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THE CONSTITUENTS AND BIOLOGICAL EFFECTS OF *ARUNDO DONAX* - A REVIEW

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ABSTRACT

Arundo donax is considered as one of the medicinal plants. Traditionally, the rhizome or rootstock was used for dropsy. Root or rhizome boiled in wine with honey was used for cancer. *Arundo donax* was also used for condylomata and indurations of the breast. The root infusion was considered as antigalactagogue, depurative, diaphoretic, diuretic, emollient, hypertensive, hypotensive, and sudorific. *Arundo donax* is also used as haemostatic, in toothache, and for the treatment of pertussis and cystitis. It contained proteins, carbohydrates, lignin, cellulose, hemicelluloses, alkaloids, indoles, fatty acids, trace elements and many other bioactive metabolites. The previous studies showed that the plant exerted antibacterial, antifungal, anthelmintic, anticancer and other pharmacological effects. It also enhanced milk production and fattening performance. This review will highlight the constituents and pharmacological effects of *Arundo donax*.

Keywords: *Arundo donax*, traditional uses, chemical constituents, pharmacology.

INTRODUCTION

Plant derivates had been employed by populations to prevent different kind of diseases for centuries. The knowledge of plant properties was acquired by ancient civilization that passed down from generation to generation until today. *Arundo donax* contained proteins, carbohydrates, lignin, cellulose, hemicelluloses, alkaloids , indoles, fatty acids, trace elements and many other bioactive metabolites. The previous studies showed that the plant exerted antibacterial, antifungal, anthelmintic, anticancer and other pharmacological effects. It also enhanced milk production and fattening performance.

Synonyms

Although there are many scientific names, but the currently accepted scientific name of giant reed is *Arundo donax* L. There are several recognized varieties, including *Arundo donax var. lanceolata* Döll; *Arundo donax var. variegata* E.Vilm.; *Arundo donax f. versicolor* (Mill.) Beetle; *Arundo donax var. angustifolia* Döll; *Arundo donax var. barbigera* (Honda) Ohwi; *Arundo donax var. coleotricha* Hack.; *Arundo donax var. versicolor* (Mill.) Kunth; and *Arundo donax var. versicolor* (Mill.) Stokes [1-3].

Taxonomic classification

Kingdom: Plantae
Phylum: Spermatophyta
Subphylum: Angiospermae
Class: Monocotyledonae
Order: Cyperales
Family: Poaceae
Genus: Arundo
Species: *Arundo donax* [2].

Common names

Arabic: kasab, zal, pos, ghab farsi, ghab roomi, kasab al-reeh, qish; Australia: bamboo, Danubian reed, e-grass, elephant grass, giant Danube grass, oboe reed; Brazil: cana do brejo, cana do reino, cana-brava, canno do reino, capim plumoso, taquara-do-reino; Chile: cañamo; Colombia: caña brava; Costa Rica: caña hueca; Cuba: caña de Castilla, caña de río, caña hueca, cañita de la india; Dominican Republic: cañita; English: Giant reed, Spanish reed, giant cane and giant feather-reed grass; Fiji: ngasau ni vavalangi; French: canne de Provence, grand roseau; Germany: Pfahlrohr; Haiti: herbe roseau, Roseau; Hindi: baranal, baru, doka, nal, naldura, nar, nara, narasal, narhal, narr, rajal, tinta; Italy: canna commune, canna comune, canna di Provenza; Kannada: baalada kaddi, bilee laalada kaddi, hulagilu hullu, hulugalagu, hulugila-hullu, hulugilu, hulugilu hullu, laalada kaddi; Malayalam: ama; Marathi: nal; Netherlands: Pijlriet; Puerto Rico: caña gigante, guajana; Sanskrit: dhamana, nala, potagala, sarah, sunyamadhya; South Africa: Spaanse-riet;

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Spain: falso bamboo, gallipato alcublano, junco gigante; Tamil: caravanam, koraikkuccu, korukachi, korukkai, kuruvi-p-pul, velam; Telugu: adavikikasa-gaddi, adavikikkasagadi, kaki veduru, paatuveduru, patu veduru, peepalu; Tonga: kaho, kaho folalahi; Uruguay: caña musical [2-5].

Description

Arundo donax is a tall, erect, perennial cane- or reed-like grass. It was one of the largest herbaceous grasses, it can grow to 2-10 m tall. Its root structure is very strong, with the fleshy, almost bulbous, creeping rootstocks (rhizomes) forming compact bundles from which grow the fibrous roots, penetrating deep into the soil. The horizontal rhizomes give rise to many-stemmed, hollow, cane-like clumps allowing it to form large colonies many meters across. These tough, individual stems or culms are divided by partitions at the nodes like in bamboo, each node 12-30 cm in length and can reach diameters of 1-4 cm with walls 2-7 mm thick. They commonly branch during the second year of growth, rarely multiple, just single lateral branches from nodes. The outer tissue of the stem is of a silicaceous nature, hard and brittle with a smooth glossy surface that turns pale yellow when the culm is fully mature. The pale, blue-green leaves clasp the stem broadly with a heart-shaped, hairy-tufted base, 2-6 cm wide at the base and tapering to a fine tip, up to 70 cm or more in length. The leaves are arranged alternately throughout the culm and very distinctly two-ranked, in a single plane. The culms can remain green throughout the year but often fade with semi-dormancy during the winter or in droughts. The flowers are borne in large plume-like panicles, 30-65 cm, at the upper tips of stems between March and September and are closely packed in a cream to brown-coloured cluster. The spikelets, flowering units comprised of one or more florets enclosed by two bracts or glumes, are several flowered, approximately 12 mm long with florets becoming successively smaller. The segmented central axis of the spikelet, the rachilla, is glabrous and dis-articulates above the glumes and between the florets. The more or less unequal glumes are 3-nerved membranous, narrow, slender, pointed and as long as the spikelets. Lemmas, the larger, outer, bract which, along with the palea, serves to contain the florets held within, are thin, 3-nerved and covered with fine, soft hair. They are narrowed upwards with the nerves ending in slender teeth [3,6-9].

Distribution

It was native to the Mediterranean area, introduced to many subtropical and warm temperate regions, where it was grown as an ornamental and was often found as a stray from cultivation [9-11]. It has been cultivated throughout Asia, southern Europe, northern Africa and the Middle East for thousands of years. In North America, it was intentionally introduced from the Mediterranean to the Los Angeles area in the early 1800s [12-14].

Traditional uses

The uses of *Arundo donax* have been dated back to 5,000 B.C where the Egyptians used *Arundo donax* leaves as lining for underground grain storage. It has been stated that mummies were wrapped with *Arundo donax* leaves. In the 4th Century A.D. However, in more recent times *Arundo donax* has been commercially cultivated for the production of reeds for musical instruments. This type of commercial cultivation has been traced back for nearly 5,000 years. Not only has *Arundo donax* been used for musical instruments it has been cultivated for horticultural purposes, such as garden fences and trellises [15]. Medicinally, the rhizome or rootstock was used for dropsy. Root or rhizome boiled in wine with honey and used for cancer. *Arundo donax* was also used for condylomata and indurations of the breast. The root infusion was used as antigalactagogue, depurative, diaphoretic, diuretic, emollient, hypertensive and sudorific [16-20]. *Arundo donax* is also used as haemostatic, in toothache [19] and for the treatment of pertussis and cystitis [20].

Part used: rhizome, root leaves and stem were used medicinally

Physicochemical properties

Ash: 2.39%, extractives, cold water: 6.15%**,** hot water: 8.01%, sodium hydroxide 1%, alcohol-benzene: 1.29%, dichloromethane: nodes 13.04% and internodes11.16%, ethanol: nodes 5.88% and internodes 4.18% [21-22].

Chemical constituents

Per 100 g, the green roughage is reported to contain on a zero moisture basis, 6.9 g protein, 1.3 g fat, 82.6 g total carbohydrate and 37.5 g fiber. The carbohydrates of *Arundo donax* consisted of: rhamnose 0.15 %, mannose 0.35 %, arabinose 2.00 %, galactose 0.84 %, xylose 33.88 %, glucose 62.13 %, 4-O-methyl glucuronic acid 0.65% [23]. *Arundo donax* showed an average of 22% lignin [21], 42% α-cellulose and 27% hemicelluloses. However, Shatalov *et al*., observed that the levels of monosaccharides in the nodes and internodes (% respectively) were: arabinose 3.22 and 35.91, xylose 0.16 and 1.17, mannose 59.54 and 2.47, galactose 30.92 and 0.88 and glucose 0.83 and 64.91 [22]. It was also contained calcium 0.30–0.67%, P 0.08–0.15g, K 2.04–3.19%, and Mg 0.20–0.30%. The alkaloids especially gramine were isolated from the plant. Reed of Chinese origin contains 50.3% cellulose and 15.7% lignin [24-25].

The plant contained alkaloids including tryptamine, bufotenidine, gramine and arundamine [22,26]. Some studies have found that this plant was rich in active tryptamine compounds, Dutta and Ghosal were recovered 20 mg of DMT from 200 grams of the dry whole plant. It was accompanied by 520 mg of gramine, 128 mg of bufotenine and traces of 5-MeO-DMT, as well as unidentified indoles. Five indole-3-alkylamine bases, N,N-dimethyl-tryptamine, 5-methoxy-N-methyltryptamine, bufotenine, dehydro-bufotenine, and bufotenidine were isolated from the rhizomes of *Arundo donax* L [27-31].

The results of general chemical analysis evidenced the different relative abundance of holocellulose, lignin, proteins, extractives and ashes in internodes, nodes and foliage, at different stages of maturity. In internodes, nodes and foliage about 70–80% of hemicelluloses were easily extracted with 5% KOH aqueous solutions. The analysis of hemicelluloses indicated that they were consisted mainly from arabino-glucuronoxylans with a xylose, (arabinose: uronic acid ratio of 91–93:5–7:2 for internodes). The high content of xylose was found in *Arundo donax* stem. The easy extraction of hemicelluloses opens new perspectives for the use of the reed as a source of pentosans. The results obtained by the permanganate oxidation method indicated that *Arundo donax* lignins were essentially H-G-type with approximate H:G:S proportions of (32–36):(59–61):(5–8) in internodes. The H units are constituted mainly by esterified *p*-coumaric acid [32-34].

Milled wood lignin and dioxane lignin from different morphological regions (nodes and internodes) of *Arundo donax* reed were subjected to a comprehensive structural characterization. Both node and internode lignins are HGS-type lignins, with a significant amount of H units (including *p*-coumaric acid type structures). The S/G ratio was (1.13−1.32), the weight-average molecular weight was (20400−24500), the methoxyl group content was (0.90−0.98), the phenolic hydroxyl group content was (0.23−0.27), and the aliphatic hydroxyl group content was (1.00−1.09). However, some structural differences between node and internode lignins were observed. The former has much more phenolic acids (*p*-coumaric and ferulic), 8.8% in node versus 1.2% in internode and less β-O-4 (0.32 and 0.49 per aromatic unit) in node and internode, respectively) [35-36].

Giant reed was low in protein but has a comparatively high concentration of phosphorus in the upper portions even when grown on soils with an extremely low concentration of this mineral. Mineral contents (percentages of oven-dry weight) included: calcium in the old plant, in the upper half 0.52 and in the lower half 0.67, in young plant in the upper half 0.30 and in the lower half 0.43; Magnesium in the old plant , in the upper half 0.25 and in the lower half 0.32, in young plant in the upper half 0.12 and in the lower half 0.19; Potassium in the old plant, in the upper half 2.04 and in the lower half 2.42, in young plant in the upper half 3.09 and in the lower half 3.19. Carbohydrates in the old plant, in the upper half 23.2 and in the lower half 21.7, in young plant in the lower half 20.0 and in the lower half 20.7 [37-38].

Chemical composition of lipophilic extractives in *Arundo donax* reed (mg/kg) included: n-Alkanes 77.9: *n*-Docosane 0.5, *n*-Tricosane 0.2, *n*-Tetracosane 0.6, *n*-Pentacosane 6.3, *n*-Hexacosane 3.9, *n*-Heptacosane 15.8, *n*-Octacosane 6.7, *n*-Nonacosane 37.0, *n*-Triacontane 0.8, *n*-Hentriacontane 5.4, *n*-Dotriacontane 0.3, *n*-Tritriacontane 0.4. Steroid hydrocarbons 127.4: Ergostatriene 14.5, Ergostadiene 9.3, Estigmastadiene 8.4, Estigmasta-3,5,22-triene 49.2, Estigmasta-3,5-diene 46.0. Fatty acids 1137.7: *n*-Tetradecanoic acid 3.5, *n*-Pentadecanoic acid 1.8, *n*-Hexadecanoic acid 276.3, *n*-Heptadecanoic acid 10.0, 9,12-Octadecadienoic acid 30.0, 9-Octadecanoic acid 55.7, *n*-Octadecanoic acid 73.6, *n*-Nonadecanoic acid 3.1, *n*-Eicosanoic acid 50.0, *n*-Heneicosanoic acid 3.3, *n*-Docosanoic acid 35.7, *n*-Tricosanoic acid 25.3, *n*-Tetracosanoic acid 55.7, *n*-Pentacosanoic acid 33.5, *n*-Hexacosanoic acid 144.1, *n*-Heptacosanoic acid 14.3, *n*-Octacosanoic acid 134.9 , *n*-Nonacosanoic acid 53.9, *n*-Triacontanoic acid 7 109.9, *n*-Hentriacontanoic acid 6.2, *n*-Dotriacontanoic acid 16.9. Fatty alcohols 194.3: *n*-Hexacosanol 33.4, *n*-Octacosanol 54.9, *n*-Triacontanol 57.7, *n*-Dotriacontano 48.3. Aldehydes 81.6: *n*-Hexacosanal 10.4, *n*-Octacosanal 22.9, *n*-Triacontanal 48.3. Sterols/triterpenols 528.1, Campesterol 90.6, Stigmasterol 46.4, B-Sitosterol 281.0, Stigmastanol 71.9, 7-oxo-Sitosterol 428 6.5, β-Amyrin 426 8.2, α-Amyrin 23.5. Tocopherol 17.7: β-Tocopherol 6.8, α-Tocopherol 10.9. Triterpenoid and steroid ketones 43.9: B-Amyrenone 10.2, α-Amyrenone 5.9, Cycloartenone 14.2, Stigmasta-3,5-dien-7-one 3.2, Stigmast-4-en-3-one 4.6, Stigmast-4-en-3,6-dione 3.6, Stigmastane-3,6-dione 2.5. Steryl/triterpenyl esters 68.1: Sitosteryl ester 16.1, B-Amyrinyl ester14.0, a-Amyrinyl ester 38.0. Steryl glucosides 151.6: Campesteryl 3-β-d-glucopyranoside 30.6, Stigmasteryl 3-β-d-glucopyranoside 8.0, Sitosteryl 3-B-d-glucopyranoside 113.0. Monoglyceride 367.5: 2,3-Dihydroxypropyl tetradecanoate 5.5, 2,3-Dihydroxypropyl hexadecanoate 94.2, 2,3-Dihydroxypropyl octadecanoate 86.6, 2,3-Dihydroxypropyl eicosanoate 35.1, 2,3-Dihydroxypropyl docosanoate 43.0, 2,3-Dihydroxypropyl tetracosanoate 46.9, 2,3-Dihydroxypropyl hexacosanoate 56.2. Diglycerides 47.6: Dipalmitin, 1,2-(P2) 7.8 , Dipalmitin, 1,3-(P2) 12.1, Palmitoylstearin (PS) 16.8, Distearin, 1,2- and 1,3-(S2) 10.9 [39].

PHARMACOLOGICAL EFFECTS

Antibacterial and antifungal effects

Aqueous extract of the stem nodes of *Arundo donax* exerted antibacterial activity against methicillin resistant *Staphylococcus aureus* (MRSA) in a concentration of 128 µg/ml. The aqueous extracts of the reed nodes (which contain the white hemicellulose membrane) demonstrated a marked dose-dependent anti-biofilm activity, in preventing MRSA biofilm formation and disrupting established biofilms. These results may suggest that the traditional application of the reed membrane to fresh lacerations may be useful as a prophylactic for biofilm-related infection [40].

The antimicrobial effects of methanolic extracts of 14 medicinal plants species were examined comparing to conventional therapeutic antibiotics against standard bacterial strains (*Staphylococcus aureus, Micrococcus luteus, Klebsiella pneumonia, Escherichia coli* and *Pseudomonas aeroginosa). Arundo donax* extract showed the maximum effect against *Escherichia coli* and *Pseudomonas aeroginosa* among the examined fourteen medicinal plants species. The antimicrobial effects of 4% methanolic extracts of *Arundo donax* were comparable to Cephalotin (30mcg), Piperacilin (30mcg) and Amikacin

(30mcg) against *Escherichia coli* and Piperacilin (30mcg) and Amikacin (30mcg) against *Pseudomonas aeroginosa* [41].

Arundo donax also exerted antifungal activity against four Basidiomycetes (*Trametes versicolor* CTB 863A , *Coniophora puteana* BAM Ebw.15, *Gloephyllum trabeum* BAM Ebw. 109, and *Postia placenta* FPRL 280) [21].

Anthelmintic effects

Crude aqueous-methanol extracts of the leaves of *Arundo donax* and its chloroform, petroleum spirit and ethyle acetate fraction were tested against *H. contortus*. *Arundo donax* (25-50 mg/ ml) exerted anthelmintic effects ($P \geq 0.05$). 56.7% mortality of *H. contortus* was recorded by 10 hours post-exposure with crude aqueous methanol extracts of *Arundo donax* 50 mg/ ml. There was 100% mortality of worms in Levamisole treatment (used as a reference drug) within 2 hours post-exposure. However, the anthelmintic effects of the plant was dose and time dependent. The ranking of efficacy of the *Arundo donax* fractions against *H. contortus* were ethyl acetate, chloroform aqueous followed by petroleum spirit fraction. Dose and time dependent ovicidal effects were recorded for these plant extracts. In egg hatch test, *Arundo donax* exhibited ovicidal activity with LC_{50} of 200.1 µg/ ml; whereas, crude powder of *Arundo donax* resulted in 50.5% reduction in fecal egg count in sheep naturally infected with gastrointestinal nematodes [42].

Arundo donax extracts had anthelmintic properties (around 55% efficacy) against gastrointestinal parasites (*Ascaris* sp., *Oesophagostomum* sp. and *Paramphistomum* sp.) of cattle [43].

Antifeedant activity

Arundo donax revieled significant antifeedant activity against the boll weevil, *Anthonomus grand* [31]**.** Bioassays indicated that while sterols showed limited anti-feedant activity, significant activity was shown by the isolates tricontanol, tricin, and tetramethyl-N, N-bis-2,6 dimethylphenyl cyclobutane-1, 3-diimine [16,44].

Antiproliferative effect

Arundo donax was used incombination with *Spartium junceum* L. and *Cynodon dactylon* L. for the treatment of tumors (without specifying which kind of tumour) [45].

A lectin with antiproliferative activity towards human cancer cell lines and mitogenic towards human peripheral blood mononuclear cells was purified from the rhizomes of *Arundo donax* (Linn.). The molecular mass of native lectin was 32 kDa as determined by gel filtration chromatography. The *Arundo donax* lectin (ADL) was thermostable upto 55 °C and showed optimum activity in the range of pH 7.0–9.0 and comprised of 2.1% carbohydrate content [46].

A lectin (ADL) isolated and purified from *Arundo donax* rhizomes agglutinated native rabbit, pig erythrocytes and with lower intensity rat and human A, B and AB erythrocytes, and its hemagglutinating activity is independent of divalent cations, but it was decreased by denaturating and reducing agents. *Arundo donax* lectin displayed cytotoxic effect on *Dysdercus peruvianus* and nematicide activity against *Meloidogyne incognita*. ADL decreases the germinability and delayed the mean time for germinability of *Lactuca sativa* L. diasphores, and also showed significant mitogenic and chemotactic effect. The lectin induced toxicity in mice when administered intraperitoneally with dose of 300 mg/kg and 800 mg/kg, it caused 100 % death of the animals 30 h after its administration. Seven isoforms of ADL were separated. ADL-III is rich in Glu/Gln, Gly and Asp/Asn and Cys residues, and its N-terminal a and b chains contain tryptophan residues. ADL-III showed significant mitogenic activity. ADL was able to bind to transformed cells from T-47D, HT-29 and T-24 lines *in vitro*. Immunohistochemical techniques showed that ADL was localized in the fiber cell walls and in some few cortical parenchyma cells of the rhizome [47].

Effect on milk production and fattening performance

Due to its high fiber and low protein content, *Arundo donax* foliage is poorly digested. The reported digestibility values were about 47 to 52% for DM digestibility and about 54-56% for OM digestibility [48-51]. A commercial bolus made of a mixture of several powdered plants including *Arundo donax* L improved milk yield in dairy cows, which was attributed to the presence of components reported to be galactogogues [48-49]. However a higher DM digestibility of 69% was reported in an early study [52]. In lambs, fresh giant reed forage gave better fattening performance than giant reed hay [53]. Fresh giant reed forage and giant reed silage (ensiled 3% molasses on fresh basis) were better digested by Rahmani sheep than giant reed hay or berseem hay [51].

Central nervous effect

The rhizome of *Arundo donax* contained at least five tryptamines, including N,N-DMT, 5-MeO-DMT and bufotenine. It was reported that they produced no psychoactive effects [54], 50 mg of rhizome extract did not produce psychedelic effects [55], but instead, it caused mild but long lasting allergic reactions, which include blurred vision, watery and swollen eyes, conjunctivitis, and hives [54].

Effects on smooth muscles

A defatted ethanolic extract of the rhizomes produced hypotensive and antispasmodic effects against histamine-, serotonine- and acetylecholine- induced spasms. Bufotenidine showed three main pharmacological actions, antiacetylecholine effect, histamine release and uterine stimulant effects [56]. The alkaloid gramine was said to be a vasopressor, raising the blood pressure in dogs after small doses and causing a fall in larger doses [24,31,37,57-58].

Other pharmacological effects

Bufotenidine isolated from *Arundo donax* showed neuromuscular blocking activity [59]. *Arundo donax* L.,

was used as part of herbal preparation as herbal expectorant**.**

Dosage
Root 50-100 ml decoction [57].

CONCLUSION

Arundo donax exerted many pharmacological effects. There is a great promise for development of novel drugs from *Arundo donax* to treat human diseases.

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