce gastric acid secretion as well as prevent gastric ulceration resulting from auto digestion by stomach secretions. The test rats received the plant extract (250 and 500 mg/kg), controls received the distilled water (1 ml) and those of the 4th group received cimetidine (Tagamet lot 260B, cedex 26-92090 Paris) (200 mg/kg) by oral route, 1 h before the experiment. The pylorus of each rat was tied under light ether anesthesia and the abdominal incisions were closed. The rats were sacrificed 6 h later and the gastric juice produced by each was collected, centrifuged (6000 r/min) and the volume measured. Ulcers produced in the glandular region of the stomachs were measured and scored: score 0 (no ulcer); score 1 (dilation of vessels and small dots of ulcer); score 2.5 (ulcers 4 mm long) and score 5 (ulcers ≥5 mm long).

**Measurement of gastric acidity**: Samples of gastric contents (1 ml) were analyzed for hydrogen ion concentration by pH-metric titration with 0.1N NaOH solution using a digital pH-meter. The acid content was expressed as mEq/L.

**Ulcer healing test**

**Acetic acid-induced chronic ulcers**: The method described by Takagi et al. (1969) was used. Briefly, laparotomy was performed under light ether anaesthesia on experimental rats that were deprived of food during the preceding 24 h. Fifty microliters of 30% glacial acetic acid was injected into the wall of the stomach corpus at the region of the lesser curvature, and the stomach wall wiped using cotton wool soaked in a 0.9% NaCl solution. The abdominal incisions were stitched up and disinfectant (Betadine) applied to the area every day to avoid infection. The animals then continued to receive their regular diet, with free access to water. Four days after the operation, a control group of six rats was killed using ether, and the stomachs were removed and cut open along the greater curvature in order to establish the degree of ulceration prior to the onset of treatment: ulcer area = length × width of ulcer (mm²). The mucus covering, gastric wall, was measured and the stomachs were stored (in formaldehyde solution) awaiting histological studies. The remaining rats were divided into four groups of six rats each. These rats were treated once a day for two weeks. Group 1 (controls) received 1 ml of distilled water by gavage, while groups 2 and 3 were given 250 and 500 mg/kg of the extract of **A. schweinfurthii**, respectively, dissolved in 1 ml of distilled water. Group 4 rats were given 50 mg/kg of ranitidine (Azantac 300 mg, lot 621, Laboratoire Glaxosmith, Cedex, France). An additional group of 6 healthy non-ulcerated rats (negative control) was subjected to the same experimental conditions and underwent all the experimental manipulations but were given neither the plant extract
Treatment | Dose (mg/kg) | N | Ulcer index (mean ± SEM) | Inhibition (%) | Mucus production (mg)
---|---|---|---|---|---
Control | - | 6 | 5.44 ± 1.53 | - | 92.50 ± 5.00
A. schweinfurthii | 250 | 6 | 5.25 ± 2.06 | 3.49 | 117.50 ± 5.90*
A. schweinfurthii | 500 | 6 | 0.88 ± 0.17** | 83.82 | 140.00 ± 6.88*
Sucralfate | 60 | 6 | 1.78 ± 0.45* | 67.27 | 77.00 ± 1.35

N: Number of rats; *P<0.05 statistically significant relative to control; **P<0.01 statistically highly significant relative to control.

Table 1. Effects of stem bark aqueous extract of A. schweinfurthii on gastric lesions induced by HCl/ethanol in rats.
aqueous extract of *A. schweinfurthii* was used to prevent the formation of gastric lesions induced using absolute ethanol. Inhibition of lesion formation was poor (9.18%) at the dose of 500 mg/kg. The aqueous extract of *A. schweinfurthii* and sucralfate (60 mg/kg) both showed significantly low potencies against absolute ethanol-induced gastric lesions.

**Pylorus-ligated gastric secretion and ulceration**

Table 4 shows the results obtained when the animals were subjected to pylorus ligation. When the extract of *A. schweinfurthii* (500 mg/kg) was administered, ulcer index and ulcerated surface were 3.61 and 14.33 mm² compared with 5.00 and 35.7 mm² for controls. This significant reduction (p<0.01) of the ulcerated surface was accompanied by a significant increase (p<0.01) secretion of mucus. For 58.00±4.80 mg in control rats, the amount of mucus was increased to 135.00±1.60 and 141.35±1.42 mg in rats treated with plant extract at doses of 250 and 500 mg/kg, respectively. The plant extract had no significant effect on the volume and gastric acidity.

**Acetic acid-induced chronic ulcers**

Table 5 shows a dose-dependent enhancement of the healing of acetic acid-induced chronic gastric ulcers following daily treatment with aqueous stem bark extract of *A. schweinfurthii* (EAS). On day 4, ulcer areas reduced from 81.00 to 47.00 mm² in control rats. Following two weeks of treatment with EAS, ulcer areas reduced from 47.00 mm² in controls to 0.08 and 0.02 mm², respectively, for the rats receiving 250 and 500 mg/kg of the extract. A healing rate of 80.42% was recorded for ranitidine (50 mg/kg). Unlike ranitidine, EAS promoted significantly higher levels of mucus production (96.62 and 124.75 mg at 250 and 500 mg/kg) during the treatment period as compared to the controls (58.13 mg/kg).

Histological analysis revealed the presence of a sclerotic block, leukocyte infiltration and edema in rats negative control 1 (sacrificed on day 4 rats). In rats negative control 2, there was presence of fibrillations. Rats treated with aqueous extract of *A. schweinfurthii* showed the normalization of gastric tissue with a well-developed mucosa.

**DISCUSSION**

The results of this study clearly show that the aqueous stem bark extract of *A. schweinfurthii*, when administered 1 h before injury with HCl/ethanol, reduced significantly (p<0.01) the mucosal lesions produced by this ulcerogenic solution. The accompanying significant dose-dependent increases in mucus production suggest that the gastric mucosal strengthening mechanism contributes to the anti-irritant potential of the extract (Table 1).

Treatment with indomethacin reduces prostaglandin and bicarbonate secretion and gastric mucosal blood flow in animals. The inhibition of prostaglandins predisposes the stomach and duodenum to mucosal damage, whereas stimulation of prostaglandins can be protective (Selling et al., 1987). When the cytoprotective effect of an anti-ulcer agent is significantly reduced by pre-treatment with indomethacin, it is usually interpreted that cytoprotection is mediated by endogenous prostaglandins.
Table 4. Effects of stem bark aqueous extract of *A. schweinfurthii* on pylorus ligation-induced gastric mucosal ulceration in rats.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dose (mg/kg)</th>
<th>Total ulcer Area (mm²)</th>
<th>Volume of gastric juice (ml)</th>
<th>Gastric acidity (mEq/L)</th>
<th>Mucus production (mg)</th>
<th>Ulcer index</th>
<th>Inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-</td>
<td>35.75 ± 5.00</td>
<td>5.15 ± 0.40</td>
<td>88.00 ± 8.92</td>
<td>58.00 ± 4.80</td>
<td>5.00 ± 0.00</td>
<td>-</td>
</tr>
<tr>
<td><em>A. schweinfurthii</em></td>
<td>250</td>
<td>28.33 ± 3.07</td>
<td>5.01 ± 0.42</td>
<td>83.60 ± 5.25</td>
<td>135.00 ± 1.60**</td>
<td>4.29 ± 0.41</td>
<td>14.2</td>
</tr>
<tr>
<td><em>A. schweinfurthii</em></td>
<td>500</td>
<td>14.33 ± 2.29**</td>
<td>3.86 ± 0.61</td>
<td>85.20 ± 4.81</td>
<td>141.35 ± 1.42**</td>
<td>3.61 ± 0.82</td>
<td>27.8</td>
</tr>
<tr>
<td>Cimetidine</td>
<td>200</td>
<td>5.95 ± 0.74**</td>
<td>3.27 ± 0.59*</td>
<td>80.20 ± 2.10</td>
<td>44.23 ± 2.86</td>
<td>1.56 ± 0.20</td>
<td>68.8</td>
</tr>
</tbody>
</table>

Each value represents the mean ± SEM of 6 animals; *P<0.05 statistically significant relative to control; **P<0.01 statistically highly significant relative to control.

Table 5. Effects of stem bark aqueous extract of *A. schweinfurthii* on the healing rate of chronic acetic acid-induced gastric ulcers in rats.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dose (mg/kg)</th>
<th>Ulcer area (mm²)</th>
<th>Healing rate (%)</th>
<th>Mucus (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlβ</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>60.53 ± 3.83</td>
</tr>
<tr>
<td>Controlγ</td>
<td>-</td>
<td>81.00 ± 13.37</td>
<td>-</td>
<td>55.26 ± 3.38</td>
</tr>
<tr>
<td>Controlγ</td>
<td>-</td>
<td>47.00 ± 4.81</td>
<td>41.97</td>
<td>54.25 ± 4.14</td>
</tr>
<tr>
<td><em>A. schweinfurthii</em></td>
<td>250</td>
<td>0.08 ± 0.00**</td>
<td>99.82</td>
<td>96.62±3.40*</td>
</tr>
<tr>
<td><em>A. schweinfurthii</em></td>
<td>500</td>
<td>0.024±0.00**</td>
<td>99.94</td>
<td>124.75±3.41**</td>
</tr>
<tr>
<td>Ranitidine</td>
<td>50</td>
<td>9.20 ± 2.19**</td>
<td>80.42</td>
<td>58.13 ± 4.39</td>
</tr>
</tbody>
</table>

N: Number of rats; α: Healthy, non-ulcerated control rats; β: Control rats killed 4 days post operation to establish initial degree of acetic ulceration; γ: Control rats given vehicle for 14 days following ulcer induction; *P<0.05 statistically significant relative to control; **P<0.01 statistically highly significant relative to control.

(Tan et al., 2002). The results of this study therefore suggest that, in addition to increased mucus production via prostaglandin, the extract may confer direct cytoprotection by effects similar to endogenous prostaglandin.

Absolute ethanol is highly corrosive to the gastric mucosa. Its pathogenic mode of action on gastric mucosa involves, in addition to superficial aggressive cellular necrosis, the release of tissue-derived mediators such as histamine and leucotrine C₄. These mediators act on the gastric micro vasculature, triggering a series of events that result in mucosal and possibly sub mucosal tissue destruction (Oates and Hakkinen, 1988). The results of this study suggest that the aqueous stem bark extract of *A. schweinfurthii* does not prevent the generation or the necrotic action of these mediators on the gastric micro vasculature. These results are similar to those obtained with the leaf methanol extract of *Ocimum suave* (Tan et al., 2002).

Histological analysis revealed the presence of sclerosus block in stomachs, a leukocyte infiltration and oedema in negative control 1 rats (rats sacrificed at day 4), which indicates the presence of inflammation caused by injection of acetic acid in the stomach wall. In the injured area, vasodilatation and increased permeability of the walls of small blood vessels leads to the passage of water and plasma proteins into damaged tissue. Then, leukocytes migrate to the inflamed area where they accumulate (Stevens and Lowe, 1997).

In the negative control rats 2 (rats sacrificed at day 18), the presence of fibrillation showed that ulcer healing was underway. Indeed, fibroblasts and myoblasts migrate and multiply at the injured area. Fibroblasts synthesize collagen, which is the origin of the scar formation (Stevens and Lowe, 1997). The presence of oedema, block leukocyte infiltration and sclerosis in these rats demonstrate the persistence of inflammation; this is explained by the fact that in the absence of treatment, the ulcer healing is slow and incomplete. Normalization of stomach tissue with a fully developed mucosa in rats treated with aqueous extract of *A. schweinfurthii* shows that the extract would accelerate ulcer healing and stimulates the regeneration of the gastric mucosa.

Phytochemical studies of *A. schweinfurthii* have revealed the presence of flavonoids, polyphenols, tannins and leucoanthocyans (Njayou et al., 2000). Polyphenols compounds protect the gastrointestinal mucosa from lesions produced by various experimental ulcer models and against different necrotic agents. Polyphenols have antihistaminic properties, thus, decreases histamine levels, as well as preventing the release of histamine from gastric mast cells and inhibiting the gastric H⁺/K⁺
proton pump and diminish acid gastric secretion. On the other hand, they possess cytoprotective effects, which increase the mucosal blood flow, stimulate the synthesis of muco-bicarbonate in the gastric mucosa and increase prostaglandins levels. However, the most important mechanism of action responsible for the anti-ulcer activity of flavonoids is their antioxidant properties, which involve free radical scavenging, transition metal ions chelation, inhibition of oxidizing enzymes, increase of proteic and non proteic antioxidants and reduction of lipid peroxidation (Kelly et al., 2009). Flavanoids have also been reported to offer some protection in ulcer development by increasing capillary resistance and improving microcirculation (Sahiba et al., 2011). This extract also has the alkaloids which have gastro-cytoprotective and antiulcer activities (Hashizume et al., 1978). Njayou et al. (2000) revealed the presence of tannin and leucoanthocyans in A. schweinfurthii. Tannins are known to protect the outermost layer of mucosa and to render it less permeable and more resistant to chemicals and mechanical injury or irritation and thus prevent ulcer development (Heloina et al., 2008). Others species of Anthocleista have been shown to exhibit gastric cytoprotection effects. The stem barks of Anthocleista vogelii possess potent antiulcer properties (Ateufack et al., 2006). The acute toxicity study of the stem barks aqueous extract of A. schweinfurthii shows that the lethal dose 50 (LD50) is greater than 2000 mg/kg and the dose of 1000 mg/kg used in subacute toxicity presented no significant toxic effects (Mezui et al., 2015). Therefore, therapeutic doses of extract of A. schweinfurthii (250 and 500 mg/kg) used in this study would be non-toxic.

Conclusion

Oral administration of EAS (250 and 500 mg/kg), dose-dependently, prevented gastric lesion formation (p<0.001). This cytoprotective action was accompanied by significant increases in gastric mucus production. In pylorus ligation, the extract did not reduce acidity and volume of gastric juice. All doses of the extract showed a highly significant (p<0.001) reduction of ulceration with a healing rate over 90%. The results of this work showed that the extract of A. schweinfurthii is neither anti-secretory or an antacid. This extract protects the gastric mucosa even when gastric acidity is high and accelerates the healing of chronic gastric ulcers. These experiments confirmed the traditional management of peptic ulcers. Further work is envisaged to evaluate the antioxidant power of the A. schweinfurthii extract as well as its possible toxicity.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

This project was supported by the International Foundation for Science (IFS), Stockholm, Sweden, through Grant F/2882-2 (PVT) and Ministry of High Education of Cameroon through the special allocation account for the modernization of university research in Cameroon.

REFERENCES

Review

Potential medicinal application and toxicity evaluation of extracts from bamboo plants

Jun Panee

Department of Cell and Molecular Biology, John A Burns School of Medicine, University of Hawaii at Manoa. 651 Ilalo street, Honolulu, HI 96813, USA.

Received October 24, 2014; Accepted 4 June, 2015

Bamboo plants play a significant role in traditional Asian medicine, especially in China and Japan. Biomedical investigations on the health-benefiting effects as well as toxicity of different parts and species of bamboo have been carried out worldwide since the 1960s, and a wide range of protective effects of bamboo-derived products has been documented, such as protection against oxidative stress, inflammation, lipotoxicity, cancer, and cardiovascular disease. Some of these products may interfere with male and female reproductive function, thyroid hormone metabolism, and hepatic xenobiotransformation enzymes. The diversity of bamboo species, parts of the plants available for medicinal use, and different extraction methods suggest that bamboo has great potential for producing a range of extracts with functional utility in medicine.

Key words: Bamboo, traditional medicine, natural product, antioxidant, inflammation, cancer, lipotoxicity, cardiovascular disease, toxicity, reproduction, thyroid hormone, phase I and phase II hepatic enzymes.

INTRODUCTION

Bamboo refers to plants in the subfamily Bambusoideae, which is a part of the true grass family. This subfamily consists of more than 70 genera and about 1,450 species (Gratani et al., 2008), and members of this subfamily grow in diverse climates from subarctic to tropical regions. The versatile application of bamboo in people's daily lives in Asia was vividly described by William Edgar Geil in his book A Yankee on The Yangtze: being a narrative of a journey from Shanghai through the central kingdom to Burma, which was first published in 1904 (Geil, 2010). He wrote, “A man can sit in a bamboo house under a bamboo roof, on a bamboo chair at a bamboo table, with a bamboo hat on his head and bamboo sandals on his feet. He can at the same time hold in one hand a bamboo bowl, in the other hand bamboo chopsticks and eat bamboo sprouts. When through with his meal, which has been cooked over a bamboo fire, the table may be washed with a bamboo cloth, and he can fan himself with a bamboo fan, take a siesta on a bamboo bed, lying on a bamboo mat with his head resting on a bamboo pillow…He might then take a walk over a bamboo suspension bridge, drink water from a bamboo ladle, and scrape himself with a bamboo scraper.”

In addition to the uses in daily life, different parts of bamboo have also been employed in traditional Asian medicine for a variety of purposes, as summarized by Dr.
S. Dharmananda at the Institute for Traditional Medicine (Portland, OR) in his online article “Bamboo as Medicine” (http://www.itmonline.org/arts/bamboo.htm). In traditional Chinese medicine, bamboo is generally considered cooling, calming, and phlegm resolving, and is incorporated in many traditional formulas to treat lung and stomach heat, febrile disease, and correct up-flowing qi (qi is a fundamental concept in traditional Chinese medicine referring to the energy flow in a living being).

The earliest scientific documentation of potential medicinal use of bamboo was published in the early 1960s (Sakai et al., 1963), followed by a series of studies carried out by Shibata et al. in the 1970s (Okabe et al., 1975; Shibata et al., 1976, 1978, 1979). Bamboo, as a biomedical research topic was relatively silent during the 1980s and 1990s, but research interest increased worldwide since the beginning of this century (Panee, 2008). In this article, the author summarizes recent findings on both health benefits and toxicity of extracts derived from different parts and species of bamboo.

**Bamboo leaf extracts**

Traditional Chinese medicine distinguishes bamboo leaves into two kinds. (1) Kuzhuye (“Ku” means bitter, “Zhu” means bamboo, and “Ye” means leaf), dried leaves of *Pleioblastus amarus* (Keng) Keng f. “It is pungent, sweet, slightly bitter, and cold, and enters the heart and lung meridians. It is often used to treat febrile diseases when there is heat in the heart, lung, or chest” (Yang, 2002). (2) Danzhuye (“Dan” means bland), which are dried leaves and stem of *Lophatherum gracile* Brongn. “It is less strong in clearing heat than the bitter form, but is good at promoting urination, thereby leaching out the heat from the heart and the small intestine. In clinical practice, it is used to treat urinary dysfunction, which starts or worsens in stressful situations. It is also used to treat eczema due to damp heat” (Yang, 2002). According to Dr. S. Dhammananda, the leaves of the black bamboo [*Phyllostachys nigra* (Lodd.) Munro] are used similarly as “Danzhuye” in Japan.

In current biomedical research, the leaves of bamboo seem to be the part of the plant triggering the most intensive interest, possibly because the leaves comprise a significant portion of the total biomass of bamboo plants, are easy to harvest and process, and some can even be obtained as waste of bamboo timber industry. Extracts and compounds from the leaves of *Sasa senanensis* (Franch. & Sav.) Rehder, *Phyllostachys nigra* (Lodd.) Munro, and *Phyllostachys edulis* (Carrière) J. Houz have been the most commonly studied, although a few published studies have been on the leaves from other bamboo species, such as *Indocalamus tessellatus* (Munro) Keng f, *Bambusa arundinacea* Wild, and *Sasa borealis* (Hack.) Makino & Shibata (Chen et al., 1998; Muniappan and Sundararaj, 2003; Park et al., 2007).

**Potential health benefits of bamboo leaf extracts**

*Phyllostachys edulis* (Carrière) J.Houz: This species of bamboo is known as “Maozhu” in Chinese or “Moso” in Japanese, and it is one of the largest and fastest-growing bamboo species in the world. Studies carried out in the author’s laboratory have shown that an ethanolic extract from the leaves of *P. edulis* (Carrière) J. Houz contains high levels of polyphenols and flavonoids (Lin et al., 2008). This bamboo extract (termed as BEX) protects a variety of cells against lipotoxicity induced by high levels of palmitic acid (Panee et al., 2008). Specifically, BEX inhibits palmitic acid-induced overproduction of proinflammatory cytokines, such as interleukin 6 (IL-6) and monocyte chemoattractant protein 1 (MCP-1) (Higa et al., 2011), and this anti-inflammatory effect is partially mediated by flavonoids such as tricin and 7-O-methyltricin (Higa et al., 2012) through NFkappaB and AP-1 pathway inhibition (Higa and Panee, 2011). In addition, BEX also seems to affect the central nervous system and cancer development. For example, BEX as a dietary supplement ameliorated anxiety-like neurobehaviors in mice fed high fat diet (Del Rosario et al., 2012), and decreased the incidence of DMBA-induced mammary tumors in rats (Lin et al., 2008).

Further protective effects have been reported on 3-O-caffeoyl-one-methylquinic acid, an antioxidant isolated from the leaves of *P. edulis* (Carrière) J. Houz. This compound was found to upregulate the expression of heme oxygenase-1 (HO-1) and other Nrf2- dependent phase II detoxifying genes, and protect against peroxide-induced cytotoxicity (Kweon et al., 2004; Kweon et al., 2006). This compound also prevents photocarcinogenesis via apoptotic elimination of tumor protein 53 (p53) mutant and DNA-repair defective cells (Kweon et al., 2007).

Furthermore, it has been documented that a butanol-soluble extract from the leaves of *P. edulis* (Carrière) J. Houz contains derivatives of chlorogenic acid and has antioxidant activity (Kweon et al., 2001). Essential oils of *P. edulis* (Carrière) J. Houz extracted by steam distillation contain cis-3- hexenol and have antioxidant and antimicrobial activities (Jin et al., 2011).

*Phyllostachys nigra* (Lodd.) Munro: Commonly known as “black bamboo”, this is another major species in the genus *Phyllostachys*. Flavonoids extracted from black bamboo leaves have potent antioxidant activities (Hu et al., 2000; Zhang et al., 2002). Among these flavonoids, flavone c-glucosides and p-coumaric acid reportedly have long retention time in the colon and may contribute to free radical scavenging (Zhang et al., 2007). Luteolin 6-C-(6"-O-trans-cafeoylgluco)side, an antioxidant isolated from the leaves, has been reported to protect against oxidative stress-induced cytotoxicity in retinal ganglion cells (Lee et
al., 2010). It also enhances the activity of aldose reductase and inhibits the formation of advanced glycation end products, and therefore may potentially have a role in the prevention of diabetic complications (Jung et al., 2007). Orientin, another antioxidant obtained from the leaves of black bamboo, exerts vaso-relaxant activity through the inhibition of intracellular Ca\(^{2+}\) release and extracellular Ca\(^{2+}\) influx (Fu et al., 2005). Orientin also prevents apoptosis induced by hypoxia and reoxygenation in myocardium and cardiomyocytes. The mechanism for this effect is inhibition of the activation of mitochondrial apoptotic pathway (Fu et al., 2006).

These studies suggest potential for cardio-protective effects. The acetone fraction of the leaves of *P. nigra* (Lodd.) Munro has been shown to enhance leukemia cell differentiation (Kim et al., 2007b), and inhibit interleukin-12 (IL-12) production in lipopolysaccharide-activated macrophages via decreasing NF-kappaB binding activity (Kim et al., 2007a). These preliminary findings suggest potential anti-leukemia and anti-inflammation effects of the acetone extract.

*Sasa senanensis* (Franch. & Sav.) Rehder: This species is known as Kumaizasa bamboo, found in Hokkaido, and is used in traditional medicine in Japan. Between 1998 and 2004, several articles documented a wide range of biological functions of an alkaline extract made from the leaves of this species of bamboo (the product was named “Sasa Health”). When the diet of mice was supplemented with this extract, the incidence and growth of mammary tumors in mice with spontaneous or Her2/NeuN-induced mammary tumorigenesis was inhibited (Ren et al., 2004; Tsunoda et al., 1998), spontaneous motor activity of both intact and gonadectomized mice was influenced (Nagasawa and Hattori, 2001), and some of the deleterious effects of administering BEX to pregnant rats were alleviated. These and the deleterious effects of restricted feeding were alleviated (Nagasawa et al., 2001).

Some anti-tumor effects of a new hot water extract from Sasa leaves were published in 2010. This extract inhibited the incidence and growth of 7,12-dimethylbenz[a]anthracene (DMBA)-induced mammary tumors and the growth of inoculated sarcoma and melanoma cells (Seki and Maeda, 2010). The anti-tumor efficacy of the extract was attributed to immunopotentiation. 1,3-β-glucan has been identified as the probable primary immunopotentiating factor in this extract (Seki et al., 2010).

**Toxicity evaluations of bamboo leaf extracts**

**Ethanolic extract from the leaves of *Phyllostachys edulis* (Carrière) J. Houz:** It has been shown in the author’s laboratory that the aforementioned ethanolic extract from the leaves of *P. edulis* (Carrière) J. Houz (BEX) has regulatory effects on phase I and phase II enzymes in mouse liver. For example, it upregulates the activities of cytochromes P450 (CYP) enzymes CYP1A2 and CYP3A11, and uridine diphosphate glucuronosyltransferase (UGT), and slightly down regulates the activity of glutathione-S-transferase (GST). In obese/diabetic mice the activities of CYP1A2 and CYP3A11 are upregulated, and supplementation with BEX further upregulates these phase I enzymes (Koide et al., 2011). Although these effects are not toxic per se, potential interactions between BEX and drug metabolism should be considered, especially in obese/diabetic subjects.

**Antioxidant-rich extract from *P. nigra* (Lodd.) Munro:** An antioxidant-rich extract prepared from the leaves of *P. nigra* (Lodd.) Munro containing a high level of polyphenols has been reported to be non-toxic. Acute oral toxicity tests showed that the maximum tolerated dose of this product was greater than 10 g/kg body weight in both rats and mice, without mutagenic effects. A subchronic administration of this product for up to 90 days resulted in a no-observed-adverse-effect level (NOAEL) at a dose of 4.30 g/kg per day (Lu et al., 2005). When pregnant rats were treated with this extract at the NOAEL dose, the pregnant rats did not show significant changes in fertility and gestation index, and there were no effects on embryo-fetal number, viability, sex ratio, and development observed (Lu et al., 2006).

**Abortifacient effect of the leaves of *Bambusa vulgaris* Schrad:** In contrast to the aforementioned antioxidant-rich extract from the leaves of the *P. nigra* (Lodd.) Munro, an extract from the leaves of *B. vulgaris* Schrad is used to induce abortion in Nigerian folk medicine. An aqueous extract of *B. vulgaris* Schrad leaves, containing alkaloids, tannins, phenolics, glycosides, saponins, flavonoids and anthraquinones, was found to dramatically increase abortion frequency and decrease fetal survival rate in pregnant rabbits at doses of 250 to 500 mg/kg body weight per day (Yakubu and Bukoye, 2009). This dose was associated with increased resorption index and post-implantation loss, decreased serum progesterone, follicle-stimulating and luteinizing hormones, and decreased alkaline phosphatase activity and glucose concentration in the uterus (Yakubu and Bukoye, 2009; Yakubu et al., 2009). Interestingly, leaves of *B. vulgaris* Schrad (boiled or raw) are also used to relieve labor pains or as a postpartum cleanser for live stock (Lans et al., 2007).

**Bamboo shoot extracts**

In traditional Chinese medicine, bamboo shoots are used to ease labor and the expulsion of the placenta by inducing uterine contractions. A poultice of the shoots is often used for cleaning wounds and healing infections. Bamboo shoot decoction taken along with honey is used...
to treat respiratory disorders. However, to most people bamboo shoots are best known as food. Fresh, dried, or fermented bamboo shoots are used in numerous Asian recipes. Nutrient analysis on freshly emerging juvenile bamboo shoots has shown high contents of amino acids, proteins, carbohydrates, vitamins, and minerals, and a low content of fat. As bamboo shoots age, the dietary fiber and moisture start to increase while vitamin and mineral contents decrease (Nirmala et al., 2007).

**Potential health benefits of bamboo shoots**

Consumption of bamboo shoots (360 g per day for 6 days as a dietary fiber, the species of bamboo used in this study was not disclosed by the authors) reportedly decreased serum total cholesterol, low-density lipoprotein (LDL), and the atherogenic index, and increased fecal volume and bowel movement frequency in healthy young women when compared with controls on a dietary fiber-free diet (Park and Jhon, 2009). Bamboo shoot oil extracted from *P. edulis* (Carrière) J. Houz (250 to 1000 mg/kg body weight per day) has been documented to decrease the same aforementioned serum parameters (total cholesterol and LDL), as well as serum triacylglycerol, phytosterol and lipoprotein lipase. This same oil extract ameliorated fatty liver and increased the cholesterol content in feces in rats challenged with a high fat diet. These lipid-lowering effects have been attributed to inhibition of cholesterol absorption and increase of cholesterol excretion (Lu et al., 2010). A high level of acetylcholine, an important neurotransmitter in the cholinergic nervous systems of vertebrates and insects, has been found in the upper portion of bamboo shoots (Horiuchi et al., 2003). Nutritional and clinical applications of bamboo shoots based on the presence of this compound have not been explored.

**Toxicity evaluations of bamboo shoot extracts**

**Impact on male fertility:** It has been reported that an ethanolic extract of the tender shoots of *Bambusa arundinacea* Willd (dose of 300 mg/kg body weight per day) changed the structural and functional integrity of the epididymis and reduced fertility of male rats. A 7-day treatment markedly reduced the count and motility of sperm (Manonayagi et al., 1989), and decreased the fertility index by 85 percent (Vanithakumari et al., 1989). Mating activity was significantly compromised after 4 days of treatment. After withdrawal of the treatment for approximately one week, although the mating activity completely recovered, the fertility index only increased by 8 percent (Vanithakumari et al., 1989). The serum profile of protein and oxaloacetic/pyruvic transaminase activity suggested that this extract had no systemic toxicity (Vanithakumari et al., 1989).

**Potential interference with thyroid function:** Thyroid hormones, such as thyroxine (T4) and triiodothyronine (T3), have critical roles in regulating cortical cerebral neuronal migration during fetal brain development. It is postulated that maternal hypothyroxinemia, during the period of fetal neuronal cell migration (weeks 8 to 12 of pregnancy) may result in morphological changes in fetal brain leading to autism (Román, 2007). Thyroid peroxidase (TPO) is a thyroid enzyme liberating iodine for the production of T4 and T3. Both raw and cooked extracts from the shoots of *Bambusa arundinacea* Willd have been found to inhibit TPO activity in an *in vitro* system and to have hypothyroid-like effects *in vivo* (Chandra et al., 2004a; Chandra et al., 2004b), which is thought to be due to the high contents of anti-thyroidal substances, such as cyanogenic glucoside, thiocyanate, and glucosinolate, in bamboo shoots (Chandra et al., 2004a). Feeding bamboo shoots to rats for up to 3 months significantly increased thyroid weight and iodine excretion, and decreased TPO activity and levels of T3 and T4 (Chandra et al., 2004a, b). Iodide supplementation in these experiments reduced, but did not abolish the effects of bamboo shoots on thyroid function (Chandra et al., 2004a, b). These studies suggest that consumption of shoots of *B. arundinacea* Willd during pregnancy may result in birth defect (such as autism).

**Other effects:** Consumption of bamboo shoots was positively associated with hyperuricemia; a risk factor for cardiovascular disease in an epidemiological study in Taiwan (Chuang et al., 2011). In a study done in three hospitals in Thailand, dietary intake of bamboo shoots was associated with aggravation of dyspepsia (Premgamone et al., 2010). Although arsenic is predominantly found in inorganic forms in most terrestrial plants, a significant amount of organic arsenic was found in shoots of *P. edulis* Carrière) J. Houz despite an absence of such compounds in the soil, suggesting a possible arsenic methylation process in the shoots, especially in the core section (Zhao et al., 2006). The toxicological aspect of this finding has yet to be further explored.

**Bamboo stem products**

In traditional Chinese medicine, bamboo stems can be processed into varied forms as summarized. (1) Zhuru (bamboo shavings), dried, long and thin slices shaved from the intermediate layer of the bamboo stalk after the outer skin is removed. It is “sweet and slightly cold”, and used for stomach heat syndromes that produce incorrect flow of qi, commonly causing nausea, loss of appetite, hiccups or vomiting (Yang, 2002). (2) Tianzhuhuang, also known as tabashir, is a dried resinous secretion with very high silica content (up to 85 percent silica) from the knots
of certain female species of bamboo (Jones et al., 1966). It is "sweet and cold", clears heat, resolves phlegm, relieves convulsion, especially used in remedies for children’s feverish disorders and epilepsy (Yang, 2002). (3) Zhuli, is the liquid sap obtained from the ends of freshly cut bamboo pieces with outer surface removed and exposed to heat. Zhuli is "colder" than Zhuru and Tianzhuuhuang, enters the heart, lung, and stomach meridians. It has a lubricating nature, strongly eliminates phlegm-heat, and is used to treat epilepsy, schizophrenia, hemiplegia, facial paralysis, and numbness and tingling or cramp of the limbs (Yang, 2002). (4) Bamboo vinegar, a liquid condensed from the vapor generated by heating bamboo at very high temperature in an airless vessel (a process to make bamboo charcoal). It has high content of acetic acid, accompanied by phenols. Bamboo vinegar is largely produced in Japan and is used to treat varied skin diseases. Recent biomedical research has been mainly focused on the biological function of bamboo shavings, bamboo vinegar, and ethanolic extracts of bamboo culms, as summarized.

**Potential health benefits of products derived from bamboo stems**

**Bamboo shavings:** Recent studies have been conducted on triterpenoid-rich extracts prepared using carbon dioxide supercritical fluid extraction from the shavings of different bamboo species. An extract from the shavings of *P. nigra* var. *henonis* (Mitford) Rendle (100 to 300 mg/kg body weight per day) decreased serum total cholesterol and total triglyceride levels in hyperlipidemic rats (Jiao et al., 2007). The same extract also reduced systolic blood pressure per day decreased serum total cholesterol and total triglyceride levels in hyperlipidemic rats (Jiao et al., 2007). In vitro results suggested that friedelin, a main triterpenoid compound in the extract, probably contributed to the vasodilatory effect (Jiao et al., 2007). An extract from the shavings of *B. tuloides* Munro (40 to 250 mg/kg body weight/day) had an anti-fatigue effect in mice (that is, it helped prolong the duration of weight-loaded swimming and climbing), also increased hepatic glycogen content, and decreased serum urea nitrogen and lactic acid levels (Zhang et al., 2006).

**Bamboo vinegar:** Bamboo vinegar is known as "Chikusakueki" in Japan, "Zhook-Ryeok" in Korean, and "Zhucu" in Chinese. In recent publications, bamboo vinegar has been studied under the name of Bambusae cuulis in Liquamen (BCL).

Transdermal administration of BCL (produced from *P. bambusoides* Siebold & Zucc, 100 μl to the entire dorsal skin) on hairless mice suppressed the development of 2,4-Dinitrochlorobenzene (DNCB)-induced atopic dermatitis-like skin lesions, and the proposed mechanisms included improved skin barrier function, suppression of the overproduction of serum IgE and leukocytes, and balancing the expression of Th1/Th2 cytokines in the spleen (Qi et al., 2009). Using an in vitro model (human keratinocyte cell line HaCaT), the same group reported that BCL suppressed of IFN-γ-induced expression of thymus and activation-regulated chemokine (TARC) and macrophage-derived chemokine (MDC), as well as NF-κB activation, at least in part due to its antioxidant capacities (Qi et al., 2012). The antioxidant activity of BCL was confirmed by another publication (Je et al., 2009), which also documented the inhibitory effects of BCL on oxidant-induced cell death and DNA damage. 1,2-dihydroxybenzene and 1,3-dihydroxybenzene have been isolated from BCL produced from *P. nigra* var. *henonis* (Gramineae), both showed free radical scavenging activity, inhibited nitric oxide production in lipopolysaccharide-stimulated RAW 264.7 macrophage cells, reduced tyrosinase activity and melanin production in B16F10 melanoma cells, and therefore was considered to have anti-oxidative, anti-inflammatory and whitening properties (Park and Lee, 2012).

Due to the high temperature employed in the production, bamboo vinegar contains tar-derivatives that can be potentially carcinogenic. Using an in vitro transformation model, BALB/c 3T3 A31-1-1 cells treated with 3-methylcholanthrene (3-MCA) and 2-O-tetradecanoylphorbol-13-acetate (TPA), bamboo vinegar produced from *Phyllostachys pubescens* J. Houz was shown to be not carcinogenic nor co-carcinogenic (Kimura et al., 2002).

**Bamboo culm extracts:** An ethanolic extract from the culm of *P. bambusoides* Siebold & Zucc has been reported to ameliorate risk factors of cardiovascular diseases in mice treated with a high cholesterol diet: Adding this extract to the diet at 1-3 percent (wet weight) decreased plasma total cholesterol, and increased high-density lipoprotein (HDL) (Lee et al., 2008b). This extract also decreased hepatic lipid peroxidation, protein carbonylation, and NFkappaB activity, and increased hepatic antioxidant enzyme activities (Lee et al., 2008a, b).

**Toxicity evaluations of bamboo stem products**

The only toxicity study conducted on bamboo stem products was on the aforementioned triterpenoid-rich extract from the shavings of *P. nigra* var. *henonis* (Mitford) Rendle. This extract showed essentially no toxic effect. The oral maximum tolerated dose was over 10 g/kg body weight in both rats and mice. No mutagenicity was found by Ames, mouse bone marrow cell micronucleus, or mouse sperm abnormality tests. No abnormal symptoms, clinical signs or deaths were observed in rats during a 30-day subchronic feeding study using doses up to 830
mg/kg body weight per day. No abnormalities in organ development and hematological parameters were associated with feeding of this product (Zhang et al., 2004).

**Concluding remarks**

This review documents the medicinal use of bamboo in traditional Asian medicine, and summarizes current scientific findings on the biological effects of bamboo-derived products. The potential health-benefiting effects are summarized in Table 1 (*in vivo* studies) and Table 2 (*in vitro* studies), the toxicity and side effects are listed in Table 3. Figure 1 shows that products more health benefiting effects of bamboo-based products are documented in the literature compared to its toxic effects. It is evident that the ethnopharmacological knowledge was the driving force behind some of the research, such as those on bamboo vinegar and skin diseases, while most of the studies have oriented toward “modern diseases”, such as heart diseases, obesity, and cancer. The difficulty of translation between the concepts in the traditional medicine (such as the “cool” nature of the bamboo-based medicine) and the conventional western knowledge system hinders full exploration of the ancient literature by biomedical researchers. Meanwhile this review also reveals the lack of scientific investigation on some of the well-documented bamboo medicine, such as Danzhuye, Kuzhuye, Tianzhuhuang, and Zhuli. Although the extracts from the leaves and stems of bamboo plants may have overlapping functions with these traditional ingredients in Chinese medicine, direct investigation on these materials may reveal valuable information that can enhance our understanding on the concepts of the traditional medicine.

**Conflicts of Interest**

The authors have not declared any conflict of interest.

**ACKNOWLEDGEMENTS**

This study was made possible by grant numbers R21 AT003874 (Panee) and R21 AT005139 (Panee) from NCCAM and ORWH, 8G12MD007601 from
Table 1. Summary of reported health-benefiting effects of bamboo extracts from studies using in vivo models.

<table>
<thead>
<tr>
<th>Species</th>
<th>Plant part</th>
<th>Extraction method</th>
<th>Research model</th>
<th>Treatment</th>
<th>Dose, route, duration and control</th>
<th>Result</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sasa senanensis</em></td>
<td>Leaf</td>
<td>Alkaline extraction</td>
<td>Her2/Neu mouse</td>
<td>Enhanced tumorigenesis</td>
<td>Chronic delivery in drinking water, 0.044%-0.088% Fe-Chlorophyllin Na (reference compound), extract-free as control.</td>
<td>Inhibited mammary tumor incidence</td>
<td>Ren et al. (2004)</td>
</tr>
<tr>
<td>(Franch. &amp; Sav.) Rehder</td>
<td></td>
<td></td>
<td>SHN mouse</td>
<td>Spontaneous tumorigenesis</td>
<td></td>
<td></td>
<td>Tsunoda et al. (1998)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ICR mouse</td>
<td>Gonadectomy</td>
<td></td>
<td></td>
<td>Nagasawa and Hattoni (2001)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SHN mouse</td>
<td>Food restriction</td>
<td></td>
<td></td>
<td>Nagasawa et al. (2001)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot water extraction</td>
<td>SD rat</td>
<td>DMBA treatment</td>
<td>0.03-0.5% (w/w) lyophilized extract in diet, up to 7 wks for tumor inoculation, up to 26 wks for DMBA treatment, extract-free as control.</td>
<td>Inhibited mammary tumor incidence and growth</td>
<td>Seki and Maeda (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(100 C)</td>
<td>BALB/c mouse</td>
<td>Fibrosarcoma and sarcoma inoculation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C57BL/6 mouse</td>
<td>Melanoma inoculation</td>
<td></td>
<td>Inhibited tumor growth, prolonged survival time</td>
<td>Seki et al. (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot water extraction</td>
<td>ddY mouse</td>
<td>Sarcoma inoculation</td>
<td>0.05-0.5% (w/w) extract in diet, up to 120 days, extract-free as control.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(up to 196 C)</td>
<td>C57BL/6 mouse</td>
<td>Colon carcinoma Inoculation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phyllostachys nigra</em></td>
<td>Leaf</td>
<td>Ethanolic extraction</td>
<td>SD rat</td>
<td>Absorption and excretion tests</td>
<td>Single gavage delivery, 1 g dry mass per kg body weight.</td>
<td>Long retention time of flavone C-glucosides in colon</td>
<td>Zhang et al. (2007)</td>
</tr>
<tr>
<td>(Lodd.) Munro</td>
<td></td>
<td></td>
<td>Wistar rat</td>
<td>Cardiac ischaemia/reperfusion</td>
<td>0.5-2.0 mg/kg, 10 min before ischemia. Sham, orientin-free, and verapamil as controls.</td>
<td>Prevented apoptosis in cardiomyocytes</td>
<td>Fu et al. (2006)</td>
</tr>
<tr>
<td><em>Phyllostachys edulis</em></td>
<td>Shoots</td>
<td>Trimmed and boiled</td>
<td>Healthy young women</td>
<td>dietary supplementation</td>
<td>360 g bamboo shoots/day, 6 days; diet containing 25 g cellulose as control.</td>
<td>Decreased atherogenic index, and increased fecal volume and bowel movement frequency</td>
<td>Park and Jhon (2009)</td>
</tr>
<tr>
<td>(Carrière) J.Houz</td>
<td>Stem (Shaving)</td>
<td>CO2 supercritical fluid extraction</td>
<td>SD rat</td>
<td>Hyperlipidemic diet</td>
<td>Hyperlipemia study: 0.04-0.25 g/Kg, 2 wks, extract-free as control; hypertension study: 0.1-0.3 g/Kg, 1 wk, Tween80 as control.</td>
<td>Reduced cholesterol and triglyceride in serum</td>
<td>Jiao et al. (2007)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spontaneous</td>
<td>-</td>
<td></td>
<td>Reduced systolic pressure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hypertensive rat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phyllostachys edulis</em></td>
<td>Leaf</td>
<td>Ethanolic extraction</td>
<td>SD rat</td>
<td>DMBA treatment</td>
<td>11 g dry mass per 4057 Kcal, ~1% w/w, mixed in diet, chronic treatment up to 6 months, extract-free experimental diet or normal diet as controls.</td>
<td>Inhibited mammary tumor incidence</td>
<td>Lin et al. (2008)</td>
</tr>
<tr>
<td>(Carrière) J.Houz</td>
<td></td>
<td></td>
<td>C57BL/6J mouse</td>
<td>High fat diet</td>
<td></td>
<td>Decreased MCP-1 in serum. Ameliorated anxiety-like neurobehaviors</td>
<td>Higa et al. (2011) and Del Rosario et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>Shoots</td>
<td>CO2 supercritical fluid extraction</td>
<td>SD rats</td>
<td>High fat, high cholesterol diet</td>
<td>0.25-1g/Kg in drinking water, 6 wks, extract-free and 0.25 g/kg beta-cholesterol as controls.</td>
<td>Hypolipidemic effect</td>
<td>Lu et al. (2010)</td>
</tr>
</tbody>
</table>
### Table 1. Cont’d.

<table>
<thead>
<tr>
<th>Species</th>
<th>Compound/fraction</th>
<th>Evaluation method</th>
<th>Function</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bambusa tuldoides</em> Munro</td>
<td>Stem (Shaving) CO₂ supercritical fluid extraction</td>
<td>BALB/c mice Weight-loaded swimming test and climbing test</td>
<td>Anti-fatigue activity</td>
<td>Zhang et al. (2006)</td>
</tr>
<tr>
<td><em>Phyllostachys bambusoides</em> Siebold &amp; Zucc</td>
<td>Stem (Clum) Ethanolic extraction</td>
<td>C57BL/6 mice High-cholesterol diet</td>
<td>Decreased atherogenic index, increased hepatic antioxidant enzyme activities</td>
<td>Lee et al. (2008a) and Lee et al. (2008b)</td>
</tr>
<tr>
<td><em>Bambusa arundinacea</em> Wildi</td>
<td>Leaves Methanol extraction</td>
<td>Albino rats Carrageenin-induced paw oedema or immunologically induced inflammation</td>
<td>Against carrageenin- and immunologically-induced paw oedema, antulcer activity.</td>
<td>Muniappan and Sundararaj 2003</td>
</tr>
</tbody>
</table>

### Table 2. Health-benefiting effects of fractions and compounds from bamboo plants demonstrated in *in vitro* studies.

<table>
<thead>
<tr>
<th>Species</th>
<th>Compound/fraction</th>
<th>Evaluation method</th>
<th>Function</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Phyllostachys nigra</em> (Lodd) Munro</td>
<td>Total flavonoids of leaves Cell-free assay</td>
<td>Anti-free radical, IC₅₀ for O₂ was 11 μg/ml, IC₅₀ for OH was 5.3 μg/ml</td>
<td>(1) Antioxidative, inhibited aldose reductase activity (IC₅₀ was 0.0134 μM); reduced advanced glycation endproducts formation. (2) Attenuated oxidative stress in retinal ganglion cells</td>
<td>Zhang et al. (2002)</td>
</tr>
<tr>
<td></td>
<td>luteolin 6-C(6''-O-trans-caffeoylglucoside)</td>
<td>(1) Cell-free assay. (2) RGC-5 cell survival rate</td>
<td>(1) Vasodilatation, IC₅₀ was 7.27 μM, inhibiting intracellular Ca²⁺ release and extracellular Ca²⁺ influx (2) Against I/R-induced apoptosis, modulated mitochondrial permeability transition, regulated PI3K/Akt pathway</td>
<td>Jung et al. (2007) and Lee et al. (2010)</td>
</tr>
<tr>
<td></td>
<td>Orientin</td>
<td>(1) Thoracic aortic rings from rabbit. (2) H9c2 cardiomyocytes ischemia/reperfusion (I/R) model</td>
<td>(1) Heme oxygenase-1 induction and cytoprotection. (2) Prevented photocarcinogenesis via apoptotic elimination of p53 mutant and DNA-repair defective cells. (3) Induced Nrf2-dependent phase II detoxifying genes and altered intracellular glutathione redox</td>
<td>Fu et al. (2006), Fu et al. (2005) and Lu et al. (2011)</td>
</tr>
<tr>
<td><em>Phyllostachys nigra</em> var. Henonis (Mitford) Rendle</td>
<td>Chlorogenic acid, caffeic acid, and luteolin 7-glucoside Cell-free assay</td>
<td>Antioxidant; pro-oxidant at the presence of transitional metal ions</td>
<td></td>
<td>Hu et al. (2000)</td>
</tr>
<tr>
<td></td>
<td>Acetone fraction of leaves Raw264.7 cells and mouse spleen cells, Lipopolysaccharides (LPS) stimulation</td>
<td>Reduced IL-12 production in LPS-activated macrophages via NF-kappaB inhibition</td>
<td></td>
<td>Kim et al. (2007a)</td>
</tr>
<tr>
<td></td>
<td>3-O-caffeoyl-one-methylquinic acid Cell-free assay</td>
<td>Antioxidant activity</td>
<td></td>
<td>Kweon et al. (2004), Kweon et al. (2007) and Kweon et al. (2006)</td>
</tr>
<tr>
<td><em>Phyllostachys edulis</em> (Carrière) J.Houz</td>
<td>Butanol fraction of leaves; chlorogenic acid derivatives Cell-free assay</td>
<td></td>
<td></td>
<td>Kweon et al. (2001)</td>
</tr>
</tbody>
</table>
Table 2. Cont’d.

<table>
<thead>
<tr>
<th>Species</th>
<th>Plant part</th>
<th>Extraction method</th>
<th>Research model</th>
<th>Treatment</th>
<th>Dose, route, duration and control</th>
<th>Result</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sasa borealis</em> (Hack.) Makino &amp; Shibata</td>
<td>Butanol fraction of leaves; isoorientin; 2”-O-alpha-L-rhamnoside</td>
<td>(1) Cell-free assay. (2) Oxidative damage to HepG2 cells</td>
<td>(1) Cell-free assay. (2) Oxidative damage to HepG2 cells</td>
<td>For isoorientin, DPPH radical scavenging activity IC50 was 9.5 µM, cytoprotection against peroxide-induced damage in HepG2 cells IC50 was 1.1 µM; for 2-O-alpha-L-rhamnoside, the 2 values were 34.5 µM and 0.8 µM, respectively</td>
<td>Park et al. (2007)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Summary of toxicity and side effects of bamboo extracts observed in *in vivo* studies.

<table>
<thead>
<tr>
<th>Species</th>
<th>Plant part</th>
<th>Extraction method</th>
<th>Research model</th>
<th>Treatment</th>
<th>Dose, route, duration and control</th>
<th>Result</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Phyllostachys edulis</em> (Carrière) J.Houz</td>
<td>Leaf</td>
<td>Ethanoic extraction</td>
<td>C57BL/6J mouse</td>
<td>High fat diet</td>
<td>11 g dry mass per 4057 Kcal, ~1% w/w, 6 months, extract-free experimental diet or normal diet as controls.</td>
<td>Extract upregulated hepatic CYP1A2 and CYP3A11 activities, in synergy with obese/diabetic condition</td>
<td>Koide et al. (2011)</td>
</tr>
<tr>
<td><em>Phyllostachys nigra</em> (Lodd.) Munro</td>
<td>Leaf</td>
<td>Regurgitant boiling water extraction</td>
<td>SD rat</td>
<td>Oral acute and subchronic toxicity Mutagenicity</td>
<td>Up to 4.3 g/kg for 90 days, extract-free as control.</td>
<td>Non-toxic</td>
<td>Lu et al. (2005)</td>
</tr>
<tr>
<td>Stem (shaving)</td>
<td></td>
<td>Not disclosed</td>
<td>SD rat</td>
<td>Oral acute toxicity Mutagenicity</td>
<td>Oral gavage 1-10 g/kg, 30 days, extract-free as control.</td>
<td>Non-toxic</td>
<td>Lu et al. (2006)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO₂ supercritical extraction</td>
<td>SD rat</td>
<td>Oral acute toxicity Mutagenicity</td>
<td>Oral gavage 1-10 g/kg, 30 days, extract-free as control.</td>
<td>Non-toxic</td>
<td>Zhang et al. (2004)</td>
</tr>
<tr>
<td><em>Bambusa vulgaris</em> Schrad</td>
<td>Leaf</td>
<td>Cold water extraction</td>
<td>Dutch rabbit</td>
<td>Pregnant condition</td>
<td>250 and 500 mg/kg in drinking water, days 1-9 or 18-20 of pregnancy, extract-free water as control.</td>
<td>Increased abortion frequency and decreased fetal survival rate</td>
<td>Yakubu and Bukoye (2009)</td>
</tr>
<tr>
<td></td>
<td>Shoots</td>
<td>Ethanoic extraction</td>
<td>Male rat</td>
<td>Fertility tests</td>
<td>300 mg/kg, 7 days, extract-free as control.</td>
<td>Reduced fertility index and count/motility of sperm</td>
<td>Manonayagi et al. (1989) and Vanithakumari et al. (1989)</td>
</tr>
</tbody>
</table>
Table 3. Cont’d.

<table>
<thead>
<tr>
<th>Raw or boiled</th>
<th>Rat</th>
<th>Chronic oral delivery</th>
<th>Hypothyroidism effects</th>
<th>Chandra et al. (2004a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves</td>
<td>Methanol extraction</td>
<td>Rat</td>
<td>Acute toxicity study</td>
<td>Non-specific</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/3 of the diet was replaced by bamboo shoots, up to 90 days, bamboo-free diet as control.</td>
<td>The LD50 was 1812.5 mg/kg (i.p.) and 2552.2 mg/kg (p.o.). The animals were less active compared to the vehicle controls.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NIMHD, and 5G12RR003061 (RCMI/BRIDGES), U54RR022762 (RTRN Small Grant Program) and 5P20RR016467-11 and 8P20GM103466-11 (INBRE II) from NCRR. Its contents are solely the responsibility of the author and do not necessarily represent the official views of the NCCAM, ORWH, NIMHD, NCRR, or the National Institute of Health (NIH).

REFERENCES


