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A Comprehensive Review of Ficus benghalensis : Phytochemical constituent and its Pharmacological Activity

Shanu Mishra [1], Dr.Arvind Srivastava [1], Dr Shweta Srivastava1, Raj K Prasad1,*

[1]Department of pharmacognosy, Shambhunath institute of pharmacy, Jhalwa, Prayagraj, Uttar Pradesh.

Abstract

The Banyan tree, or *Ficus benghalensis* Linn., is a well-known species in the Moraceae family with a long history of use in traditional healthcare systems like Ayurveda, Siddha, and Unani throughout the Indian Subcontinent and other Asian countries. Prized for its wide growth, longevity, and ecological significance, almost every part of the tree—leaves, bark, aerial roots, fruits, buds, and latex—has been used historically to treat a remarkably wide range of human ailments.

Current research on the chemical components and biological activities of *F. benghalensis* is summarized in this thorough review. Phytochemical studies have shown a rich profile of secondary metabolites, primarily comprisi ng flavonoids, terpenoids, sterols, phenolics, alkaloids, and carbohydrates, with particular compounds differing among plant parts**.**

Pharmacological studies have largely supported conventional claims, show a broad spectrum of biological activities like its antioxidant, anti-diabetic, anti-inflammatory, antimicrobial, anticancer, immunomodulatory, wound healing, and hepatoprotective effects. These activities are often attributed to the synergistic action of its complex phytochemical composition. While preclinical evidence is compelling, the review highlights critical research gaps, including the need for detailed mechanistic elucidations, comprehensive toxicological assessments, pharmacokinetic profiling, and robust human clinical trials to fully translate its therapeutic potential into modern pharmaceutical applications. Emerging research in nanotechnological applications for enhanced delivery and efficacy also presents a promising future direction for this revered medicinal plant.

Keywords: Ficus benghalensis, Medicinal plants, Phytochemicals, Traditional medicine, Pharmacological activity, Secondary metabolites, Ethnopharmacology, Herbal drug development, Ayurvedic medicine, Banyan tree

1. Introduction

1.1 *Ficus benghalensis* Botany and Distribution

Banyan, banyan fig, or Indian banyan is a big evergreen tree in the Moraceae family and India's national tree[1,2]. Its horizontal branches, enormous fluted trunk, and descending aerial roots that become woody structures make it unique [3**]**. A single tree can grow to 200 meters in diameter and 30 meters in height when its aerial roots anchor into the ground and generate new trunks[4**]**. The "strangling fig" name comes from this trait **[**5,6].

Figure 1-Banyan figs

F. benghalensis is native to India, Pakistan, Nepal, Sri Lanka, and the East Himalaya. It thrives in monsoon and rainforests. It survives light frost and drought well. The tree is grown beyond its natural habitat in many tropical nations, including Colombia, for its beautiful ornamental value and shade in hot weather. Parks and roads often have it. Leathery, oblong to elliptic leaves are 10–40 cm long and 7–20 cm wide with lateral veins. The tree produces sessile, globose, 1-2 cm figs that mature brilliant crimson. For frugivorous birds, these figs are essential. Because seeds that survive their digestive systems germinate and develop faster, frugivorous birds—essential to seed spread—eat these figs [7,8].

Ficus, especially *F. benghalensis*, which produce the most oxygen through photosynthesis, are ecologically significant. The plant's vascular system contains latex-like sticky substance that helps it self-heal and protects it. *F.benghalensis* .massive size long lifespan and vast canopy make it a revered tree in India, where it is associated with Hindu gods and represents eternal life. Since generations have closely interacted with and monitored the plant, its profound ecological and cultural integration has made it simpler to obtain traditional knowledge about its properties.

The features that make it a "strangling fig," which also have healing properties, enhance its metaphorical significance as a potent, life-sustaining plant. This solid ecological and cultural foundation has preserved a large range of traditional medicinal knowledge and is a good place to start modern scientific investigation into its pharmacological potential [9,10].

1.2 Traditional Medicine

Traditional medical systems like Ayurveda, Siddha, and Unani use *Ficus benghalensis* as a key source of bioactive compounds due to its ethnobotanical history. Almost every component of this plant—leaves, stem bark, aerial roots, fruits, buds, and latex—is used to treat various human ailments, showing its adaptability.

Traditional uses for plant parts include:

Leaves: Used to cure wounds, abscesses, pimples, vaginal infections, persistent diarrhea, nausea, vomiting, and other skin disorders. They alleviate leucorrhea and other vaginal discharges and boost immunity when eaten [11].

Figure 2-Banyan leaves

Stem Bark: A decoction of stem bark treats diabetes, leucorrhea, asthma, urinary difficulties, colds, coughs, piles, and neurological illnesses. It may naturally boost immunity and memory [12].

Latex: Externally for arthritis, tonsils, lumbago, earaches, heel cracks, maggot wounds, rheumatism, and bleeding piles. Internally, it purifies blood for urinogenital and urinary illnesses, is an aphrodisiac, treats diarrhea and dysentery, and aids in conception [13].

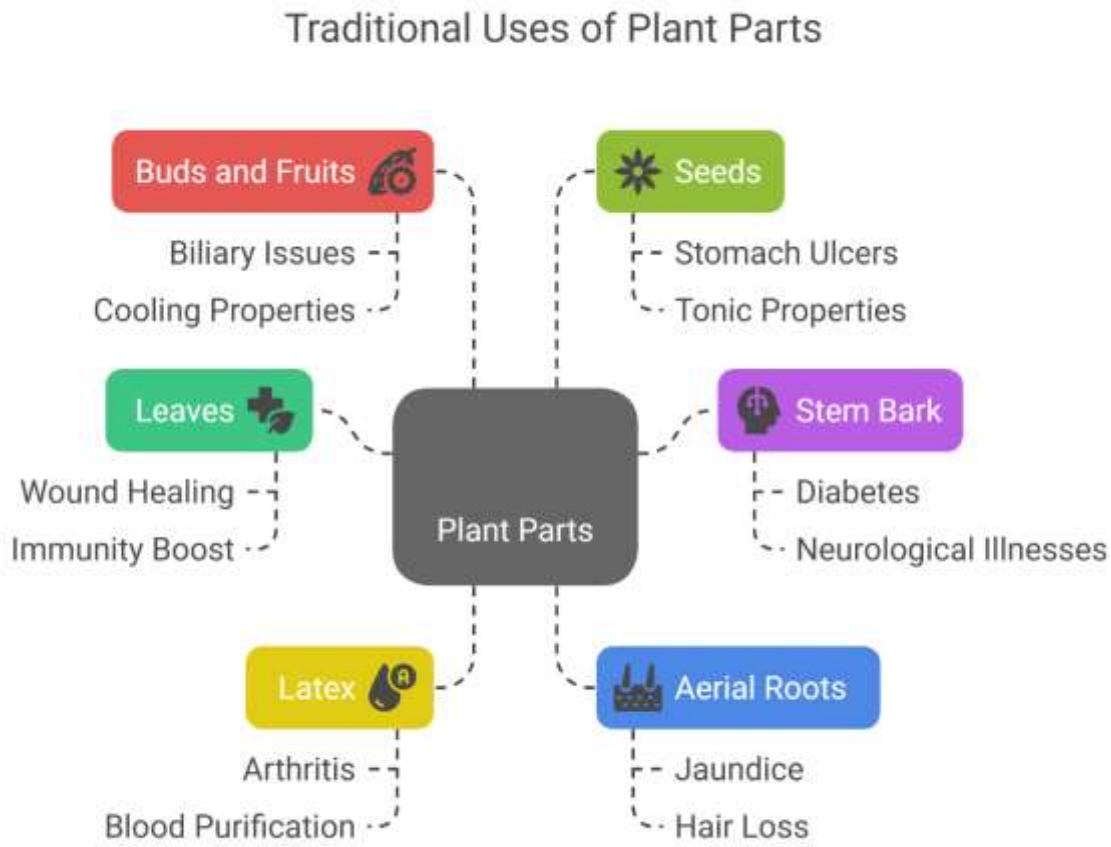
Aerial Roots: It has long treated jaundice, leucorrhea, diarrhea, vomiting, joint and body pain, and excessive hair loss. Known for styptic properties, they alleviate biliousness, liver inflammation, spermatorrhea, syphilis, and obstinate vomiting [14].

Buds and Fruits: Treats biliary issues, hemoptysis, diarrhea, dysentery, and bleeding. For cooling and tonic, ripe fruits are utilized [15].

Figure 3-Banyan tree fruits

Seeds: a stomach ulcer food supplement with cooling and tonic properties [16].

F. Benghalensis is a multifaceted therapeutic agent, as shown by its long list of traditional uses that cover almost every part of the plant and treat digestive, inflammatory, cancer, and reproductive disorders. This variety of usage strongly suggests a complex mixture of bioactive chemicals, some of which may have pleiotropic (many) effects or each may have different pharmacological effects. Since it has been used to treat inflammation and diarrhea, it may contain chemicals that modulate inflammatory and gastrointestinal motility pathways. Traditional knowledge is a powerful empirical resource that guides modern plant research [17, 18].



1.3 Scope and Importance

This review presents a thorough and critical analysis of *Ficus benghalensis'* phytochemical composition and the diverse biological activities of its extracts and isolated compounds to bridge the gap between traditional ethnomedicinal claims and modern scientific validation [19]. It will demonstrate its medicinal potential. Identify research gaps and advise sustainable use and conservation of benghalensis for innovative phytotherapeutics.

2. *Ficus benghalensis* Phytochemistry

2.1 Overview of Major Chemical Classes

Most phytochemicals are secondary metabolites, giving plants several medicinal uses. *Ficus benghalensis* contains a high concentration of these compounds, which increases its pharmacological effects. Extracts from *F. benghalensis* General phytochemical screening has shown numerous significant chemical classes including:

Terpenoids: This class ranges from ketones and derivatives to triterpenoids, including pentacyclic triterpenes. These compounds often have anti-inflammatory and anti-cancer properties [20,21].

Flavonoids and flavonols: The polyphenolic chemicals flavonoids and flavonols are renowned for their anti-inflammatory and antioxidant effects [22].

Phenolic compounds : In addition to flavonoids, phenolic compounds significantly boost the plant's antioxidant potential [23].

Sterols: Sterols, including phytosterols, have hypolipidemic and anti-inflammatory effects and share structural similarities with cholesterol [24].

Alkaloids: Nitrogen-containing organic compounds with potent pharmacological effects [25].Carbohydrates, such as sugars, glycosides, and lectins, play a role in immune modulation and biological recognition [26].

F.benghalensis many traditional uses are due to its multi-target pharmacological action and large range of chemical classes. Traditional usage in inflammatory and oxidative stress-related illnesses are supported by science since flavonoids and phenolic substances are rich and directly correspond with antioxidant and anti-inflammatory activity [28].

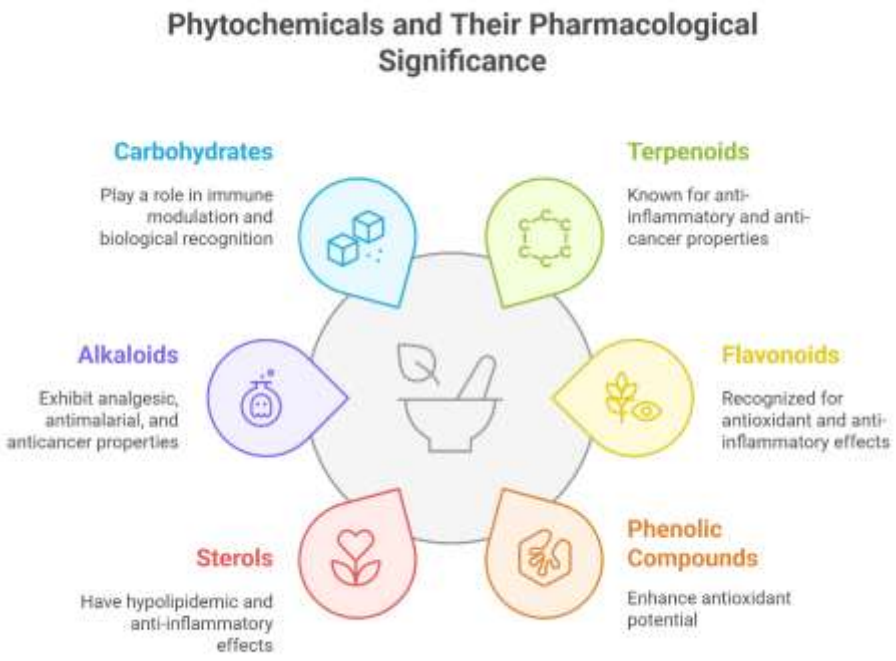
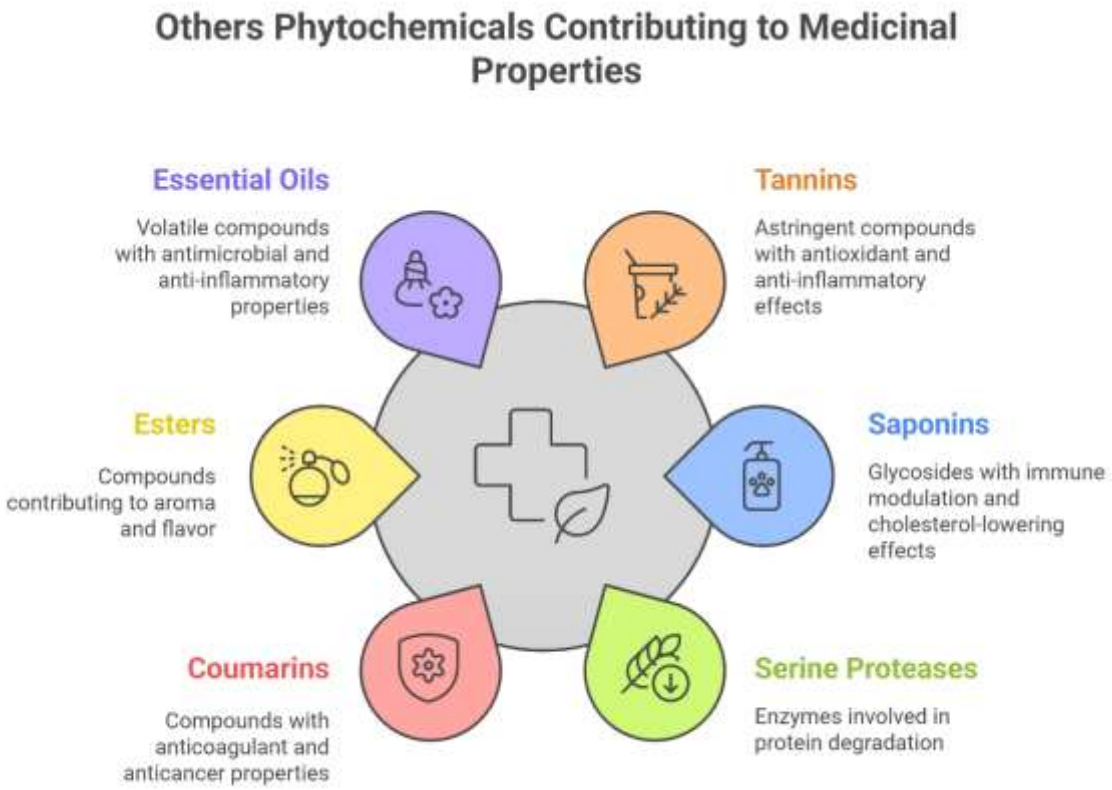


Figure 4: Ficus benghalensis phytochemicals

Other Courses: Tannins, saponins, proteins (serine proteases), coumarins (furocoumarins), esters (methyl and carboxylic acid esters), and essential and volatile oils [27].



2.2 Plant Part-Specific Isolated Compound Analysis.

Ficus benghalensis parts have different phytochemical compositions, which affects their pharmacological profiles and traditional uses.

Below is a comprehensive list of recognized compounds by chemical class and plant part:

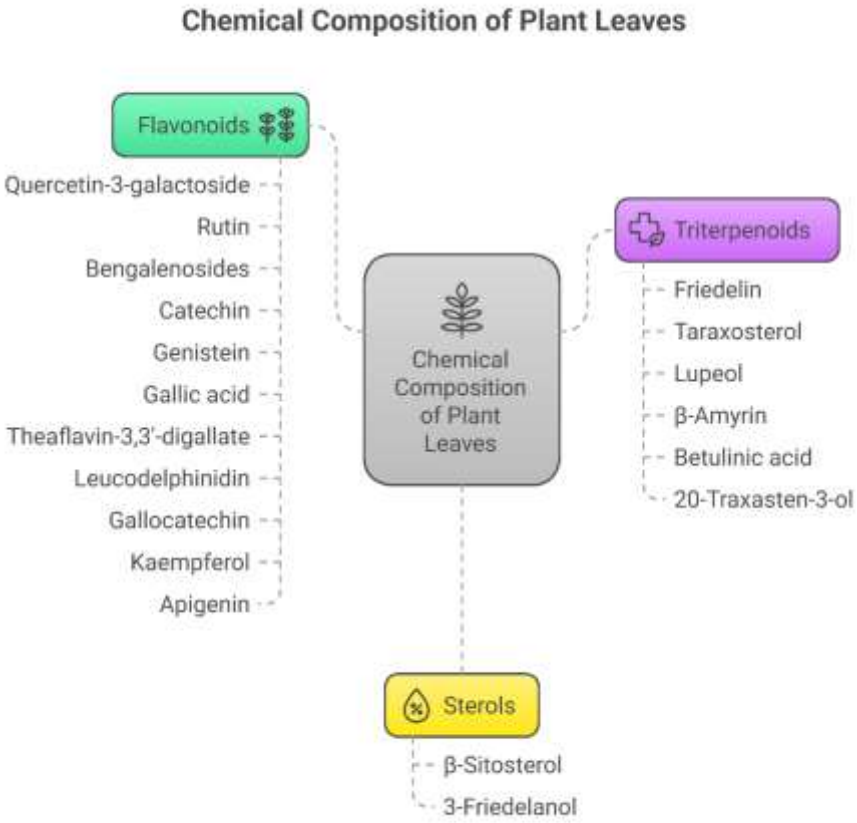
Table 1: Complete *Ficus benghalensis* Chemical Constituent List

Plant Part	Chemical Class	Specific Isolated Compounds (with relevant snippet IDs)
Leaves	Flavonoids/Flavonols	Quercetin-3-galactoside , Rutin , Bengalenosides (5,7 dimethyl ether leucoperalgonidin-3-0-α-L-rhamnoside) , Delphinidin-3-o-α-L rhamnoside , Pelargonodin-3-o-α-L-rhamnoside , Leucopelargonidin-3-0-α-L rhamnoside , Leucopelargonin glycoside of leucopelargonidin , Catechin , Genistein , Gallic acid , Theaflavin-3,3′-digallate , Leucodelphinidin , Gallocatechin , Kaempferol , Apigenin **[29]**
Leaves	Terpenoids/Sterols	Friedelin , Taraxosterol , Lupeol , β-Amyrin , β-Sitosterol , 3-Friedelanol , Betulinic acid , 20-Traxasten-3-ol **[30]**
Leaves	Coumarins	Psoralen , Bergapten **[31]**
Leaves	Other	Proteins , Crude protein (9.63%) , Crude fibers (26.84%) , Calcium oxalate (2.53%) , Phosphorus (0.4%) , Rhein , Anthraquinone **[32]**
Bark	Anthocyanidin Derivatives	Methyl ethers of leucodelphinidin-3-O-L-rhamnoside , Leucopelargonidin-3-O-L-rhaamnoside , Lecocyanidin-3-O-D-galactosylcellobioside , Leucodelphinidin derivative , Bengaleno side (Aglucoside) , Leucopelargonin derivative , Leucocynidin derivative , Glycoside of leucopelargonid **[33]**
Bark	Aliphatic Long Chain Ketones	Pentatriacontan-5-one , Tetratriacont-20-en-2one , Heptatriacont-6-en-10-one **[34**]
Bark	Sterols/Triterpenoids	Beta-sitosterol glucoside , Meso-inositol , Lupeol , Lupeol acetate , α-Amyrin acetate , Gluanol acetate , Lanostadienylglucosyl cetoleate **[35]**
Bark	Other	Tannins , Phenolic compounds , Reducing sugars , Alkaloids , Heneicosanyl oleate , 5,3-dimethyl ether-leucocyanidin-3-0-alpha-D-galactosyl cellobioside , Leucoanthocyanin **[36]**

Plant Part	Chemical Class	Specific Isolated Compounds (with relevant snippet IDs)
Aerial Roots	Triterpenoids/Sterols	n-Tritriacontan-10-one , 30-Lauryloxy-urs-12-en-3β-olyl butyrate , Urs-12-en-23,6α-olide 3β-olyl palmitate , Lupanyl acetate , 3-acetoxy-9(11),12-ursandiene , Stigmasterol , Friedelanol , Cyclolaudenol , Epifriedelanol , Lupeol , Amyrin acetate , Lupenyl acetate , Dihydrobrassicasterol , Furostano , 4,22-stigmastadiene-3-one , 1-Heptatriacotanol , Protodioscin **[37]**
Aerial Roots	Phenolic Compounds	4-Hydroxyacetophenone , 4-Hydroxybenzoic acid , 4-Hydroxymellein , p-Coumeric acid , Quinic acid **[38]**
Aerial Roots	Fatty Acids/Esters	Myristic acid , Palmitic acid , Methyl ester palmitic acid , Heptadecanoic acid , Linoleic acid , Linoleoyl chloride , Eicosadienoic acid , Methyl ester stearic acid , Alpha-monostearin , Phthalic acid, dioctyl ester **[39]**
Aerial Roots	Other	Flavonoids , Bengalensinone , Benganoic acid , Beta-progesterone , Triacontanol , Cycloartanyl acetate , Isoflavonoids , Cyclic peptides , Apocarotenoids , Fatty acyl amides , Hydroxybenzoates , Hydroxycinnamates , Lignans **[40]**
Fruits	Fatty Acids/Esters	Hexadecanoic acid , 5-Decenedioic acid , Methyl esters of 14,17-octadecadienoic acid , Undecanoic acid , 5,6-dimethyl, dimethyl ester , Hexadecanoic acid, 14-methyl , Heptadecanoic acid, 16 methyl , Oxiraneoctanoic acid, 3 octyl **[41]**
Fruits	Carbohydrates	Lectin (Ficus benghalensis agglutinin - FBA) , Galactose , α-D-glucose , D-galactose , D-fructose , α-D-glucoside , Aglucoside **[42]**
Seeds	Carbohydrates	Lectins (FBA) [**43]**
Seeds	Fatty Acids	Palmitic acid , Oleic acid , Linoleic acid , Linolenic acid , Vernolic acid , Stearic acid , Malvalic acid , Sterculic acid , Lauric acid , Myristic acid **[44]**
Latex	Other	Tannins , Flavonoids , Steroids , Glycosides ,

Plant Part	Chemical Class	Specific Isolated Compounds (with relevant snippet IDs)
		Saponins , Isoprenoids **[45]**
Heartwood	Triterpenoids/Sterols	Taraxasterol tiglate , Tiglic acid ester of ψ-taraxasterol , Ergosterol acetate , Amyrin acetate , Lupenyl acetate**[46]**
Heartwood	Other	Quinic acid **[47]**

Rutin and quercetin-3-galactoside in leaves and anthocyanidin derivatives in bark give a chemical basis for antioxidant and anti-inflammatory activities. Known for their anti-inflammatory and free radical-scavenging properties, these compounds have traditional uses. New chemicals extracted from aerial roots, such as 30-lauryloxy-urs-12-en-3β-olyl butyrate, n-tritriacontan-10-one, and urs-12-en-23,6α-olide 3β-olyl palmitate, show the ongoing finding of unique chemical entities in Benghalensis has untapped drug lead potential [48,49,50].



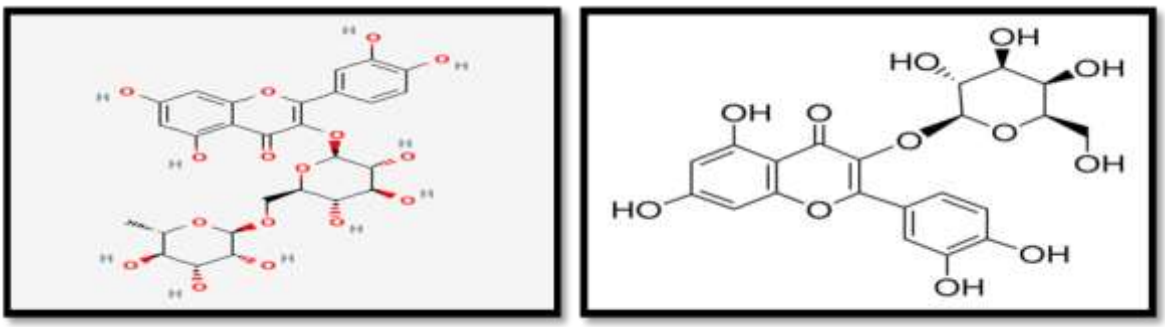


Figure 5—Rutin and quercetin-3-galactoside structure.

The phytochemical profile may vary, so be aware. *F.benghalensis* is reportedly "completely devoid of volatile oils, gums, mucilage, carbohydrates, triterpenoids, and aromatic acids" in some studies, while others list specific triterpenoids and carbohydrates, including friedelin, taraxosterol, lupeol, and β-amyrin. Some bark extraction and testing methods indicate no saponins, flavonoids, steroids, or carbonyl compounds, whereas others detect them. This discrepancy emphasizes the importance of harvest season, plant age, geographic location, and—most importantly—phytochemical extraction methods (such as solvent polarity and methodology) and analytical methods. This variability emphasizes the need for research and commercial use standardization, since different extraction methods might separate different chemical classes for targeted therapeutic purposes.

3. Drug Actions

Ficus benghalensis extracts and isolated chemicals exhibit many pharmacological properties, supporting its traditional usage. These functions are generally linked to its varied phytochemical ingredients' synergy.

Table 2: *Ficus benghalensis* Pharmacological Activities [51,52].

Activity	Plant Part(s)	Extract/Compound	Experimental Model/Mechanism	Key Findings/Dosage
Antioxidant	Fruit	Ethanolic extract	DPPH, ABTS, Nitric oxide, Hydroxyl ions scavenging, Phosphomolybdenum, Fe3+ reduction	IC50 values: DPPH (32.20 µg/ml), ABTS (13.69 µg/ml), Nitric oxide (57.74 µg/ml), Hydroxyl ions (34.37 µg/ml).
	Leaf	Hydroalcoholic, n-hexane, n-butanol, water, chloroform extracts; Methanolic extract	DPPH, ABTS assays; Folin-ciocalteu reagent	Hydroalcoholic (IC50 32.3 µg/ml, DPPH), n-hexane (IC50 28.2 µg/ml, DPPH); HEC (IC50 52.0 µg/ml, ABTS), HF (IC50 58.2 µg/ml, ABTS). Phenolic content: 54 µg/ml GAE/100gm.
	Root	Aqueous, Methanolic, Ethanolic extracts	DPPH, H2O2 scavenging; FRAP activity	Aqueous: 96.07% (DPPH), 69.23% (H2O2) at 250 µg/ml. Methanolic: IC50 80.14 (DPPH), 982.93 (FRAP). Ethanolic: IC50 38.66 (DPPH), 261.24 (FRAP).
	Stem bark	Aqueous extract	Lipid peroxidation inhibition; Increased antioxidant enzymes (catalase, SOD, glutathione peroxidase) in hypercholesterolemic rabbits	IC50 80.24 µg/ml (lipid peroxidation). Enzymes increased by 22-90%.
	Latex	Methanolic extract	DPPH, FRAP, Phosphomolybdenum activity	IC50 values: DPPH (28.6 µg/ml), FRAP (49.8 µg/ml), Phosphomolybdenum

Activity	Plant Part(s)	Extract/Compound	Experimental Model/Mechanism	Key Findings/Dosage
				(31.8 µg/ml).
	Seed	Ethanolic extract	DPPH scavenging, Nitric oxide, Lipid peroxidation, FRAP activity	IC50 values: DPPH (446.9 µg/mL), Nitric oxide (596.0 µg/mL), Lipid peroxidation (557.0 µg/mL).
Antidiabetic	Bark	Aqueous extract	α-glucosidase inhibition, Sucrose inhibition; STZ-induced diabetic rats (insulin secretion, glycolysis, glucose uptake, gluconeogenesis)	IC50 values: α-glucosidase (77.0 µg/mL), Sucrose (141.0 µg/mL). Reduced BGLs by 48.61-68.24% at 150-500 mg/kg.
	Leaf	Ethanolic extract	Alloxan-induced diabetic albino rats	Reduced triglycerides, cholesterol, and glucose levels at 200-400 mg/kg BW.
	Fruit, Bark, Aerial roots	Ethanolic extracts	Alloxan-induced diabetic rat models	Significant reduction in BGLs (31.73%, 18.33%, 28.84% respectively); fruit extract most potent.
	Leucopelargonin (compound)	Stem bark extract	Insulin production from beta cells; regulates BGLs	Stimulated beta cells of Islets of Langerhans.
	Pelargonidin 3-O-alpha-L rhamnoside (flavonoid)	Stem bark	Reduced BGLs; improved glucose tolerance; increased insulin secretion	Reduced BGLs by 19%, improved glucose tolerance by 29%.
Anti-inflammatory	Leaf	Ethanolic extract fatty acid glucoside; Methanolic extract	LPS-stimulated RAW 264.7 macrophages (inhibited cyclooxygenases, increased NO/iNOS, bound to EGFR); Formalin-induced paw edema; Carrageenan-induced hind paw edema	Significant activity, reduced paw edema by 65.21% at 200 mg/kg.
	Aerial root	Aqueous extract	Carrageenan-induced paw edema; Cotton-pellet-induced granuloma in rats	Significant dose-dependent activity at 100–200 mg/kg p.o..
	Bark	Ethanolic, Aqueous, Methanolic extracts	Carrageenan-induced hind paw edema; Cotton-pellet-induced granuloma; Acetic acid-induced vascular permeability; Freund's complete adjuvant-induced arthritis rat	Reduced paw edema by 31.50-69.86% at 50-200 mg/kg. Normalized body weight, arthritic score, ankle diameter, paw volume.
Antimicrobial	Fruit latex	-	Gram-positive/negative bacteria (*S. pyogenes, S. aureus, E. coli, P. mirabilis, K. pneumonia, P. aeruginosa, Seratia spp., Salmonella spp.*); Fungus species (*C. albicans, C. cruzii, C. tropicalis, C. sojae, C. kefyr*)	More inhibitory effects than *F. elastic* fruit latex.
	Leaf, Root, Fruit	Ethanolic, Methanolic, Aqueous extracts	Various bacteria (*S. aureus, E. coli, P. protobacteria, B. cereus*); Fish pathogen (*Aeromonas hydrophila*); HIV-1UG070, HIV-1VB59 in TZM-bl and PM1 cells	ZOI 5.4-9.6 mm (bacteria). ZOI 10-12 mm (*A. hydrophila*). IC80 5.2-6 µg/mL (HIV).

Activity	Plant Part(s)	Extract/Compound	Experimental Model/Mechanism	Key Findings/Dosage
	Stem bark	-	*S. aureus*, *K. pneumonia*, *P. aeruginosa*; Enterotoxigenic *E. coli*	ZOI 10-13 mm at 1 mg/ml; MIC 0.04-0.1 mg/ml. Remarkable activity against enterotoxigenic *E. coli* at 200 mg/ml.
	Aerial root	Aqueous, Hexane, Methanol, Ethanol extracts	Various bacterial strains (*S. aureus*, *V. anguillarum*, *E. faecalis*); Dental pathogens	Sustained activity. ZOI > 20 mm.
Anticancer /Cytotoxic	Panchvalkala (bark)	Aqueous extract	Cervical cancer cell lines (SiHa, HeLa) using MTT assay; Mouse papilloma models	Significant reduction in viability (75.2% SiHa, 75.03% HeLa) at 80 µg/ml. Induced apoptosis, reduced tumor growth.
	Aerial roots	Ethanolic extract	Breast cancer (MDA-MB-231), Lung cancer (A549), Cervical cancer (HeLa) cell lines	IC50 values: 97.89, 17.81, 49.27 µg/ml respectively.
	Latex	Ethanol, Ethyl acetate extracts	Peripheral blood lymphocytes, Neuroblastoma (IMR 32), Colorectal (HCT 116), Human breast (MDA MB 231, MCF-7) cells	Ethanol extract: IC50 123.27 (IMR 32), 99.82 (HCT 116). Ethyl acetate extract: IC50 75.66 (MDA MB 231). Ethanolic extract: IC50 101.55 (MCF-7).
Immunomodulatory	Panchvalkala (bark)	Aqueous extract	Increased thymus/spleen indices, splenocyte proliferation, Th1 cytokine levels; Mouse papilloma model	Modulated immune response, retarded tumor growth.
	Leaf	Hydroethanolic extract and fractions; Ethanol extract	Phagocytic action of neutrophils; Killed *C. albicans*; Human peripheral blood mononuclear cells	N-butanol/n-hexane fractions: 89.66%/80.33% phagocytosis stimulation. Highest % killed *C. albicans* (35.33%/36.33%). Enhanced growth of PBMCs.
	Aerial root	Aqueous extract; Water, Ethanolic extracts	Hypersensitivity and hemagglutination reactions; Hypersensitivity assays; Phagocytosis, phagocytic index	Increased hypersensitivity reactions and antibody titers at 50 mg/kg BW. Increased percentage phagocytosis and phagocytic index.
Wound Healing	Leaves	Petroleum ether extract formulation; Aqueous extract	Excision wounds (albino rat models); Incision, excision, dead space wound models in rats	100% wound healing in 21 days. Increased breaking strength, wound contraction, hexosamine content.
	Bark	Ethanolic, Hydroalcoholic, Aqueous	Excision wound models; Incision model	Complete healing in 17.19-18.37 days. Significant reduction in

Activity	Plant Part(s)	Extract/Compound	Experimental Model/Mechanism	Key Findings/Dosage
		extracts		wound area, increased breaking strength.
	Roots	Aqueous, Ethanolic extracts	Incision, excision, dead space wound models in rats	Increased breaking strength (502.30g aqueous, 455.80g ethanol). 100% wound contraction in 13.33 days (aqueous).
Hepatoprotective	Fruit	Ethanolic extract	Acetaminophen, CCl_4, Erythromycin-induced hepatotoxicity (goat liver); Perchloromethane-induced hepatotoxicity (New Zealand albino rat models)	Effective results, attributed to free radical scavenging or restoring catalase. Significant reduction in elevated liver biomarkers (AST, ALT, ALP), total serum bilirubin, malondialdehyde.
	Bark	-	Paracetamol and CCl_4-induced hepatotoxicity models	Significantly reduced levels of serum ALP, SGOT, SGPT, and bilirubin.
	Aerial roots	Methanolic extract	Isoniazid-rifampicin-induced increase in serum marker enzymes and TBARS	Prevented increase in marker enzymes and TBARS. Increased total protein content and reduced glutathione levels.
	Latex	-	Paracetamol and CCl_4-induced hepatotoxicity (albino rat models)	Improved liver functions, significantly improved total protein levels, reduced SGPT, SGOT, ALP, and bilirubin levels.
	Leucopelargonin derivative	Stem bark	CCl_4-induced hepatotoxicity in rats	Decreased levels of total cholesterol, lipoproteins, triglycerides, biomarker enzymes. Reduced HMG-CoA reductase, glucose 6-phosphate dehydrogenase activities, increased antioxidant enzymes.
Anthelmintic	Leaf	Alcoholic, Aqueous extracts	Indian earthworm (*Pheretima posthuma*)	Significant dose-dependent activity; alcoholic extract most potent (2.12 min to paralyze, 7.34 min to kill at 100 mg/ml).
	Roots	Aqueous, Methanolic, Chloroform, Petroleum ether extracts	Indian earthworms	Paralyzed worms in 3.02-4.03 min, killed in 4.34-6.18 min at 20 mg/ml.
	Fruit	Aqueous extracts	Earthworm (*Pheretima Posthuma*)	100% mortality within 1 hour at 37.5 mg/mL.

Activity	Plant Part(s)	Extract/Compound	Experimental Model/Mechanism	Key Findings/Dosage
	Latex	-	Earthworm (*Pheretima Posthuma*)	Caused paralysis and eventually death.
Antihyperlipidemic/Hypocholesterolemic	Stem bark	Aqueous extract	Hypercholesterolemic rabbits	Decreased levels of LDL, VLDL, serum cholesterol, triacylglycerol by 54-60%. Increased HDL to 30.6 mg%, decreased triacylglycerol to 89 mg%. 48% decrease in total cholesterol after 4 weeks.
Analgesic	Leaf	Methanolic, Aqueous, Ethanolic extracts	Acetic acid-induced writhing; Eddy's hot plate; Tail immersion tests	Showed potential analgesic activity. Significant activity at 200 mg/kg.
	Bark	Ethanolic, Aqueous extracts	Acetic acid-induced writhing	26.61-61.28% inhibition by ethanolic extract; 40.72-69.75% inhibition by aqueous extract at 100-400 mg/kg.
	Root	Aqueous extract	Swiss albino mice (Hot-plate reaction time, Tail-flick reaction time, Writhing test)	Significant observation in the writhing test at 200 mg/kg BW.
Antistress/ Antiallergic	Stem bark	Ethanol, Aqueous, Ethyl acetate extracts	Milk-induced asthma in mice	Potent antistress and antiallergic activity by decreasing eosinophils and leucocyte count.
	Fruit	Methanolic extract	Swimming endurance, Anoxia stress tolerance, Immobilization stress animal models	Remarkable dose-dependent antistress activity; considered adaptogenic agent.
	Bark	Methanolic extract	Acetylcholinesterase inhibitory activity against SHSY5Y cell lines	IC50 value of 228.3 µg/mL.
Anticoagulant	Leaf	Methanolic extract	Human plasma	Prothrombin time of 21.7 seconds (control 13.3s); Activated partial thromboplastin time of 67.3 seconds (control 43.3s).
Larvicidal	Leaf	Methanolic extract	Early second, third, fourth instar larvae of *Culex quinquefasciatus, Anopheles stephensi, Aedes aegypti*; Early third instar larvae of *Culex tritaeniorhynchus, Anopheles subpictus*	LC50 reported for different instars and mosquito species. Highest efficacy against *C. tritaeniorhynchus* and *A. subpictus*.
Antipyretic	Leaf	Ethanol, Water, Chloroform extracts	Brewer's yeast-induced pyrexia in rats	Water and chloroform extracts significantly reduced elevated body temperatures at 200 mg/kg BW i.p..
	Bark	Ethanolic, Aqueous	Yeast-induced hyperthermia in rat models	Significant activity at all doses.

Activity	Plant Part(s)	Extract/Compound	Experimental Model/Mechanism	Key Findings/Dosage
		extracts		
Antinociceptive	Stem bark	-	Swiss albino mice (Tail-flick, Formalin tests); Clonidine-induced dose-dependent catalepsy; Tail-flick, Hot-plate latency, Allodynia, Acetic acid writhing tests in mice	Remarkable increase in time elapsed till tail flicking and decrease in licking response duration. Significant inhibition of catalepsy. Significantly increased pain threshold.
Anticataleptic	Bark	Aqueous, Ethyl acetate extracts	Cataleptic mice injected with clonidine and haloperidol	Aqueous extract showed potent inhibitory activity for clonidine-induced catalepsy.
Nanotechnological Applications	Leaf, Latex, Bark, Aerial root	Various extracts	Green synthesis of Iron oxide, Zinc oxide, Copper oxide, Silver, Selenium, Magnesium oxide, Sulfur, Zirconia, Gold, Titanium dioxide Nanoparticles (NPs)	Used for anti-cancer, antimicrobial, super capacitance, photocatalytic dye degradation, insecticidal, catalytic reduction, tissue repairing, antioxidant, agricultural applications.
Commercial Applications (Patents)	Various parts	Phytochemicals, extracts	Skin care, Hair care, Metabolic Disorders, Animal Care, Agricultural Application, Fuel Additives	Decrease facial lines/wrinkles, increase collagen, promote melanin, manage diabetes/obesity, treat animal skin disorders, insect repellant, enhance plant growth, reduce harmful emissions.

3.1 Antioxidant activity

To reduce cellular damage from oxidative stress and free radicals, which are connected to chronic diseases like diabetes, cancer, and inflammatory disorders, *Ficus benghalensis* has excellent antioxidant action. The plant's antioxidant action comes from its ability to scavenge free radicals and reduce oxidative stress, which prevents or delays oxidation and protects biomolecules. Multiple plant section studies have shown this effect.

The strongest DPPH and ABTS radical scavenging activity is seen in fruit ethanol extracts, along with nitric oxide and hydroxyl ions. DPPH and ABTS tests showed strong activity for the leaves' hydroalcoholic and n-hexane extracts. Water, methanol, and ethanolic root extracts showed high antioxidant activities against hydrogen peroxide, DPPH, and ferric reducing antioxidant power (FRAP). In hypercholesterolemic rabbits, the aqueous stem bark extract prevented lipid peroxidation and increased endogenous antioxidant enzymes such glutathione peroxidase, catalase, and superoxide dismutase. Phosphomolybdenum, FRAP, and DPPH experiments showed methanolic latex extracts may scavenge [53].

Due to the consistent antioxidant activity throughout plant parts and extracts, which is often connected with phenolic and flavonoid content, its traditional usage in oxidative stress-related diseases such inflammation,

diabetes, and cancer is supported. It suggests a key defense mechanism for F. Benghalensis is a valuable natural antioxidant for commercial and clinical applications.

3.2 Diabetes Prevention

Scientific interest in *Ficus benghalensis's* antihyperglycemic and antidiabetic properties supports its long-standing usage in diabetes treatment. The plant acts as an antidiabetic by increasing pancreatic beta cell insulin secretion, tissue glucose and glycolysis uptake, and gluconeogenesis reduction.

After *F. benghalensis* extracts significantly lower blood glucose levels (BGLs), especially in rats and rabbits with streptozotocin (STZ) and alloxan-induced diabetes. Bark extracts lower BGLs dose-dependently by causing Islets of Langerhans beta cells to release insulin. An aqueous bark extract revealed potent antidiabetic and ameliorative effects in STZ-induced diabetic rats' histological tests.

In alloxan-induced diabetic rats, hydroalcoholic bark extract reduced BGLs and normalized lipid, renal, and hepatic profiles. *F. benghalensis* also directly reduces glucose. benghalensis inhibits sucrose and alpha-glucosidase hydrolysis. Enzymes that control postprandial glucose rises are crucial. Leucopelargonin from stem bark controls BGLs and promotes insulin production. Pelargonidin 3-O-alpha-L rhamnoside, another flavonoid, increased insulin secretion, glucose tolerance, and BGL loss. The extra-pancreatic (enzyme inhibition, glucose absorption modification) and pancreatic (insulin stimulation) antidiabetic action mechanisms propose a holistic strategy to glucose management [54].

The discovery of molecules like leucopelargonin proposes lead compounds for therapeutic development, and its multifarious function suggests it may treat diabetes naturally.

3.3 Anti-inflammatory

Ficus benghalensis has long been used to treat inflammatory illnesses due to its anti-inflammatory properties. The plant decreases inflammation by regulating inflammatory mediators and suppressing prostaglandin-forming cyclooxygenases (COX).

Many experiments have revealed that *F. benghalensis* extracts reduce inflammation in rats with formalin-induced paw edema, carrageenan-induced hind paw edema, and cotton pellet granuloma. In rat models, methanolic leaf extract reduced paw edema. Bark extracts in water and alcohol have cured paw edema and cotton-pellet-induced granuloma. These extracts also reduce myeloperoxidase and prevent marker enzyme rises. Compared to mature plants, young plant bark ethanolic extracts demonstrated a higher anti-inflammatory effect, suggesting that plant age may alter bioactivity.

Several extracts and compounds have shown direct molecular interactions. A leaf ethanolic extract fatty acid glucoside directly bound to the epidermal growth factor receptor, inhibited cyclooxygenase, and increased nitric oxide and inducible nitric oxide synthase in lipopolysaccharide-stimulated macrophages, causing considerable anti-inflammatory activity F's capacity to prevent pro-inflammatory lysosomal contents suggests lowering inflammation. benghalensis extracts stabilize human red blood cell membranes, which resemble lysosomal

membranes. The plant's cytokine modulation, membrane integrity, and enzyme inhibition anti-inflammatory effects demonstrate its therapeutic potential for a variety of inflammatory illnesses [55]. The discovery that younger plant material has stronger anti-inflammatory effects stresses the importance of harvest time in maximizing therapeutic usage.

3.4 Antimicrobial

Since *Ficus benghalensis* has broad-spectrum antibacterial activity against many bacteria and fungi, its historic use to treat infections and skin disorders is scientific. This function destroys or stops microbial development. It often targets fungal pathways, ruptures cell membranes, inhibits enzymes, or causes pathogenic oxidative stress.

Studies have found inhibitory effects from many plant components and microbiological strains. Fruit latex inhibited Candida species and Gram-positive (*Streptococcus pyogenes, Staphylococcus aureus*) and Gram-negative (*Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa*) bacteria. Leaf, root, and fruit extracts inhibit different microorganisms to substantial degrees. Ethanolic leaf extract suppressed *Aeromonas hydrophila*, a fish pathogen. Methanolic leaf extract contains genistein and catechine, which inhibit *B. cereus* and *P. aeruginosa*. Aqueous leaf extract was also effective against HIV isolates HIV-1VB59 and HIV-1UG070.

Against *S.aureus, K. pneumonia,* and *P. aeruginosa*, stem bark showed excellent antibacterial activity at low minimum inhibitory concentrations. Extracts from subterranean roots also inhibited Gram-positive and Gram-negative bacteria and *Aspergillus niger*.

F. benghalensis broad-spectrum antibacterial effect against bacteria and fungus, including drug-resistant species, makes it a promising source for novel antimicrobials. This is crucial given the global antibiotic resistance crisis. The green synthesis of AgNPs using *F. benghalensis* leaf extract shows its modern uses [56]. Bactericidal against *E. coli* and other oral infections indicate its potential for innovative antibiotic delivery strategies.

3.5 Cancer/Cytotoxic/Antiproliferative Effects

Ficus benghalensis has been used traditionally to treat several diseases, including cancer, and new study suggests it may have anticancer, cytotoxic, and antiproliferative characteristics. The majority of these actions target quickly dividing cells, restrict cell proliferation, and decrease unregulated cell division.

Studies using various human cancer cell lines show significant cytotoxicity. *F. benghalensis* was found in Ayurvedic formulations in cell lines and mouse papilloma models bark (Panchvalkala) triggered apoptosis and significantly reduced cervical cancer cell viability (SiHa and HeLa). This was linked to decreased human papillomavirus oncoproteins E6 and E7, activation of tumor suppressor proteins p53 and pRb, decreased mitochondrial membrane potential, and enhanced generic caspase expression.

Hydroalcoholic bark extract also killed adenocarcinomic human alveolar basal epithelial cells (A549). Against cervical cancer (HeLa), lung cancer (A549), and breast cancer (MDA-MB-231) cell lines, aerial root ethanolic

extract had varied IC50 values. In addition, latex extracts (ethanol and ethyl acetate) showed promising antiproliferative effects against breast cancer, neuroblastoma, colorectal, and peripheral blood lymphocytes. Leaves include anti-cancer chemicals such β-sitosterol, lupeol, and psoralen, and triterpenes block growth factors, cell cycle regulatory proteins, and apoptotic proteins [57].

Tumor suppression, cell cycle modification, and apoptosis induction have been found to fight cancer. This shows *F. benghalensis* derived medications may work together or target different cancer stages. They are ideal candidates for new cancer treatments like combination therapy or multi-target medicines due to their complexity.

3.6 Immunomodulation

Ficus benghalensis potential to stimulate, inhibit, or modify the adaptive or innate immune system supports its historic usage in strengthening immunity and treating immunological-related disorders. In vitro, an aqueous Panchvalkala extract, an Ayurvedic formulation with F. benghalensis bark enhanced thymus and spleen indices, promoted splenocyte proliferation, upregulated T-helper1 (Th1) cytokine levels (Interleukin-2), and delayed tumor growth in a mouse model of papilloma. Hydroethanolic leaf extract and its fractions promoted human neutrophil phagocytosis, with n-butanol and n-hexane being the most active.

The highest percentage of *Candida albicans* eliminated in these fractions suggests even better immune activity. Ethanolic leaf extract increased human peripheral blood mononuclear cell growth.

Laboratory investigations showed that aerial root aqueous extracts increased antibody titers and hypersensitivity at certain dosages. Methanolic root extract enhanced plaque-forming cells, circulating antibody titer, lymphocyte levels, and rosette formation, and improved hematological parameters. *F.benghalensis* suggests a complicated host immune system relationship which regulates innate (phagocytosis) and adaptive (antibody formation and T-helper1 cytokines) responses [58].

Makes *F. benghalensis* may include immunomodulators, which cure autoimmune diseases, chronic infections, and some cancers. Natural defenses are also strengthened by them.

3.7 Healability

Ficus benghalensis has been used to heal wounds for generations, and new research shows that it promotes tissue repair and function after skin damage. Wound healing involves complex steps like inflammation, proliferation, and remodeling. *F. bengalensis* extracts appear to help.

Various plant parts have been examined for wound healing. A leaf-derived petroleum ether extract formulation healed excision wounds 100% in albino rats in 21 days. In dead space, excision, and incision wound models, aqueous leaf extract increased wound contraction, hexosamine levels, and collagen protein content, increasing wound breaking strength.

Ethanolic and hydroalcoholic bark extracts healed excision wounds in 17–18 days, reducing wound area and epithelialization times. These extracts also significantly increased incision model wound breaking strength.

In similar experiments, aqueous and ethanolic root extracts showed stronger wound breaking strengths and wound contraction percentages in excision models. Anti-inflammatory and antioxidant compounds in the plant support F's multi-stage wound healing. *F.benghalensis* extracts influence inflammation, proliferation, and remodeling [59].

This supports the plant's long-standing usage in wound treatment by demonstrating a holistic tissue restoration strategy in which its components work together to promote different healing stages.

3.8 Liver Protection

F.benghalensis, shows significant hepatoprotective action supporting its traditional role in protecting the liver from toxic substances and controlling metabolic processes, storage, secretions, and body detoxification.

F. Benghalensis extracts have been tested for hepatotoxicity prevention. Ethanolic fruit extract prevented acetaminophen, carbon tetrachloride (CCl4), erythromycin, and perchloromethane-induced hepatotoxicity in goat liver and New Zealand albino rat models. Coumarins in the fruit extract diminish lipid peroxides and replenish catalase or scavenge free radicals. Bark extracts significantly reduced excess bilirubin and liver indicators (serum ALP,SGOT,SGPT) in CCl4- and paracetamol-induced hepatotoxicity animals.

Aerial root methanolic extract significantly increased total protein and lowered glutathione while reducing isoniazid-rifampicin-induced blood marker enzyme and TBARS increases. In albino rat models of paracetamol and CCl4-induced hepatotoxicity, oral latex significantly increased total protein and lowered SGPT, SGOT, ALP, and bilirubin [60].

Leucopelargonin derivative from stem bark also protected the liver from CCl4-induced hepatotoxicity by increasing antioxidant enzyme levels and reducing total cholesterol, lipoproteins, triglycerides, and biomarker enzymes. Hepatoprotection against toxins, antioxidants, and enzyme-regulation make it a promising natural liver tonic. In drug-induced liver damage or chronic liver illnesses, natural compounds can protect or support the liver.

3.9 Other Important Activities

Ficus benghalensis exhibits several biological traits in addition to its pharmacological activities, highlighting its therapeutic adaptability.

Anthelmintic Activity: Extracts from leaves, roots, fruits, and latex exhibit strong anthelmintic activity against many helminths, including the Indian earthworm *Pheretima posthuma*. These extracts often have dose-dependent effects like standard anthelmintics [61].

Antihyperlipidemic and Hypocholesterolemic Activity: In hypercholesterolemic rabbits, an aqueous extract of stem bark significantly reduced serum cholesterol, triacylglycerol, and low-density and very low-density

lipoprotein cholesterol levels, while increasing antioxidant enzymes and good high-density lipoprotein cholesterol [62].

Analgesic Activity: The extracts from leaves, bark, and roots have been demonstrated to exhibit analgesic effects in various pain models, including hot plate and acetic acid-induced writhing in rats and mice, validating their long-standing use in pain management [63].

Antistress and Antiallergic Potential: Fruit and stem bark extracts have shown considerable antistress and antiallergic effects, suggesting adaptogenic potential. These effects are caused by reducing leukocyte and eosinophil levels and changing neurotransmitter levels [64]..

Anticoagulant Activity Methanolic leaf extract has substantial anticoagulant properties, lengthening prothrombin time (PT) and activated partial thromboplastin time (APTT) in human plasma [65].

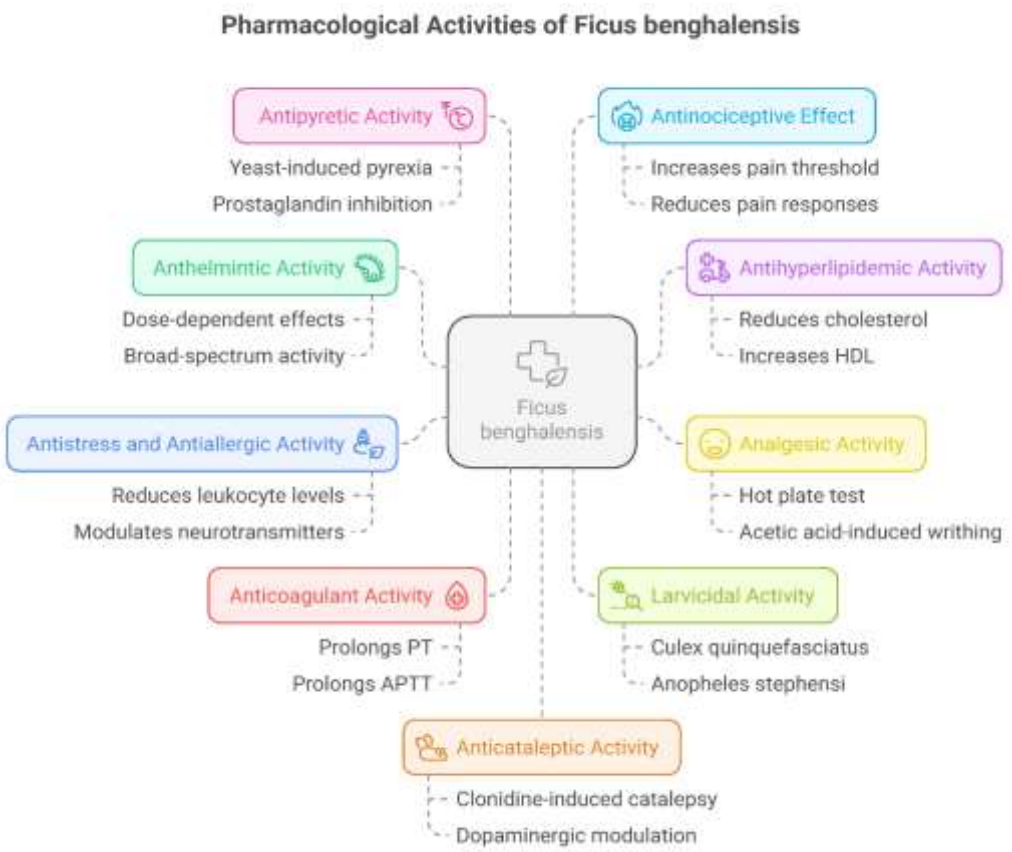
Larvicidal Activity: Methanolic leaf extract has shown larvicidal action against many mosquitoes, including Culex quinquefasciatus, Anopheles stephensi, and Aedes aegypti, suggesting potential for natural pest control [66,67].

Antipyretic Activity : Leaf and bark extracts have been shown to reduce body temperatures in rats with yeast-induced pyrexia, indicating antipyretic activity [68].

Antinociceptive Effect: In mice, stem bark extracts have been demonstrated to have antinociceptive effects, boosting pain thresholds and lowering pain responses [69].

Anticataleptic Activity: Bark extracts in aqueous and ethyl acetate effectively inhibited clonidine-induced catalepsy in mice [70].

The range of extra activities promotes *F. Benghalensis* has many medicinal uses. The neuropharmacological and anti-parasitic actions suggest a complex phytochemical interaction that may offer a comprehensive therapeutic strategy.



Nanotechnology and Business:

F. benghalensis Besides its medicinal effects, is becoming more popular in biotechnology and commerce. The green synthesis of iron oxide, zinc oxide, copper oxide, silver, selenium, magnesium oxide, sulfur, zirconia, gold, and titanium dioxide nanoparticles is increasingly using its extracts. Tissue repair, antimicrobial activity against multidrug-resistant pathogens, anti-cancer treatment, super capacitance, insecticidal effects, photocatalytic dye degradation, and catalytic reduction are improved by these plant-mediated nanoparticles. Green synthesis methods are cost-effective and ecologically benign, and the nanoparticles may improve conventional extract solubility and bioavailability, expanding medicinal administration possibilities. Consequently, this new field is a major modern advancement [71].

Additionally, patent landscapes reveal several businesses use *F. benghalensis* phytochemicals. Skincare (UV damage mitigation, collagen expression, and anti-aging), hair care (melanin production and hair growth), metabolic disease management (diabetes, obesity, and candidiasis), animal care (mastitis and other skin conditions), and agricultural applications are examples. Research is also being done on using plant-derived oils with conventional fuels to reduce harmful emissions [72].

4. Safety, toxicity, contraindications

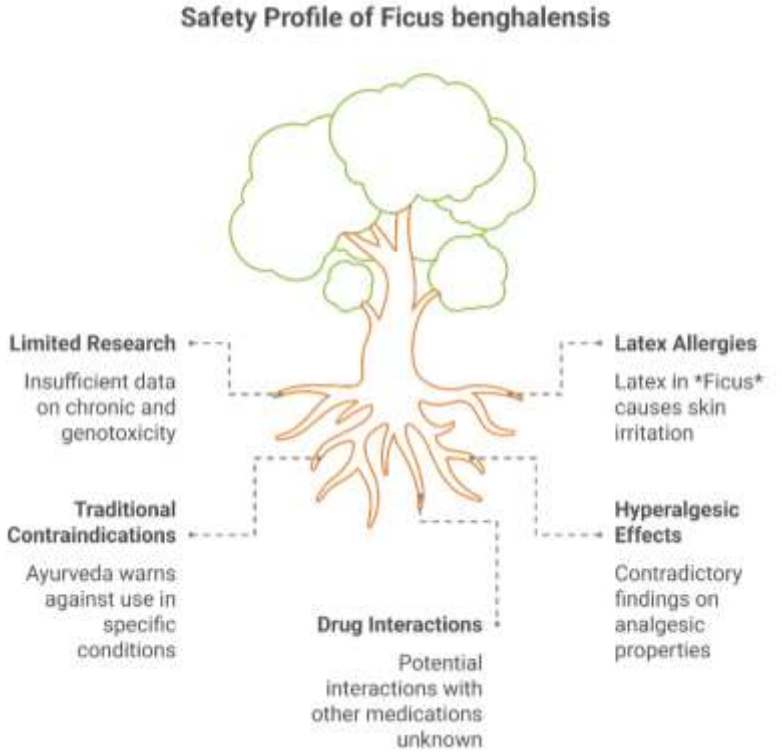
Traditional use of *Ficus benghalensis* suggests a general safety, but modern scientific studies into its toxicity and contraindications are needed to expand its use in clinical practice.

Studies of *F. benghalensis* ethyl acetate extracts' acute oral toxicity showed a substantial safety margin. aerial roots in female Wistar rats showed no adverse effects or mortality at 5000 mg/Kg body weight. This shows that aerial root extract is safe to eat and suitable for in vivo biological screening. In addition, rats given *F. benghalensis* methanolic extracts protected against isoniazid-rifampicin-induced oxidative liver damage, demonstrating a beneficial interaction that reduces drug-induced side effects [73].

Even though *F. benghalensis* is usually avoided,ancient ayurvedic writings state no known side effects from using *F.benghalensis* for constipation.
However, safety precautions and contraindications were given. Avoid direct eye contact since Ficus species, especially *F. benghalensis*, have latex can cause skin allergies. This highlights a latex preparation safety issue. Traditional dental hygiene guidelines advise against using plant twigs, which sometimes include Ficus species, for heart, eye, head, ear, throat, palate, and tongue diseases, indigestion, excessive vomiting, severe respiratory disorders, fever, facial palsy, mouth ulcers, and headaches [74].

Cleaning the tongue so hard it makes you vomit is also forbidden.Traditional use safety anecdotes are important, but the general conclusion that there is "no known adverse effect" is often based on long-term empirical observation rather than thorough contemporary toxicological studies, especially those on chronic toxicity, genotoxicity, or human clinical trials. Its hyperalgesic effects in male rats contradict its analgesic benefits in several studies. This emphasizes the necessity for robust and standardized scientific investigation to determine its safety profile and detect any adverse events or contraindications.

The protective effect against drug-induced liver damage suggests a complex drug-herb interaction profile that needs more exploration. Even if the product is safe in conventional conditions, extra toxicological research and human clinical trials are needed to ensure its safety for wider clinical usage.



5. Research gaps and future trends

Despite its widespread traditional use and promising preclinical results, *Ficus benghalensis* is understudied by modern scientific rigor, leaving several research gaps and opportunity for further investigation. Its pharmacological actions' mechanisms of action need further study. Numerous studies show biological impacts, but targets and molecular pathways are often unknown *F. Benghalensis* compounds usage for therapeutic purposes. In animal models, antidiabetic actions have showed promise, but further research is needed to determine the mechanisms. Understanding these pathways is crucial for rational drug development.

Moving *F. benghalensis* requires comprehensive toxicological assessments to establish a solid safety profile chemicals for testing. Pharmacokinetic studies are needed to understand the bioactive ingredients' absorption, distribution, metabolism, and excretion (ADME) profiles to determine doses and formulations. Acute toxicity studies show a high safety margin, but long-term, genotoxic, and reproductive toxicity research are scarce.

F. benghalensis needs human clinical trials to prove its medicinal potential.. Most pharmacological evidence comes from in vitro and in vivo animal models. To translate these promising preclinical discoveries into clinical applications, carefully prepared, randomized controlled trials must assess safety, efficacy, and optimal dosage in humans.

Given the heterogeneity in phytochemical composition due to plant age, regional origin, and extraction procedures, extract standardization protocols are necessary. Standardized extracts with consistent chemical profiles are necessary for repeatable research and trustworthy drugs. Nanotechnological research offers a novel way to solve natural component solubility and bioavailability issues. Bioassay-guided isolation and identification of new active chemicals should be the focus of future phytochemical research.

Increasing *F. benghalensis* therapeutic efficacy and medication availability,chemicals using nanoparticles and bioengineered patches may improve fungal infection treatments, where traditional drugs are resistant. Contemporary drug development and traditional thinking are reconciled by this strategy.

The species name is misspelled (Ficus bengalensis instead of Ficus benghalensis), making literature retrieval and analysis difficult. Thus, scientific databases should have high-quality content. Resolving these issues will improve research data reliability and accessibility.

6. Conclusion

The sacred Banyan tree, *Ficus benghalensis* Linn., symbolizes the wisdom of traditional Indian medicinal methods. Scientific evidence is supporting its vast ethnomedicinal history of using almost all plant components for a variety of diseases. Secondary metabolites such flavonoids, terpenoids, sterols, phenolics, alkaloids, and carbohydrates have been found in phytochemical studies. Its biological actions are supported by quercetin-3-galactoside, rutin, anthocyanidin derivatives, and new triterpenoids.

Preclinical pharmacological research suggests *F. benghalensis* is anti-inflammatory, anti-cancer, immunomodulatory, wound-healing, hepatoprotective, antidiabetic, and antioxidant. Its rich phytochemical composition's synergistic effects suggest a multi-target therapy approach that may be particularly effective in treating complex illnesses. Innovative methods for drug delivery and efficacy using environmentally friendly nanoparticle production illustrate its importance in modern biotechnology.

Even with these promising outcomes, research gaps remain. The molecular pathways behind many of its actions are unknown. To turn its preclinical potential into safe and effective pharmaceutical interventions, toxicological studies, pharmacokinetic profiles, and rigorous human clinical trials are needed. The fluctuation in phytochemical content due to extraction methods and environmental factors emphasizes the need for study and product development consistency.

In conclusion, *Ficus benghalensis* is a significant natural resource with great medicinal potential. Multidisciplinary research should include phytochemical analysis, mechanistic studies, toxicological assessments, and well-planned clinical trials. Cutting-edge medication delivery systems like nanotechnology could unlock its full therapeutic potential, allowing it to be integrated into evidence-based modern medicine and ensure its sustainable usage for world health.

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