J Appl Biol Chem (2023) 66:26, 179–185
https://doi.org/10.3839/jabc.2023.026

Online ISSN 2234-7941
Print ISSN 1976-0442

Review: Bioactive Materials

Bauhinia rufescens, Ocimum basilicum and *Salvadora persica*: a review of their chemical compounds and properties for antimicrobial, antioxidant and cytotoxicity

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Received: 13 March 2023 / Accepted: 17 April 2023 / Published Online: 2 May 2023

Abstract *Bauhinia rufescens, Ocimum basilicum* and *Salvadora persica* are well known plants used in African traditional medicine, especially in Chadian traditional medicine. They are mostly used in the treatment of infectious diseases, inflammatory diseases, fever, and so on. Studies using various *in vitro* and *in vivo* bioassay techniques support the scientific rationale for most of these usages. In this review, ethnobotanical uses, chemistry of natural products, and pharmacological and clinical data for these plants are presented.

Keywords Antimicrobial · Antioxidant · *Bauhinia rufescens* · Chadian medicinal plants · Chemical compounds · *Ocimum basilicum* · *Salvadora persica*

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Introduction

Around the world, it is widely known that traditional medicine can bring considerable value related to human and animal health care and contribute significantly to national economic performance. There has been considerable worldwide interest in traditional medicine as a powerful substitute to synthetic drugs. This interest is due to the high research expense and lack of adequate technology-based capacity for chemical drug development research, especially in underdeveloped countries. It is also important to note that the use of alternative or complementary natural therapies in developed countries to treat various conditions is receiving worldwide attention [1].

The present review focuses on the botanical description, traditional uses, chemical composition, antimicrobial, antioxidant and cytotoxic properties of *Bauhinia rufescens, Ocimum basilicum* and *Salvadora persica*, which are widely used in traditional medicine in Chad. This review aims to bring the explored potential of *Bauhinia rufescens, Ocimum basilicum* and *Salvadora persica* to the attention of natural product researchers worldwide.

The review was written using references from Chemical Abstracts, Medicinal Plant Abstracts, Google Scholar, Science direct, Duke's Phytochemical and Ethnobotany, Henriette's Herbal Homepage, PubMed, King's American Dispensatory, Phytochemical and Ethnobotany.

Botanical description and plant distribution

Bauhinia rufescens

Bauhinia rufescens is a scanty small tree or shrub that belongs to the Leguminosae family, generally 1 to 3 m tall, reaching sometimes 8 m; it is often scrubby, shrivelled, and has several stems. Ashen gray bark, very fibrous, smooth and scaly in old age, remanent pink, the branches arranged in 1 plane as a fishbone, with spine-like

lignified side branches, 10 cm in length. Leaves are very tiny, 2-lobed almost at the base, with semicircular lobes, glabrous, long-stalked, grayish-green, under 3 cm in length. Blossoms yellow-greenish to pale pink and white, 5 petaled, spatulated, about 15-20 mm in length; stamens 10, filaments hairy at base. Aggregate fruits, long, narrow and twisted pods, up to 10 cm in length, glabrous, tapering at an angle, dark reddish brown shiny, containing 4-10 seeds in each [2]. This plant is evergreen in the wetter region and deciduous in the drier region. It is distributed throughout the Sahelian zone and adjacent Sudanese zone, from Mauritania and Senegal through Niger and northern Ghana to central Sudan and Ethiopia. Native to Chad, Nigeria, Ethiopia, Mauritania, Ghana, Mali, Kenya, Tanzania, Uganda, Senegal and Sudan.

Ocimum basilicum

Ocimum basilicum is one of the most studied species of the genus *Ocimum*. *Ocimum basilicum* is a member of the Lamiaceae family. It is called “am-rihana” in Chadian Local Arabic, basilic in French and basil or sweet basil in English. It is an annual plant from 20 to 60 cm high, with oval-lanceolate leaves, reaching 2 to 3 cm. The leaves are pale green to dark green, sometimes purple in some varieties. The erect and branched stems have a square section like many labiates, they tend to become woody and bushy. The flowers, bilabiate, small and white, have the upper lip cut in four lobes. They are small and grouped in long tubular spikes, in the shape of elongated clusters. The fine, oblong seeds are black. Its cultivation requires a warm and sunny climate and an irrigable soil rich in organic matter. Basil's main parts are the leaves and the seeds. *Ocimum basilicum* is found in all regions of the tropics and subtropics, in the wild or cultivated. The widest variability is in tropical Africa, from where it is probably native, and in India. In South-East Asia, it is cultivated primarily as a gardening crop, and it is not cultivated on a commercial scale until Vietnam [3-6].

Salvadora persica

Salvadora persica is a small tree or shrub member of the *Salvadoraceae* family. It was named in 1749 after Juan Salvador y Bosca (1598-1681), a Barcelona apothecary, by the traveler and plant collector Laurent Garcin [7]. A more or less sarmentose shrub or small tree, with a poorly conformed bole, a spreading and rather dense crown, 4-9 m high. Its bark is smooth to slightly rough and then scaly, greenish white becoming light gray, with yellow to pale pink slices. The branch is glabrous, scarred between the leaves, greenish-gray, streaked along the length. The leaves are opposite, thick, almost fleshy, glabrous, glaucous green, lanceolate ovate, with acuminate or obtuse apex, sometimes mucronate, with acute or rounded base. The inflorescence in a loose, glabrous cluster, arranged at the base of the leaves and rather distributed at the end of the branch, 5 to 10 cm long. The flowers are yellow, short pedicelled, 3-4-toothed calyx with 4 imbricate petals, about 3 mm in diameter. The fruit is a globose berry, glabrous, bearing the rest of the style at the top and the persistent calyx at the base, 6 mm in diameter, red at maturity, the roots are spongy and easily crushed between the teeth [8]. *Salvadora persica* is a shrub native to the Middle East. This small tree is distributed in Africa from Mauritania and Senegal to Lake Chad, Nigeria, Mozambique and South Africa, India, Saudi Arabia, Pakistan and Iran [7].

Traditional usages

Bauhinia rufescens

The leaves in maceration have stomachic, anti-diarrheal, febrifuge and anti-dysenteric properties [2,9]. They are also used for the treatment of eye disorders and hypertension, in decoction [10,11]. Also, it has been reported that the decoction of *Bauhinia rufescens* leaves is used in the treatment of diabetes [12], mycosis [13] and fibrosis [14]. For the treatment of leprosy, syphilis and other venereal infections, the chopped, boiled roots are given as a drink [15,16]. The bark is a remedy for smallpox and some chest ailments [15,17]. In Chad, the local population uses *Bauhinia rufescens* in the treatment of typhoid fever, malaria of diabetes and in the treatment of other common infections.

Ocimum basilicum

Both the entire plant and its essential oil have a wide range of traditional medicine applications, particularly in India and Africa. In a decoction, the leaves are used for the treatment of chronic dysenteria, vomiting, kidney malfunctions, coughs, sunburns, asthma, diarrhea, flu, headaches, bronchitis, constipation, worms, and warts [5,6,18-20]. The juice of leaves is used in the nose against the cephalgia; the pulp of leaves is used per os in the fetal hypotrophy and diluted in water for the intimate toilet in the dystocia [6]. Grains are used as laxatives and are used to treat gonorrhea [21]. The folk medicine acknowledges in this plant soothing properties, or a remedy against poisons, snake bites and scorpion stings. In Chad, market gardeners plant basil along the rivers. It is also found in the gardens of urban dwellings. Packed in plastic bags, the dried leaves are sold for use as a tea drink [6].

Salvadora persica

Salvadora persica is used for the treatment of a wide variety of conditions in different localities. In Chad, the infusion or decoction of the leaves is given in the treatment of gastrointestinal infections and dysentery; the roots are used in oral hygiene. The root powder, mixed with water is used as a local application in the treatment of boils. In Algeria, Egypt, Libya, the powder of leaves blended with flour of millet and some honey in small scoops taken each morning during 40 days in the treatment of syphilis. Root bark powder, mixed with table oil to obtain a paste, applied locally 3 times a day against oral candidiasis in Tanzania. To treat back pain, the roots are pounded, soaked in water and taken orally in Uganda. In Kenya, the small boiled roots, used in infusion, cause a strong perspiration which is exploited to treat malaria. The stems are used as toothbrushes.

For the treatment of malaria, a handful of the powder of the bark of the roots blended together with half a cup of fresh water, in local application once a day during 3 days in Somalia. In Senegal, to treat bronchial diseases, the leaves of *Salvadora persica, Combretum glutinosum* and *Guiera senegalensis*, are dried and crushed, and the powder of the mixture obtained is diluted in water and taken orally [22].

Phytochemical composition

The use of solvents with different polarity, followed by fractionation steps and the use of different chromatographic techniques allowed the extraction, separation and identification of the different compounds present in the plant extracts.

Bauhinia rufescens

Several studies have revealed that the leaves of *Bauhinia rufescens* contain secondary metabolites such as tannins, flavonoids, triterpenes, alkaloids and saponins [12,23]. Koya et al. showed in their study that the predominant chemical components in the crude extracts of leaves and *Bauhinia rufescens* are flavonoids [24]. The roots contain significant concentrations of tannins according to Burkill [2] and phenolic compounds according to Maillard et al. [25]. The study on *Bauhinia rufescens* conducted by Hassan et al. showed that tannins, flavonoids, triterpenes, saponins, carbohydrates are also present in aqueous, methanolic, butanol and ethyl acetate extracts of bark of *Bauhinia rufescens* [26].

Ocimum basilicum

Nadeem et al. [27] and Lawrence et al. [28] reported that alkaloids, flavonoids, tannins, carbohydrates, saponins, anthraquinones, terpenoids, essential oil, proteins, glycosides and steroids were detected as secondary metabolism products in basil leave extracts. Gas Chromatography/Mass Spectrometry analysis of the essential oil indicated the occurrence of methyl eugenol, α-cubebene, linalool, limonene, nerol, ε-murolene, methyl chavicol etc. as major constituents [20,29].

Salvadora persica

Many chemical groups have been described in the different parts of *Salvadora persica*. These include trimethylamines, alkaloids including salvadorine with antimicrobial activity, chlorides, high levels of fluorides and silicas, sulfur, vitamin C and E (alpha- and gamma-tocopherol), and tannins [22,30,31]. Other studies noted the presence of saponins, sterols including beta-sitosterol, terpenoids, flavonoids and essential oils [32].

Antimicrobial properties

Bauhinia rufescens

Plants of the Bauhinia genus are commonly used in the treatment of infections in traditional medicine. Several investigations have proven their antimicrobial properties against pathogenic fungi, yeasts and bacteria. *Bauhinia splendens* has antimicrobial activity against pathogens, particularly gram-positive bacteria such as *Salmonella typhimurium, Staphylococcus aureus* and *Streptococcus spp* [33]. *Bauhinia variegata*, a harvested plant from Nepal, has shown antimicrobial activity against a number of microorganisms such as *Salmonella typhi, Bacillus subtilis, Shigella dysenteriae, Pseudomonas aeruginosa, Vibrio cholerae* and *Staphyllococcus aureus* [34]. Assessment of the antifungal properties of *Bauhinia forficata* has shown remarkable activity against some dermophytes such as *Epidermophyton floccosum, Microsporum canis, Trychophyton rubrum* and *Trychophyton mentagrophytes* [33]. Muhammad and Sirat investigated the antimicrobial activities of three organic extracts (methanol, ethyl acetate, petroleum ether) of *Bauhinia rufescens* on three gram positive, three-gram negative bacteria [13]. The results showed that the ethyl acetate extract acts strongly on *Bacillus subtilis* and *Pseudomonas aeruginosa*. Hassan et al. showed in their study that methanolic and ethyl acetate extracts of *Bauhinia rufescens* bark largely inhibited the growth of *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* [26]. Similarly, the results of a study conducted by Wazis et al. in Nigeria showed significant antibacterial activity of ethanol, ethyl acetate and butanol extracts of *Bauhinia rufescens* barks on *Staphylococcus aureus, Escherichia coli* and *Klebsiella spp* [9]. In addition, *Bauhinia rufescens* has antifungal properties. A dichloromethane extract of *Bauhinia rufescens* leaves harvested in Niger showed activity against *Cladosporium cucumerinum* [25]. Muhammad and Sirat showed in their study that extracts of *Bauhinia rufescens* leaves and bark act on *Aspergillus niger, Candida glabrata* and *Saccharomyces cerevisiae* [13].

Ocimum basilicum

Leaves of *Ocimum basilicum* extracted with different solvents were tested for their antibacterial potency against a range of diarrheal pathogens including, *Enterococcus faecalis* ATCC 29212, *Escherichia coli* ATCC 25922, *Shigella sp., Escherichia coli, Staphylococcus aureus* ATCC 29213, *Candida albicans* ATCC 845981, and *Candida albicans ATCC* 90028. The assessed extracts consisted of chloroform extract, an acetone extract and two different concentration of methanol extract (5 and 10 mL). However, only the methanol extracts showed inhibiting action on some of the microorganisms tested. Inhibition zones were ranged from 13 to 15 mm for *Staphylococcus aureus* 29213, *Escherichia coli* 25922, *Escherichia coli* RSHI and *Shigella* RSHI [35]. In the study conducted by Hossain et al. [36], the potential of essential oils and methanolic extracts of *Ocimum basilicum* L. to control the spectrum of the growth of foodborne pathogenic bacteria was assessed. Both the essential oils and the methanolic extracts of *Ocimum basilicum* have shown a high potential of antibacterial activity against *Bacillius megaterium, Bacillius subtilis, Bacillius cereus, Staphylococcus aureus, Escherichia coli, Listeria monocytogenes, Shigella dysenteriae, Shigella boydii, Salmonella typhi, Vibrio mimicus* and *Vibrio*

parahaemolyticus having respectively inhibition zones ranging from 11.2 to 21.1 mm and MIC values of 62.5-500 µg/mL. The recent research has shown that the essential oil of *Ocimum basilicum* has an inhibiting action on certain fungi such as *Rhizoctonia, Macrophomina phaseolina, Aspergillus niger, Aspergillus fumigates, Aspergillus flavus, Candida albicans* and *Penicillium* [37,38]. Thongchai et al. carried out a thorough study on the leaf extracts of *Ocimum basilicum* [39]. They have been investigated against Methicillin-resistant *Staphylococcus aureus* (MRSA) isolated from clinical samples. Both the crude extract and the individual compounds were found to possess strong antimicrobial potency at a dose of 34.5 mg/disc. The crude extract and linalool showed higher activity against the MRSA tested, with an MIC (<0.09 mg/mL) and MBC (≤0.09 to 0.38 mg/mL).

Salvadora persica

Salvadora persica has antibacterial properties against dental caries. Studies have shown that extracts of this plant have a biological effect comparable to that of oral sanitizers and antiplaque products, like chlorhexidine gluconate, if applied at high concentrations. Sofrata et al. demonstrated the antimicrobial action of *Salvadora persica* on oral microorganisms known to be associated with caries and periodontal disease such as *Haemophilus influenza, Lactobacillus acidophilus, Porphyromonas gingivalis, Aggregatibacter actino-mycetemcomitans* and *Streptococcus mutans* [40]. Sher et al. tested methanolic and aqueous extracts of *Salvadora persica* roots on *Pseudomonas aeruginosa, Staphylococcus aureus, Lactobacillus acidophilus,* and *Streptococcus mutans* [32]. The results of this study show that both extracts were active on all germs tested. The results of another study conducted by Al-sieni showed significant antibacterial activity of aqueous and methanolic extracts of *Salvadora persica* stem on *Streptococcus mutans, Fusobacterium nucleatum, Staphylococcus epidermidis, Streptococcus salivarius and Lactobacillus casei* [41]. Al-Lafi and Ababneh investigated the antibacterial activity of *Salvadora persica* extract against some bacteria of the oral cavity [42]. The extracts of this plant had a very strong effect on *Staphylococcus aureus* growth, and a varying effect on the various other bacterial species [43]. Noumi et al. studied and confirmed the antifungal effect of *Salvadora persica* on several Candida species, including *Candida albicans, Candida glabrata, and Candida parapsilosis* [44]. Saddiq and Alkinani demonstrated the efficacy of aqueous root extracts of the same *Salvadora persica* against *Aspergillus flavus Aspergillus fumigatus*, and *Aspergillus niger* [45]. Recently, Owis et al. reported that aqueous extract of aerial parts from *Salvadora persica* had the antiviral activity against coronavirus 2 (SARS-CoV-2), responsible for Covid-19 [46].

Antioxidant potentials

Bauhinia rufescens

Samaila and Abubakar showed the antioxidant activities of acetone and aqueous extracts of *Bauhinia rufescens* stem bark are higher than ascorbic acid used as a positive control [47]. Aliyu et al. investigated the antioxidant effects of *Bauhinia rufescens* extracts. The results of 1, 1-diphenyl-2-picryl-hudrazyl radical (DPPH$^{\bullet}$) scavenging activity showed concentration dependent antioxidant effect with no major variation at 50, 125 and 250 µg/mL compared to the standard gallic and ascorbic acids. The total phenolic content was measured to be 68.40 0.02 mg/g gallic acid equivalent and the antioxidant capacity of 0.071 0.03 nm was obtained [12].

Ocimum basilicum

The antioxidant properties of different solvent of the leaf extracts of *Ocimum basilicum* was assessed using DPPH, hydrogen peroxide (H_2O_2) and ferric reducing ability of plasma (FRAP) assay patterns [27]. The ethanolic extracts exhibited the highest antioxidant potential in all DPPH, H_2O_2 and FRAP assays stating that *Ocimum basilicum* possess antioxidant activities. In another study, the *in vitro* antioxidant potential of *Ocimum basilicum* essential oil was examined using DPPH, H_2O_2, 2, 2-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) radical (ABTS$^{\bullet}$), nitric oxide (NO), hydroxyl radical (HO$^{\bullet}$) and nitrite (NO_2) scavenging properties [48]. The results revealed that *Ocimum basilicum* essential oil possesses effective free radical scavenging activities. Basil oil significantly reduced mRNA expression of NADPH oxidase (NOX) and inducible nitric oxide synthase in lipopolysaccharide-stimulated murine macrophages at concentrations of 1-10 µg/mL.

Salvadora persica

Ibrahim et al. investigated the antioxidant activities of two hydro-ethanolic extracts of *Salvadora persica* roots using malondialdehyde, hydrogen peroxide scavenging capacity and DPPH methods [49] resulting in high antioxidant activities. The antioxidant capacity of *Salvadora persica* methanolic extract was assessed using DPPH, ABTS and phosphomolybdenum complex assays. The extract exhibited concentration-dependent radical scavenging of DPPH and ABTS with IC_{50} values of 4.8 and 1.6 µg/mL of crude extract, respectively. The total antioxidant capacities, on the basis of the reduction of molybdenum (VI) to molybdenum (V), showed an increase upon augmentation of crude extract content [50].

Cytotoxicity reports

Bauhinia rufescens

Muhammad and Sirat have evaluated the cytotoxic effects of ethyl acetate, petroleum ether and methanolic extracts of leaves and stem bark of *Bauhinina rufescens* using the Brine Shrimp Lethaly Assay [13]. The methanolic and ethyl acetate extracts of leaves possess cytotoxic potentials to *Artemia salina* with IC_{50} of 0.059 and 0.389 mg/mL, respectively. The ethyl acetate and petroleum ether extracts of the stem bark, however, were not toxic to the larvae. The cytotoxicity study on the leaf methanolic and petroleum ether extracts

using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-2H-tetrazolium bromide (MTT) technics showed that both extracts showed IC_{50} of 391.39 µg/mL for petroleum ether extract and 488.32 µg/mL for methanol extract against Vero cell lines, respectively [23].

Ocimum basilicum

The brine shrimp lethality assay of *Ocimum basilicum* methanolic extract was evaluated by Khan *et al.* showing LC_{50} of 91.56 µg/mL [51]. In a similar study, the essential oils from leaves of seven accessions of *Ocimum basilicum* L. were found to have significant activity (LC_{50} <90 µg/mL) in the brine shrimp lethality assay [52]. Mohamed Abdoul-Latif et al. [53] evaluated the cytotoxicity of *Ocimum basilicum* essential oils with the luminescence spectrophotometric method against 13 human cancer cell lines (K562, A549, HCT116, PC3, U87-MG, MIA-Paca2, HEK293, NCI-N87, RT4, U2OS, A2780, MRC -5 and JIMT-T1). The results revealed that the oils had promising anticancer effects on whole cell lines. In another study conducted by Torres et al. [54], *Ocimum basilicum* and *Ocimum gratissimum* aqueous extracts were tested for their cytotoxic, cytostatic and anti-proliferative properties against the human breast cancer cell line MCF-7. Both extracts exhibited cytostatic effects with an 80% decrease in MCF-7 cell growth at 1 mg/mL. Only *Ocimum Basilicum*, however, had cytotoxic effects, interfering with cell viability even after treatment was discontinued. In addition, *Ocimum basilicum* but as opposed to *Ocimum gratissimum* impacted the proliferation and metabolism of cells, assessed both in terms of lactate production and intracellular ATP content. Following 24 h of treatment, cells treated with *Ocimum basilicum* exhibited an apoptotic pattern, whereas cells treated with *Ocimum gratissimum* were more necrotic.

Salvadora persica

Studies of the acute toxicity of the hydro-alcoholic extract of the root of *Salvadora persica* (extracted with 70% ethanol) in fasting mice revealed no lethality or toxic response to the extract at doses up to the highest concentration tested, 1,200 mg/kg body weight, orally, until the end of the study period of 48 h [55]. Al Bratty et al. had assessed the cytotoxic effects of the ethanolic fruit extract via MTT assay on MCF7 breast, A2780 ovarian and HT29 colon cells. They found that the fruit extract showed selectivity against ovarian and colon cancer cells in comparison to normal fibroblast cells (MRC5), subsequently showing IC_{50} values of 17.50, 8.35 and 5.12 µg/mL against MCF7, A2780 and HT29 cells accordingly [56]. Furthermore, there was no toxicity found by using *Artimia salina* as a test organism and no antitumor activity against Ehrlich ascites carcinoma when various concentrations of aqueous and methanolic extracts of *Salvadora persica* were tested [41].

Conclusions

This review discussed the botanical description, phytochemical constituents, traditional use, antimicrobial potentials, antioxidant properties and cytotoxic effects of the plant *Bauhinia rufescens, Salvadora persica and Ocimum basilicum*. These plants have enormous potential and are beneficial in many disorders. Thus, the present review will be of interest to scientists who are interested in validating the unknown scientific evidence regarding these plants.

Acknowledgments This study was supported by the Partnership for Applied Science, Engineering and Technology Skills (PASET), through the Regional Scholarship and Innovation Fund (RSIF) Doctoral Award. The authors are also grateful to the SACIDS Foundation and the Korean Institute of Science and Technology (KIST).

Conflicts of interest The authors declare no conflicts of interest.

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