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Avicennia officinalis: A mangrove marvel with multidimensional medicinal potential

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Abstract
Avicennia officinalis, commonly known as Indian Mangrove, is a halophytic plant widely distributed in the coastal regions of South and Southeast Asia. Traditionally used in folk medicine, this mangrove species is a rich source of bioactive phytochemicals including flavonoids, terpenoids, alkaloids, steroids, and phenolic compounds. Various parts of the plant such as leaves, bark, and pneumatophores have demonstrated significant pharmacological activities including antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, and cytotoxic effects. This review aims to provide a comprehensive overview of the botanical characteristics, ethnomedicinal uses, phytochemical profile, and pharmacological potential of *Avicennia officinalis*. Emphasis is also given to recent research findings and the therapeutic potential of isolated compounds such as lupeol, betulin, quercetin, and stigmasterol. Understanding the pharmacognostical and biochemical attributes of this species may contribute to the development of novel plant-based therapeutics.

Keywords: *Avicennia officinalis*, Indian mangrove, phytochemicals, lupeol, traditional medicine, pharmacological activities, flavonoids, terpenoids, antioxidant, ethnopharmacology

1. Introduction

1.1 Background

The plant *Avicennia officinalis L.*, which is part of the Acanthaceae family, is recognized as a significant mangrove species. *A. officinalis L.* is an evergreen mangrove species that typically reaches heights of 8 to 18 meters and has a diameter of about 1 meter. It is commonly found across the Indian subcontinent, as well as in Indonesia, Malaysia, Brunei, Myanmar, the Philippines, Singapore, Sri Lanka, Thailand, Vietnam, and southern Papua New Guinea. This mangrove species exhibits a broad distribution throughout the coastal areas of the Indian coasts and the Andaman Nicobar Islands.

It is generally known that various portions of *A. officinalis* are often used in traditional medical procedures. This plant's seeds are used as ulcers and maturative poultices, as well as to speed up the suppuration of boils and abscesses. Aphrodisiac roots and diuretic bark are used to treat skin conditions, including scabies, rheumatism, paralysis, asthma, and snake bite. Fruits are applied as tumor plaster. To treat dyspepsia, a plant decoction with sugar and cumin is utilized. This plant's leaves shown antioxidant, anticancer, anti-inflammatory, antiulcer, and antinociceptive properties.

The ethanol bark and leaf extracts of the *A. officinalis* plant were assessed in this study for their cytotoxic, antioxidant, and antibacterial properties as well as their inhibitory effects against enzymes that break down carbohydrates, including α-amylase and α-glucosidase.[1]

The many natural products and their byproducts are thought to be a plentiful supply of bioactive phytochemicals with a wide range of uses in the management of many human conditions. The majority of people in poor nations still depend on phytomedicines to maintain their basic health. Bioactive phytochemicals, such as phenolics, alkaloids, glycosides, sterols, tannins, essential oils, etc., have demonstrated exceptional promise in the fight against illnesses linked to cytotoxicity from damaging reactive oxygen species, antibiotic resistance, etc. Numerous researches have been conducted in the last few decades

to screen for biocompatible, nontoxic phytochemicals with promising cytotoxic, antioxidant, and antibacterial properties.

Mangrove plants, which are physiologically distinct and grow in intertidal coastal regions in tropical and subtropical regions worldwide, have long been utilized as remedies to treat a variety of human illnesses. These mangroves, which grow in harsh environments, are rich in a variety of phytochemical groups with distinct bioactivity, including alkaloids, flavonoids, phenolic compounds, saponins, terpenoids, tannins, etc. They are a good source of new therapeutic ligands, but there hasn't been much research done on the chemistry and bioactivity of the plants. There are currently 84 known species of mangroves worldwide, of which 70 are real mangroves and 14 are semi mangroves.[2]

Acanthaceae is one of the major mangrove families, containing eight different kinds of medicinally significant *Avicennia* species. Locals have utilized A. officinalis extracts to treat rheumatism, paralysis, asthma, snakebite, skin conditions, ulcers, boils, tumors, and more. Numerous investigations have demonstrated the antimicrobial, antiulcer, antinociceptive, antiinflammatory, diuretic, anticancer, and antioxidant properties of various plant parts. The antibacterial, antiviral, and antifouling qualities of A. officinalis are further highlighted by recent investigations.

The extract's varied phytochemical composition is responsible for the plant's bioactivities. The plant A. officinalis has a variety of bioactive metabolites, such as glycosides, tannins, alkaloids, phenols, terpenoids, saponins, sterols, flavonoids, and others, according to phytochemical research. Drug discovery relies heavily on the hunt for novel chemical structures, and mangrove-based phytochemicals may be useful in locating these ligands because they contain complex biomolecules of several kinds.

Therefore, it is essential to describe and assess the phytochemicals from medicinal mangrove plants, such as A. officinalis, for their bioactivities, including anti-inflammatory, anti-bacterial, antioxidant, and antidiabetic properties [2, 3].

1.2 Plant introduction

Avicennia, botanically known as *Avicennia officinalis*, belongs to the Acanthaceae family. Known as baen in Bengali and timirah in Sanskrit, these terms are synonyms for the Indian mangrove species.

Mangroves are a unique network of halophytic (salt-tolerant) plants that grow when land meets water. Because of their unique morphological and physiological adaptations, mangroves are able to withstand harsh ecological conditions such as high salinity, anoxia, repeated tidal immersion, strong winds, high streams, and more. Intertidal estuarine zones in the tropic and subtropical regions [4].

Mangroves possess unique roots known as pneumatophores, or breathing roots. Through the pneumatophores' springy tissue, this causes oxygen to diffuse to the remaining portion of the plant.

Avicennia officinalis is regarded as a medicinal plant with a variety of therapeutic applications.

Bark and stem groups, as well as antimicrobials, are treated with bark extract. A few medicinal qualities antiulcer, diuretic, astringent, contraceptive, and snake nibbling remedy [4, 5].

Fig 1: *Avicennia officinalis*

Vernacular names [5]

Table: 1. Vernacular names

Language	Name
Telugu	Tella Mada
Hindi	Baen, Bina
English	Indian Mangrove, White Mangrove
Urdu	Bina, Bain
Tamil	Venkantal
Sanskrit	Timirah
Bengali	Baen, Bani, Bina

1.3 Botanical description.

Botanical name: *Avicennia officinalis*

Synonyms [6]

- Indian mangrove
- *Avicennia*
- *Avicennia oepata*
- Recka ovate

Taxonomical classification [4]

- **Kingdom:** Plantae
- **Subkingdom:** Tracheobionta (vascular plant)
- **Super division:** Spermatophyta (seed-producing plant)
- **Division:** Magnoliophyta
- **Class:** Magnoliopsida
- **Subclass:** Asteridae
- **Order:** Lamiales
- **Family:** Acanthaceae
- **Genus:** *Avicennia*
- **Species:** *Avicennia officinalis L.*

Distribution

The young *Avicennia officinalis* tree has a low, bushy crown. Distributed throughout Australia, Oceania, the southern Asian coasts, and India. originating from the Sunda Islands, Molucca Islands, Celebes, East Pakistan, Tanasserim, Andaman Islands, Sri Lanka, Thailand, Malaysia, Sumatra, Madura, Java, Borneo, and New Guinea. Tropical and subtropical areas are where it is growing [7].

Morphology

The young *Avicennia officinalis* tree has a low, thick, rough crown. As it grows, it may reach a height of 30 meters and can frame a columnar tree up to 15 meters [8].

A. Roots
The tree is well adapted to saline coastal environments and develops specialized aerial roots called pneumatophores that protrude from the soil to facilitate gas exchange in oxygen-poor waterlogged soils.

B. Leaves
The leaves are simple, opposite, oblong to elliptic in shape, and have a glossy surface. They are dark green on the upper side and lighter on the underside, with a distinctive silvery.

C. Flowers
The flowers are small, pale yellowish-white, and are arranged in clusters. Each flower has four white petals and a tubular corolla.

D. Fruits
The tree is well adapted to saline coastal environments and develops specialized aerial roots called pneumatophores that protrude from the soil to facilitate gas exchange in oxygen-poor waterlogged soils.

Fig 2: *Avicennia officinalis* a) Roots b) leaves c) Flowers d) Fruits

2. Uses

2.1 Medicinal Uses

Around the world, *Avicennia officinalis* has long been utilized as medicine. *Avicennia officinalis* is mostly used by the locals who live in the mangrove forest to treat a variety of illnesses. The entire plant is typically used to treat rheumatoid arthritis, tumors, diabetes and ulcers. [8, 9] The blossoms are used by people in South-East Asia to make some of the world's best honey, which has antioxidant and antibacterial qualities. In Java, resin that drips from the bark is said to be effective as a birth control method. [10, 11]

In Arabia, unripe seeds of *Avicennia officinalis* are used to speed up the suppuration of boils and abscesses, and the root is utilized as an aphrodisiac. The bark is applied topically in IndoChina, particularly to treat scabies. The mangrove plant has been utilized in Indian traditional medicine for treatment of a number of side effects, including ulcers, rheumatism, paralysis, asthma, and snake bites [12, 13].

Ethnomedicine, sometimes known as traditional medical cinema, is a subfield of medical anthropology, which is the study of human disease and health care systems. It focusses on people whose practices, knowledge, and experience have been verbally transmitted to subsequent generations over centuries [14].

3. Phytochemical properties

The first chemical study of the genus *Avicennia* was conducted in 1913 when Bournot isolated and found lapatochol with anti-tumor action from A. officinalis growing in India and West Africa. [23, 24] Chemical profiling of A. officinalis as a result of additional research has revealed the existence of a broad class of bioactive chemicals, including terpenoids, steroids, alkaloids, flavonoids, polyphenols, phenolic acids, saponins, and tannins [25, 26].

Luteolin, chrysoeriol 6"-(3",5"-dimethoxycoumaroyl)-7-O-βD-glucopyranoside We isolate and identify 7-O-β-D-glucopyranoside, 3'-methylluteolin, 4'-O- β D-glucopyranoside, flavogadorinin, and astaxanthin from the A. officinalis leaves [27, 28].

Avicenol C and stenocarpoquinone B are two naphthofuranquinones that have been found in the plant's twigs. Velutin, α-tocopherol, aviridoid (1S,5R,8S,9R)-2'-(Ecoumaroyl) mussaenosidic acid, a combination of 6-- and 7-methoxynaphtho(2,3-b)-furan-4,9-quinone, From the leaves of A. officinalis, avicequinone C, iridoids, avicennioside, 7-cinnamoyl-8epiloganic acid, geniposidic acid, and 2'-cinnamoylmussaenosidic acid have also been extracted and described [29, 30, 31].

Additionally, it has been claimed that the leaves contain officinosidic acid [5-hydroxy-10-O (p-methoxycinnamoyl)] and 8-O-cinnamoylmussaenosidic acid.

The iridoids loganin, 10-O-(5-phenyl-2, 4-pentadienoyl), geniposidic acid, and a disaccharide acteoside are peracetates of adoxosidic acid. According to reports, the plant's methanol extract produces 4, 4'-(1-methylethyldiene) bis-2-methyl and 1, 2, 3-benzene triol. The roots include a number of discovered and isolated diterpenoids, including ent-16-hydroxy-3-oxo-13-epimanoyl oxide, rhizophorin-B, triacontan-1-ol, ribenone, excoecarin A, ent-15-

hydroxylabda8,13E-dien-3-one, ent-3,15-dihydroxy-labda-8,13Ediene, and ent-(13S)-2,3-seco-14-labden2,8-olide-3-oic acid.

The plant's ethyl acetate extract yielded 4', 5-dihydroxy3', 7-dimethoxyflavone and 8-Oacetylharpagid iridoid, while the hexane extract yielded lupeol, betulinic acid, ursolic acid, and betulin. The α-amyrin, β-amyrin, lupeol, oleanolic acid, and ursolic acids are among the triterpenoids that were separated from the chloroform-methanol extract of fresh mangrove leaves. The sterols that were identified were cholesterol, campesterol, stigmasterol, sitosterol, and stigmast-7-en-3-β-ol. [32, 33] From the bark and leaves of A. officinalis, taraxerol, β-amyrin, taraxerone, betulin, betulinic acid, and triacontanal have been identified.

After additional processing, the light petroleum extract of aerial portions is known to produce betulinic acid, β-sitosterol, lupenone, friedelin, and lupeol.

Usolic acid, together with its methyl ester and acetate. [34, 35] Three pentacyclic triterpenoids— betulin aldehyde, betulinic acid, and betulin—were also found in the aerial roots of A. officinalis in the Krishna estuary in India, according to a phytochemical analysis [36].

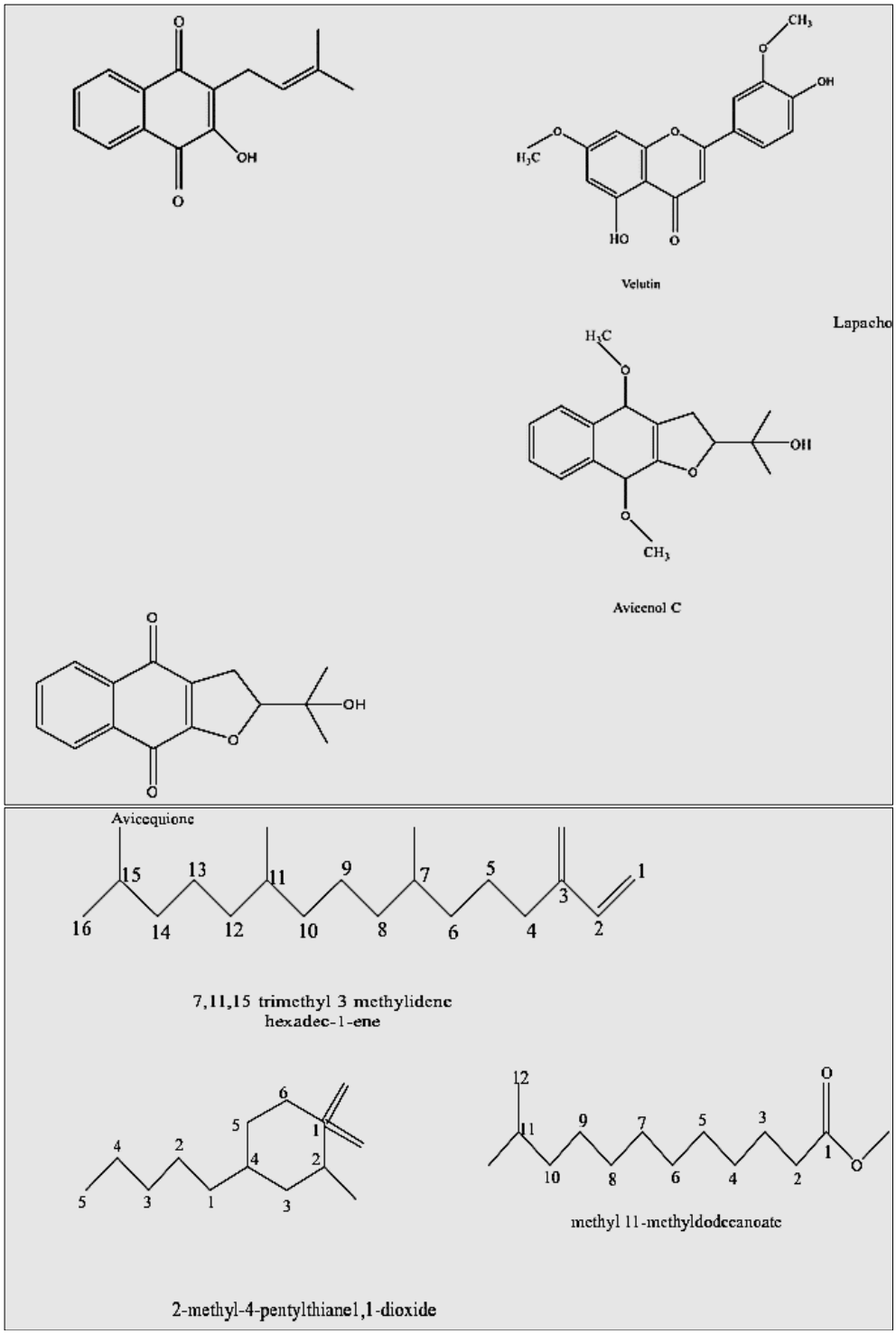

Fig 3: Chemical structures of some important constituents of *Avicennia officinalis*

4. Pharmacological properties

Table: 2. Pharmacological Properties of *Avicennia officinalis L.*

S. No	Activity	Procedure
1.	Anti-Diabetic Activity	*Avicennia officinalis* leaf and bark extracts were found to have encouraging anti-diabetic qualities in a study. A streptozotocin (STZ)-induced diabetes mouse model was used in the study, and there were five groups: Control, Normal, Standard, and two test groups. In order to induce diabetes, albino mice were selected as the experimental animals and given a single dose of 200 mg/kg of STZ. Petroleum ether and aqueous extracts from the bark or leaves of *Avicennia officinalis* were used as test chemicals in addition to the common medication metformin.[15]
2.	Anti-ulcer Activity	*Avicennia officinalis* shown noteworthy pharmacological qualities in a study, especially in terms of anti-ulcer activity. To assess the ulcerprotective properties, the study used conventional models of acute pylorus ligation (APL) and indomethacin-induced acute stomach ulcer in albino rats. Potential of the *Avicennia officinalis* leaf ethanolic extract. There were four groups in the experiment: the Control, Normal, Standard, and Test groups. While indomethacin (30 mg/kg) was given orally to cause ulceration, omeprazole (30 mg/kg) was given orally as the normal medicine. The test group received 500 mg/kg of the ethanolic extract of *Avicennia officinalis* leaves orally. The ethanolic extract considerably decreased the ulcerative lesion index in albino rats, according to the results, which were comparable to the effects of omeprazole (30 mg/kg). This decrease suggested a significant drop in ulcer development. Furthermore, the study indicated that by lowering the levels of free and total acid in the stomach environment, the leaf extract may have anti-secretory and anti-ulcer properties. Another investigation used non-steroidal anti-inflammatory medicines (NSAIDs) to emphasize the anti-ulcerogenic and gastro-protective properties of aqueous leaf extract, which are ascribed to the presence of polyphenols and hydrolysable tannins. [16, 17]
3.	Anti-cancer and Cytotoxic Activity	Pharmacological potential for cytotoxic and anti-cancer effects is demonstrated by *Avicennia officinalis*. With an LC50 of 131.2 µg/ml, a crude ethanolic extract of A. officinalis leaf demonstrated cytotoxic effects in a brine shrimp lethality bio-assay against Artemia salina. Additionally, by using Ehrlich ascitic carcinoma (EAC) cell lines to induce cancer in mice, the effectiveness of *Avicennia officinalis* leaf methanolic extract in cancer management was examined. It was discovered that the extract given to the mice had an LD value greater than 4 g/kg. By measuring the number of cells and the percentage increase in the lifespan of tumor hosts and drug-treated groups, the study assessed the extract's impact on the proliferation of cancer cells and host survival. Results indicated a notable increase in the mean survival time of EAC-transplanted mice, rising from 22.33 days in the EAC control group to 29.32 days (for 200 mg/kg) and 33.66 days (for 400 mg/kg) in the treated groups compared to the 5 fluorouracil (20 mg/kg) treated group. This increase was deemed significant. Furthermore, the extract was observed to correct hematological alterations induced by the EAC cell lines.[18]
4.	Antiinflammatory	*Avicennia officinalis* showcases significant pharmacological prowess in exerting anti-inflammatory effects. In studies conducted using rat models of inflammation induced by formalin, carrageenan, and Freund's adjuvant, the methanolic extract of *Avicennia officinalis* leaves at doses of 200 and 400 mg/kg demonstrated remarkable, dose-dependent anti-inflammatory properties. These effects were comparable to those of conventional medications such as diclofenac and indomethacin sodium. It was proposed that one of the triterpenoids present in the extract, betulinic acid, might be responsible for its anti-inflammatory effects by inhibiting prostaglandin activity. This mechanism of action suggests the extract's potential in modulating inflammatory pathways, thereby alleviating inflammationassociated symptoms [19]
5.	Antidiarrheal Activity	In experiments where mice were induced with diarrhea using castor oil, the methanolic extract derived from *Avicennia officinalis* leaves demonstrated notable antidiarrheal activity. At an oral dosage of 500 mg/kg, the extract significantly prolonged the mean latent period and reduced the frequency of defecation when compared to the standard medication loperamide (50 mg/kg). The suggested mechanism of action involves the inhibition of autocoids and prostaglandins release, which subsequently hampers motility and secretion induced by castor oil. This antidiarrheal effect is attributed to the presence of saponins, steroids, and alkaloids in *Avicennia officinalis*. [20,21]
6.	Anti-nociceptive, Analgesic, and Antipyretic Activities	Mice given 500 mg/kg of dried leaf ethanol and methanol extracts showed a 64.67% suppression of writhing in the acetic acid-induced writhing test, which is similar to the 85.95% inhibition seen by the common drug diclofenac sodium. Inhibition at a 25 mg/kg dosage. The presence of polyphenolic components including tannins and flavonoids as well as pentacyclic triterpenes in the leaf extracts may be responsible for the analgesic effect seen in mice. Additionally, the analgesic properties of the methanolic extract from the aerial portions of *Avicennia officinalis* were examined utilizing radiant heat and tail immersion techniques. The extract showed both cerebral and peripheral pathways for pain inhibition at dosages of 100 and 200 mg/kg. It was proposed that the extract reduces pain by modulating action potentials and obstructing signal transmission from sensory mediators such as delta and C fibre sensory neurons. Furthermore, oral treatment of the same extract at a concentration of 200 mg/kg demonstrated an antipyretic effect similar to that of acetyl salicylic acid in the Brewer's yeast-induced fever model. This antipyretic action could be explained by blocking the activity of the cyclooxygenase enzyme, which inhibits prostaglandin synthesis.[22]

Table: 3. Pharmacological Activities reported in *Avicennia officinalis L.* by various authors.

S. No	Plant Part with Extract	Biological Activity	Author And Year	Title	Journal
1.	Methanol Extract of Bark	Antibacterial Activity	Kathiresa n K. *et al*. 2006	Antibacterial Activity of *Avicennia officinalis* against Pathogenic Bacteria	Indian Journal of Marine Sciences
2.	Leaf Extract (Aqueous and Methanol)	Antioxidant Activity	Ravi V. *et al*. 2010	Evaluation of Antioxidant Potential of *Avicennia officinalis* Leaves	Journal of Pharmacy Research
3.	Aqueous Extract of Leaves	Hepatoprotective Activity	Kumaran K. *et al*. 2005	Hepatoprotective Effect of *Avicennia officinalis* in Paracetamolinduced Hepatotoxicity	Indian Journal of Pharmacology
4.	Petroleum Ether and Ethyl Acetate Extract of Leaves	Antiinflammatory and Analgesic Activity	Sahoo S. *et al*. 2014	Evaluation of Antiinflammatory and Analgesic Effects of *Avicennia officinalis* Leaves	Journal of Ethnopharmacology
5.	Ethanolic Extract of Leaves	Antidiabetic Activity	Devi K. *et al*. 2012	Antidiabetic Effect of *Avicennia officinalis* in Streptozotocin Induced Diabetic Rats	International Journal of Green Pharmacy
6.	Methanolic Extract of Leaves	Anticancer Activity	Roy P. *et al*. 2009	Antiproliferative Activity of *Avicennia officinalis* Leaf Extract on Cancer Cell Lines	Bangladesh Journal of Pharmacology
7.	Leaf and Bark Extracts	Cytotoxic and Antiproliferati ve Activities	Das S. *et al*. 2011	Cytotoxic Effects of *Avicennia officinalis* on Human Cancer Cell Lines	Asian Pacific Journal of Tropical Medicine
8.	Aqueous and Methanol Extract of Root	Antiviral Activity (against HSV)	Patra J.K. *et al*. 2008	Evaluation of Antiviral Properties of *Avicennia officinalis* Root Extract	Indian Journal of Virology
9.	Ethanolic Extract of Leaves	Antidiarrheal Activity	Sen A. *et al*. 2013	Antidiarrheal Properties of Leaf Extract of *Avicennia officinalis*	International Journal of Pharma and Bio Sci

5. Conclusion

Avicennia officinalis is a promising medicinal mangrove plant traditionally utilized for its diverse therapeutic benefits including antioxidant, antibacterial, antifungal, hepatoprotective, and antidiabetic activities. The increasing number of pharmacological and phytochemical investigations has contributed to the identification of various bioactive constituents responsible for its potent biological activities. These studies provide scientific validation for its traditional use in ethnomedicine, especially in coastal and estuarine regions. Despite its widespread distribution across tropical and subtropical coastal zones including India, Southeast Asia, and Australia, further in-depth research is warranted to fully explore its pharmacological potential. This review aims to consolidate existing studies from different researchers and regions to serve as a comprehensive baseline for future investigations and drug development initiatives involving *Avicennia officinalis*.

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