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EXPLORING THE PHYTOCONSTITUENTS AND PHARMACOLOGICAL PROPERTIES OF *FICUS RACEMOSA* LINN

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ABSTRACT

Medicinal plants have long been used in traditional healthcare systems for the prevention and treatment of various diseases. *Ficus racemosa* Linn., commonly known as the cluster fig or gular and belonging to the family Moraceae, is widely distributed in India, Southeast Asia, and Australia. The plant holds an important place in traditional systems of medicine such as Ayurveda, Siddha, and Unani, where different parts including bark, leaves, fruits, roots, and latex are used to treat disorders such as diarrhea, diabetes, inflammation, skin diseases, and gastrointestinal problems. Phytochemical studies have revealed the presence of several bioactive constituents in *Ficus racemosa*, including flavonoids, tannins, sterols, triterpenoids, phenolic compounds, and glycosides. Important compounds such as β-sitosterol, lupeol, gallic acid, quercetin, rutin, and kaempferol contribute to its therapeutic potential. Various experimental studies have demonstrated that extracts of the plant possess diverse pharmacological activities, including antidiabetic, anti-inflammatory, antioxidant, hepatoprotective, antimicrobial, antiulcer, analgesic, and wound-healing effects.

KEYWORDS: Ficus racemosa, Phytochemicals, Pharmacological activities, Medicinal plants.

INTRODUCTION

Since ancient times, medicinal plants have played a vital role in the prevention and treatment of various diseases. Early civilizations mostly relied on natural remedies made from plants to stay healthy and treat different illnesses. Ancient texts such as the Vedas and the Bible also mention the healing properties of herbs, showing that plant-based medicines have been an important part of traditional healthcare systems for centuries.[1] Even today, medicinal plants continue to

play an important role in healthcare, especially in developing countries where many communities still rely on them as a primary source of treatment. According to the World Health Organization (WHO), nearly 80% of the global population relies on herbal medicines to meet their basic healthcare needs. The growing preference for natural products has also encouraged scientific research, leading to the development of many modern medicines that originate from medicinal plants.[2] Among the many medicinal plants utilized in traditional healthcare systems, species of the genus Ficus have gained significant attention because of their wide range of therapeutic properties. The genus Ficus, which belongs to the family Moraceae, includes approximately 750–850 species of woody trees, shrubs, epiphytes, and hemi-epiphytes that are widely distributed across tropical and subtropical regions of the world.[3,4,5] Species belonging to the genus Ficus are commonly referred to as fig trees, many of which produce edible fruits that provide an important source of nutrition for both humans and wildlife. Beyond their ecological importance, numerous Ficus species exhibit significant medicinal value and have been widely employed in traditional systems of medicine. In several cultures, fig trees are also considered sacred and hold an important place in religious traditions and cultural practices. Among the prominent members of this genus is *Ficus racemosa* Linn., popularly known as the cluster fig tree, country fig, or gular.[4,6]

Ficus racemosa is widely distributed across India, Southeast Asia, and parts of Australia, where it commonly grows in natural habitats such as forests, hilly regions, and along riverbanks. It is a medium-sized evergreen tree that typically attains a height of about 10–16 m and is characterized by a broad canopy and large, rough-textured leaves. One of the distinctive botanical features of *Ficus racemosa* is the formation of clusters of fruits directly on the trunk and older branches, a phenomenon referred to as cauliflory. Similar to many other members of the Moraceae family, the plant exudes a milky latex when its bark or leaves are injured. *Ficus racemosa* occupies a significant position in traditional Indian medical systems, including Ayurveda, Siddha, and Unani. In Ayurvedic literature, the plant is known by several Sanskrit names, most notably Udumbara, and is often regarded as a sacred tree associated with cultural and spiritual traditions in India. The bark of *Ficus racemosa* is also one of the five components of the classical Ayurvedic formulation Panchavalkala, which consists of the bark of five medicinal trees widely used in various therapeutic preparations.[4] Classical Ayurvedic literature authored by ancient scholars such as Charaka and Sushruta documents the therapeutic significance of *Ficus racemosa*. These traditional texts describe the plant as having several medicinal properties and recommend its use for treating a variety of ailments. According to Ayurvedic descriptions, *Ficus racemosa* exhibits astringent, anti-inflammatory, and wound-healing activities, and it has been traditionally employed in the management of conditions such as bleeding disorders, inflammatory diseases, and urinary complications.[7]

Traditionally, almost all parts of the plant, including the bark, leaves, fruits, roots, latex, and root sap, have been used in herbal medicine. The bark is commonly used as an astringent and is considered effective in the treatment of diarrhea, dysentery, and piles, while the fruits are regarded as nutritive and digestive agents.[8] The latex obtained from *Ficus racemosa* is traditionally applied externally for the treatment of wounds, various skin ailments, and inflammatory conditions. Furthermore, different parts of the plant have been used in traditional medicine for the management of several disorders, including jaundice, diabetes, biliary complications, respiratory diseases such as asthma, and a range of gastrointestinal problems.[9] Because of its wide range of therapeutic applications, *Ficus racemosa* has been extensively studied in recent years to explore its pharmacological potential. Phytochemical investigations have revealed that *Ficus racemosa* contains a variety of bioactive compounds, including flavonoids, tannins, sterols, alkaloids, glycosides, and phenolic compounds.[10] These phytochemicals are responsible for the plant's diverse pharmacological activities. For instance, beta-sitosterol, a steroidal compound present in the fruit extracts of *Ficus racemosa*, has been

reported to exhibit significant antidiabetic properties.[1] Flavonoids present in the plant exhibit significant antioxidant activity, which helps protect cells from oxidative stress and contributes to the regulation of various enzymatic and metabolic processes in the body.[11] The presence of these bioactive compounds also contributes to the plant's ability to protect against microbial infections and other pathological conditions. Several experimental and clinical studies have demonstrated that extracts obtained from different parts of *Ficus racemosa* exhibit a wide range of pharmacological activities, including antidiabetic, hepatoprotective, anti-inflammatory, antimicrobial, antioxidant, antitumor, cytotoxic, antipyretic, and antitussive effects.[12] Experimental studies have demonstrated notable antinociceptive activity in the ethanolic extracts obtained from the fruit and bark of the plant. In addition, research findings indicate that bark extracts of the plant can effectively lower blood glucose levels and help improve lipid and lipoprotein profiles under diabetic conditions.[13] These findings support the traditional use of the plant in the treatment of metabolic and inflammatory disorders.

MATERIALS AND METHODS

This study involved a comprehensive review of published literature. Data were collected from online scientific databases including Google Scholar, ResearchGate, ScienceDirect, PubMed, ChemSketch, and Springer Nature, along with resources from India Flora, World Flora, and standard botanical and pharmacological reference texts.

Taxonomy and identification

Morphological characteristics

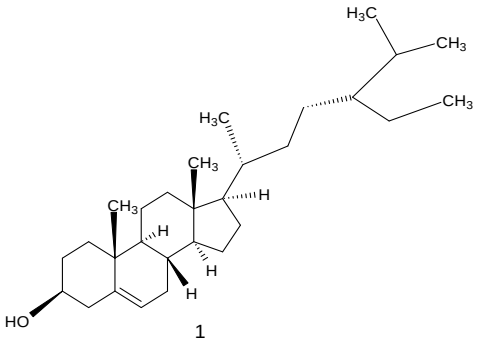
Ficus racemosa is a deciduous tree that can reach a height of 30 m. It has a buttressed bole, bark that is 8 to 10 mm thick, a surface that is smooth, coarsely flaky, and fibrous, a blaze that is creamy pink, and latex that is milky. All the morphological characteristics are represented in Table 1.[14]

Table 1: Morphological characteristics of *Ficus racemosa.*

S.No	Parts	Description	Shape	Size
1	Leaves	Simple and alternating arrangemen and thin, grooved petioles that range in length from 1 to 5cm	The Leaves have a smooth edge and can be ovate, obovate, elliptic -oblong, elliptic lanceolate	Leaf blades are usually 3.5-10com broad and 6-20cm long
2	Bark	The bark is soft,greyish green, coarsely flaking and may have fibrous fracture,0.5-1.8 cm thick	Soft and greyish green, flaking and fibrous at maturity	Bark is about 0.5-1.8 cm thick
3	Roots	Roots are long ,tan to brownish, irregular in shape and have distinct odoye with bitter taste	Long tan brownish, irregularly lobed	Varies depending on age and subastrate
4	Fruit(fig)	The fruit is green in starting and turns red when its ripen.it is soft and full of tiny seeds	Slightly flattened/round	3-5 cm
5	Seeds	Very small seeds are found inside the fruit pulp,present in large numbers	Very tiny/oval	1-2 mm
6	Latex	A sticky white liquid like sap, that comes outs when a branch or bark is injured	Thick liquid	Varies with injury
7	Syconia(fig cluster)	These unique fruit-like structure develop in clusters on the stem or close to the roots. Number of tiny flowers hidden inside them	Round	2-5 cm

Table 2: Chemical constituents of *Ficus racemosa.*

S. No.	Name of compound	Nature of compound	Molecular formula	Molecular weight g\mol	activity
1	β-Sitosterol	Sterol	C29H50O	414.71	Hypolipidemic, antidiabetic, anti-inflammatory[15]
2	Tigmasterol	Sterol	C29H48O	412.69	Anti-inflammatory, antioxidant[15]
3	Campesterol	Sterol	C28H48O	400.69	Hypocholesterolemic[16]
4	Cycloartenol	Sterol	C30H50O	426.72	Anti-inflammatory, membrane-stabilizing[16]
5	Lupeol	Triterpenoid	C30H50O	426.72	Anti-inflammatory, anticancer, hepatoprotective[17]
6	Taraxasterol	Triterpenoid	C30H50O	426.72	Anti-inflammatory, cytotoxic[17]
7	β-Amyrin acetate	Triterpenoid ester	C32H52O2	468.76	Anti-inflammatory[18]
8	Lupeol acetate	Triterpenoid ester	C32H52O2	468.76	Anti-inflammatory[18]
9	Gluanol (Glauanol) acetate	Triterpenoid ester	C32H52O2 (reported)	468.76	Antioxidant, antimicrobial[15]
10	Taraxerone / taraxerol esters	Triterpenoid	C30H48O	440.71	Anti-inflammatory[19]
11	Friedelin	Triterpenoid ketone	C30H50O	426.72	Antioxidant, anti-ulcer[15]
12	Gallic acid	Phenolic acid	C7H6O5	170.12	Strong antioxidant, anticancer[20,21]
13	Ellagic acid	Phenolic/tannin component	C14H6O8	302.19	Antioxidant, anticancer, hepatoprotective[22]
14	Protocatechuic acid	Phenolic acid	C7H6O4	154.12	Antioxidant, anti-inflammatory[23,24,25]
15	Tannic acid (tannins)	Hydrolysable tannin mixture	C76H52O46	1701	Astringent, antioxidant, antimicrobial[24]
16	Quercetin	Flavonol	C15H10O7	302.24	Antioxidant, anti-inflammatory, cardioprotective[26,27]
17	Kaempferol	Flavonol	C15H10O6	286.24	Antioxidant, anticancer[28]
18	Rutin (quercetin-3-rutinoside)	Flavonol	C27H30O16	610.52	Antioxidant, vasoprotective[1,29]
19	Myricetin	Flavonol	C15H10O8	318.24	Antioxidant, anti-inflammatory[30]
20	Leucocyanidin-3-O-β-D-glucopyranoside	Flavan-3-ol glycoside	C21H24O11	452.41	Antioxidant[31]
21	Euphol	Triterpenoid alcohol	C30H50O	426.72	Anti-inflammatory, antiviral[15]
22	Isoeuphorbol	Triterpenoid alcohol	C30H50O	426.72	Irritant, tumor-promoting (general phorbol class)[15]
23	4-Deoxyphorbol derivatives	Diterpenoid esters	C20H28O5 (core)	~348+	Strong irritant, pro-inflammatory, tumor-promoting[32]
24	Psoralen	Furanocoumarin	C11H6O3	186.16	Photosensitizer, anti-psoriatic[33,34]
25	Bergapten (5-methoxypsoralen)	Furanocoumarin	C12H8O4	216.19	Photosensitizer, anti-inflammatory[1,35]
26	Ficusin (reported coumarin)	Coumarin derivative	~C11–12 skeleton (varies)	–	Antimicrobial, anti-inflammatory (reported)[1,36]
27	Coumarin (simple coumarin)	Benzopyrone	C9H6O2	146.14	Anticoagulant precursor, fragrance[15]



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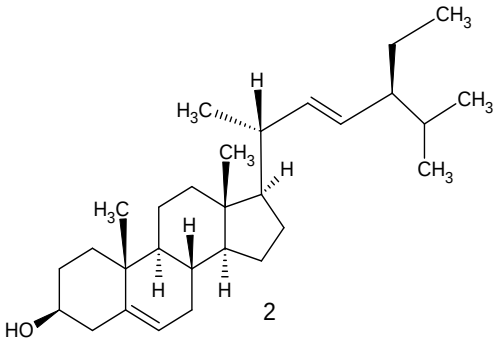

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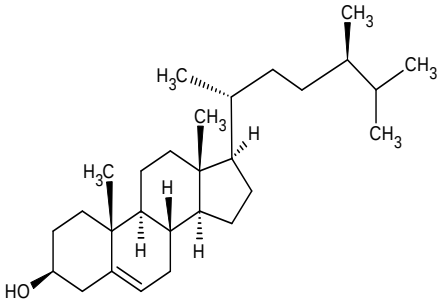

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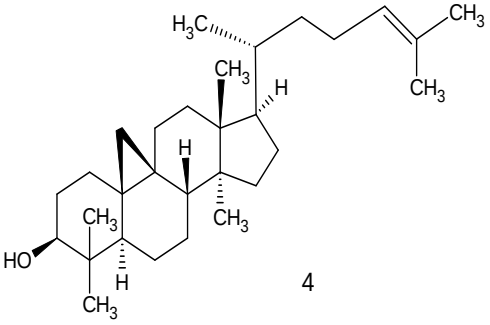

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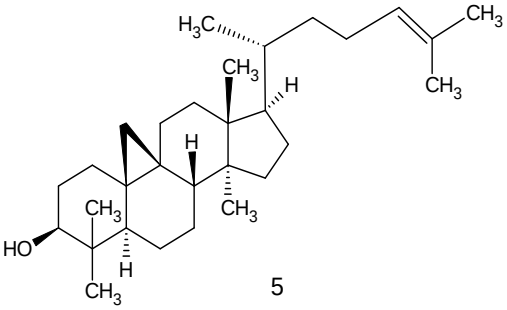

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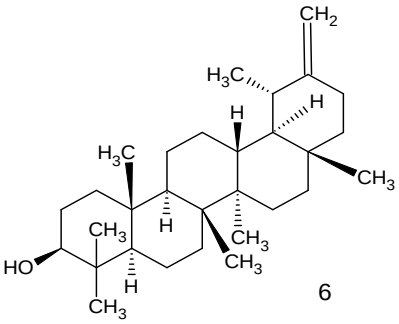

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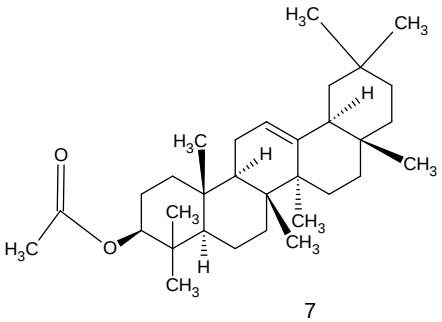

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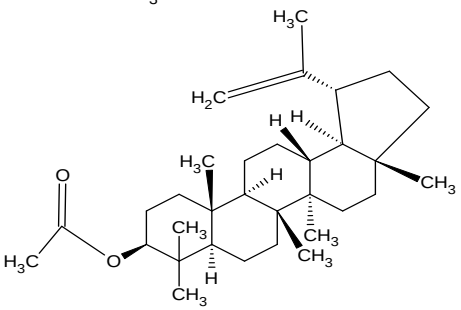

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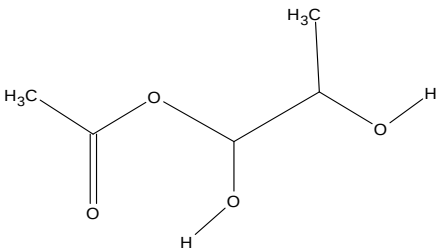

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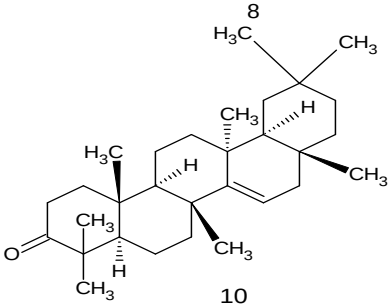

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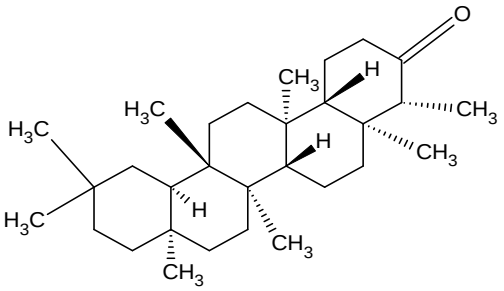

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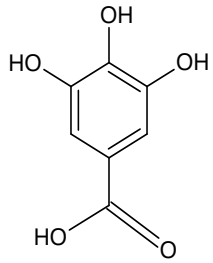

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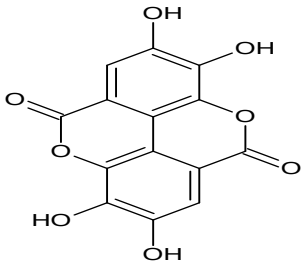

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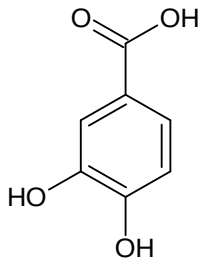

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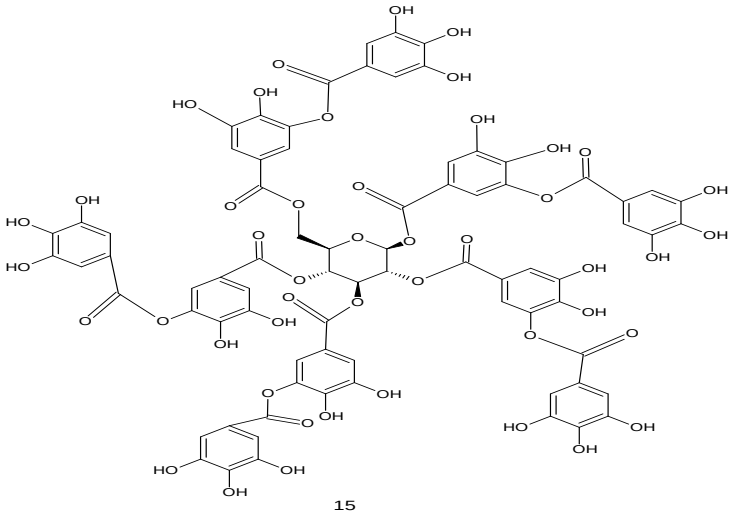

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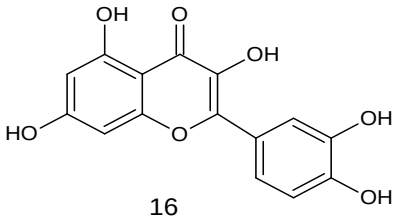

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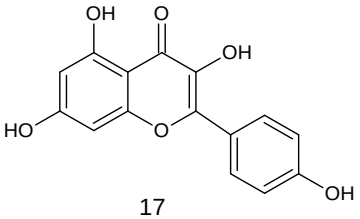

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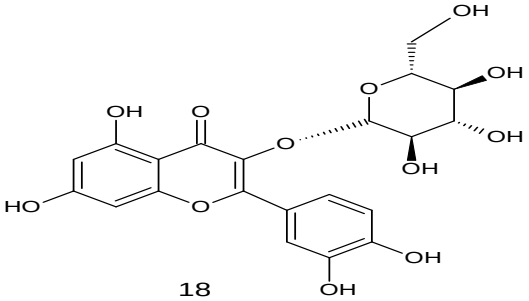

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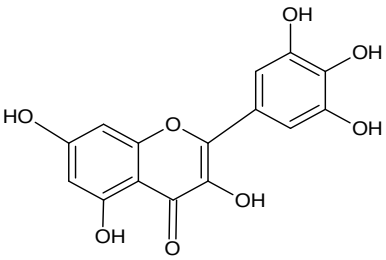

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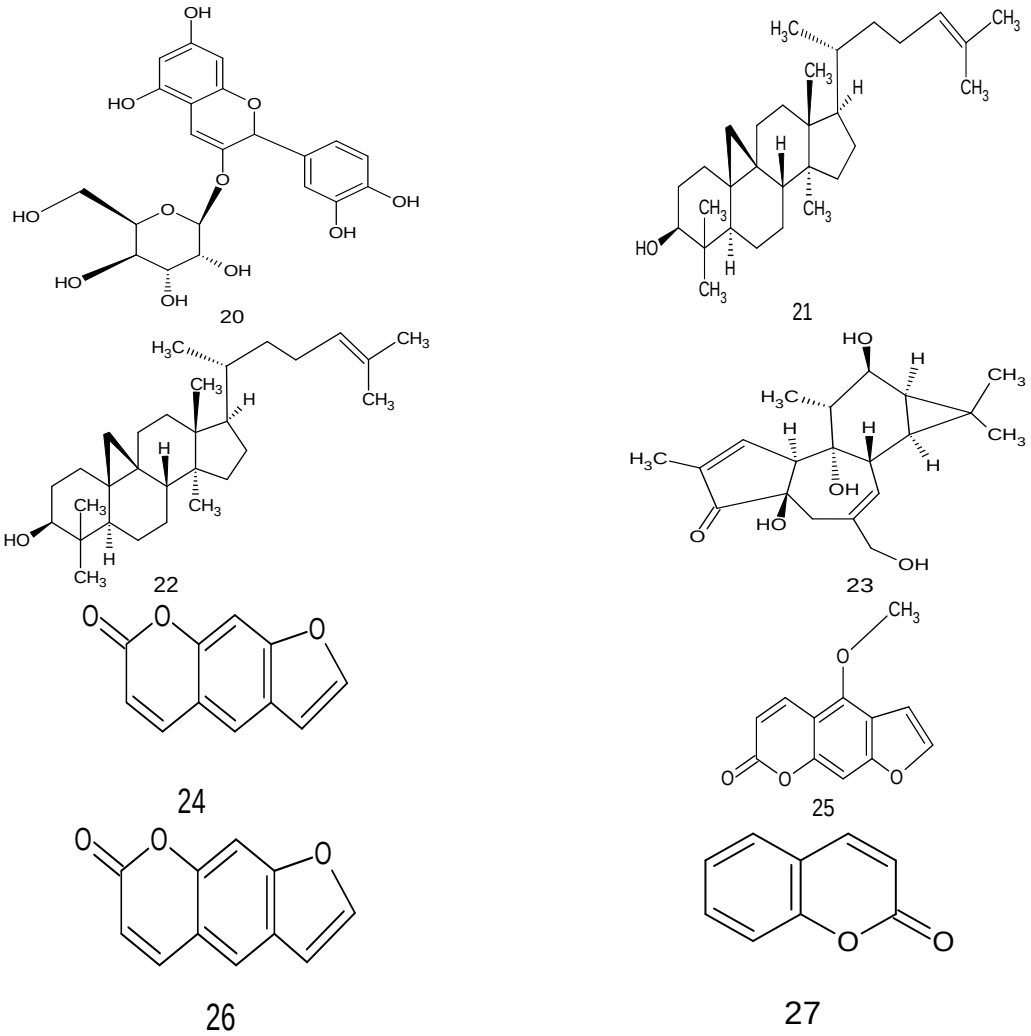

Fig. 1: Structure of chemical constituents of *Ficus racemosa.*

Phytoconstituents of *Ficus racemosa*

β-Sitosterol

β-Sitosterol is a major phytosterol commonly found in a wide range of medicinal plants and vegetables, with the molecular formula $C_{29}H_{50}O$ and a molecular weight of 414.71 g/mol. It belongs to the sterol class of phytoconstituents and has been extensively studied for its pharmacological activities. Experimental and clinical investigations have demonstrated that β-sitosterol exerts significant hypolipidemic effects, helping to lower cholesterol levels, and exhibits potent antidiabetic activity by improving insulin sensitivity and modulating glucose metabolism pathways in diabetic models. It also shows notable anti-inflammatory properties, including the ability to attenuate proinflammatory cytokine expression via modulation of signaling pathways linked to metabolic disorders. These biological activities suggest that β-sitosterol contributes substantively to the therapeutic efficacy of medicinal plants in which it is present and may serve as a promising natural agent for managing metabolic disease.[37]

Tigmasterol

Stigmasterol is a sterol with the molecular formula $C_{29}H_{48}O$ and a molecular weight of 412.69. It exhibits anti-inflammatory and antioxidant properties.[38,39]

Campesterol

Campesterol is a plant sterol with the molecular formula $C_{28}H_{48}O$ and a molecular weight of 400.69. It is considered hypocholesterolemic because it belongs to a class of phytosterols that competitively reduce intestinal cholesterol absorption and lower plasma low-density lipoprotein (LDL) cholesterol levels, contributing to cholesterol management when consumed as part of the diet or in enriched foods.[40]

Cycloartenol

Cycloartenol is a plant sterol with the molecular formula $C_{30}H_{50}O$ and a molecular weight of 426.72. It has been reported to exhibit anti-inflammatory effects and serves as a pharmacologically active phytosterol with multiple bioactivities, and studies have additionally investigated sterols like cycloartenol for their influence on membrane properties in artificial and biological systems.[36,41]

Lupeol

Lupeol is a triterpenoid with the molecular formula $C_{30}H_{50}O$ and a molecular weight of 426.72. It has been reported to exhibit anti-inflammatory, anticancer, and hepatoprotective activities in various experimental studies.[42]

Taraxasterol

Taraxasterol is a triterpenoid with the molecular formula $C_{30}H_{50}O$ and a molecular weight of 426.72. It has been reported to exhibit anti-inflammatory activity by inhibiting pro-inflammatory mediators such as nitric oxide, prostaglandin E_2, tumor necrosis factor-α and interleukins via suppression of NF-κB signaling in LPS-stimulated macrophages and attenuating inflammatory signs in animal models, and it also demonstrates cytotoxic effects against certain tumor cell types by inhibiting proliferation and inducing apoptosis in vitro.[43,44]

β Amyrin acetate

β-Amyrin acetate is a triterpenoid ester with the molecular formula $C_{32}H_{52}O_2$ and a molecular weight of 468.76. It has been reported to exhibit anti-inflammatory activity, including inhibition of inflammatory mediators and reduction of edema formation in experimental models, supporting its traditional use in inflammatory conditions.[45]

Lupeol acetate

Lupeol acetate is a triterpenoid ester with the molecular formula $C_{32}H_{52}O_2$ and a molecular weight of 468.76. Experimental investigations have demonstrated that this compound exerts notable anti-inflammatory effects, particularly through the reduction of edema formation and suppression of inflammatory responses in animal models, highlighting its pharmacological relevance as a bioactive natural product.[46]

Gluanol (Glauanol) acetate

Gluanol acetate (also reported as Glauanol acetate) is a triterpenoid ester with the molecular formula $C_{32}H_{52}O_2$ (reported) and a molecular weight of 468.76. Phytochemical investigations have described this compound as possessing notable antioxidant activity, demonstrated through free-radical scavenging assays, along with antimicrobial effects against selected bacterial and fungal strains, supporting its relevance as a bioactive natural product of pharmacological interest.[26]

Taraxerone / taraxerol esters

Taraxerone, a pentacyclic triterpenoid ketone (also referred to in contexts with taraxerol esters), has the molecular formula C30H48O and a molecular weight of 424.7 g/mol. It is found in various plants, including those related to Ficus species in phytochemical studies. Taraxerone demonstrates anti-inflammatory activity, as evidenced by its presence in active fractions from plant extracts that inhibit carrageenan-induced paw edema in mice, with additive effects alongside compounds like hopenone B and lupenone. A 2019 study in Drug Discovery reported its isolation from Tabebuia hypoleuca stems, where mixtures containing taraxerone contributed to 21-56% edema inhibition at doses around 6-50 mg/kg equivalents.[26,47]

Friedelin

Friedelin is a pentacyclic triterpenoid ketone isolated from the fruits of *Ficus racemosa*, with the molecular formula C30H50O and a molecular weight of 426.72 g/mol. It contributes to the antioxidant properties observed in *F. racemosa* extracts, such as stem bark ethanol extracts that exhibit potent free radical scavenging in pulse radiolysis assays. Friedelin also supports the plant's anti-ulcer activity, as fruit extracts (50% ethanol) demonstrate dose-dependent protection against ethanol-, pylorus ligation-, and cold stress-induced gastric ulcers in rats by reducing oxidative damage and inhibiting H+/K+ ATPase.[15]

Gallic acid

Gallic acid is a naturally occurring phenolic acid with the molecular formula C7H6O5 and a molecular weight of 170.12 g/mol. It serves as a potent antioxidant by scavenging free radicals and chelating metal ions, thereby mitigating oxidative stress in various biological systems. Additionally, gallic acid exhibits strong anticancer effects through mechanisms such as induction of apoptosis via reactive oxygen species generation, cell cycle arrest at G0/G1 phase, and inhibition of matrix metalloproteinases that suppress tumor invasion and metastasis, as demonstrated in studies on multiple cancer cell lines including HeLa and HepG2.[20,21]

Ellagic acid

Ellagic acid is a naturally occurring phenolic compound and tannin derivative with the molecular formula C14H6O8 and a molecular weight of 302.19 g/mol. Found in various fruits, nuts, and plants, it acts as a strong antioxidant by scavenging free radicals and chelating metal ions, thereby reducing oxidative stress. It exhibits anticancer properties through mechanisms like apoptosis induction, cell cycle arrest, and inhibition of tumor proliferation, while also providing hepatoprotective effects by mitigating liver damage from toxins via modulation of inflammatory pathways and antioxidant enzyme enhancement.[22]

Protocatechuic acid

Protocatechuic acid is a phenolic acid with the molecular formula C7H6O4 and a molecular weight of 154.12 g/mol, identified among the phytochemical constituents in *Ficus racemosa* alongside compounds like ursolic acid and maslinic acid. In *F. racemosa*, it contributes to the plant's strong antioxidant effects through free radical scavenging, as observed in methanol extracts of leaves and fruits that showed significant DPPH inhibition comparable to ascorbic acid. It also supports anti-inflammatory properties, likely aiding in the modulation of oxidative stress and inflammatory pathways in extracts exhibiting potent reducing power and lipid peroxidation inhibition.[23,24,25]

Tannic acid (tannins)

Tannic acid, commonly referred to as tannins, is a mixture of hydrolyzable tannins with an approximate molecular formula of C76H52O46 and a molecular weight of 1701 g/mol. In *Ficus racemosa*, tannins are abundant in methanol extracts of leaves and fruits, contributing to the plant's astringent properties used traditionally for wound healing and anti-diarrheal effects. These compounds exhibit strong antioxidant activity by scavenging DPPH, superoxide, hydroxyl, and hydrogen peroxide radicals, as shown in leaf and fruit extracts with significant total tannin content (19.72–21.39 mg GAE/g). Tannins also confer antimicrobial effects, with *F. racemosa* fruit methanol extracts inhibiting pathogens like E. coli and Staphylococcus spp. due to tannin presence alongside phenols.[24]

Quercetin

Quercetin is a flavonol with the molecular formula C15H10O7 and a molecular weight of 302.24 g/mol. It is present in *Ficus racemosa* extracts, contributing to the plant's rich polyphenolic profile alongside gallic acid and flavonoids detected via HPLC in methanol leaf and fruit extracts. Quercetin exhibits potent antioxidant activity by scavenging DPPH, superoxide, hydroxyl, and hydrogen peroxide radicals, as observed in *F. racemosa* methanol extracts with IC50 values comparable to ascorbic acid. It also provides anti-inflammatory effects through inhibition of pathways like NF-κB and cardioprotective benefits by improving endothelial function, reducing oxidative stress, and modulating lipid metabolism, supporting *F. racemosa*'s traditional uses in cardiovascular health.[26,27]

Kaempferol

Kaempferol is a flavonol with the molecular formula C15H10O6 and a molecular weight of 286.24 g/mol. Present in the bark of *Ficus racemosa* alongside racemosic acid and tannins, it contributes to the plant's antioxidant activity through free radical scavenging mechanisms observed in various extracts. Kaempferol also exhibits anticancer properties by inducing apoptosis and inhibiting tumor cell proliferation.[28]

Rutin (quercetin 3 rutinoside

Rutin (quercetin-3-rutinoside) is a flavonol with the molecular formula C27H30O16 and a molecular weight of 610.52 g/mol. Identified in the stem bark of *Ficus racemosa* alongside racemosic acid, bergenin, kaempferol, and tannins, it contributes to the plant's antioxidant activity through free radical scavenging observed in various extracts. Rutin also provides vasoprotective effects by strengthening capillaries and reducing vascular permeability, supporting *F. racemosa*'s traditional uses in circulatory health.[1,29]

Myricetin

Myricetin is a flavonol with the molecular formula $C_{15}H_{10}O_8$ and a molecular weight of 318.24. It is recognized for its strong antioxidant activity due to its multiple hydroxyl groups that enable effective free-radical scavenging, and it also exhibits anti-inflammatory effects through modulation of inflammatory mediators. Myricetin has been reported as one of the flavonoid constituents present in *Ficus racemosa*, contributing to the plant's antioxidant and anti-inflammatory properties.[30]

Leucocyanidin 3-O-β-D glucopyranoside

Leucocyanidin 3-O-β-D-glucopyranoside is a flavan-3-ol glycoside with the molecular formula $C_{21}H_{24}O_{11}$ and a molecular weight of 452.41. It is reported to possess antioxidant activity owing to its phenolic structure, which

contributes to free-radical scavenging potential. This compound has been identified among the polyphenolic constituents of *Ficus racemosa*, supporting the plant's documented antioxidant properties.[31]

Euphol

Euphol is a triterpenoid alcohol with the molecular formula $C_{30}H_{50}O$ and a molecular weight of 426.72. Pharmacological studies describe euphol as a bioactive triterpene exhibiting marked anti-inflammatory activity through modulation of inflammatory mediators and signaling pathways, and it has also demonstrated antiviral potential in experimental models.[15]

Isoeuphorbol

Isoeuphorbol is a triterpenoid alcohol with the molecular formula $C_{30}H_{50}O$ and a molecular weight of 426.72. It belongs to the broader class of phorbol-related triterpenoid constituents, compounds that are generally recognized for their irritant properties and tumor-promoting activity in experimental models through activation of protein kinase C pathways. Isoeuphorbol has been reported among the triterpenoid constituents identified in *Ficus racemosa*, as documented in phytochemical investigations of the plant.[15]

4-Deoxyphorbol derivatives

4-Deoxyphorbol derivatives are diterpenoid esters with a core structure approximated as C20H28O5 and molecular weights around 348 or higher. These compounds have been identified in the bark latex of *Ficus racemosa* alongside euphorbinol, β-sitosterol, and other terpenoids. Known for their strong irritant, pro-inflammatory, and tumor-promoting activities due to activation of protein kinase C pathways, they represent a class of phorbol-related toxins present in this plant species. This phytochemical profile is documented in comprehensive reviews of *F. racemosa* constituents, such as those compiling latex components from traditional and analytical studies.[32]

Psoralen

Psoralen is a furanocoumarin with the molecular formula C11H6O3 and a molecular weight of 186.16 g/mol. Identified in leaf extracts of *Ficus racemosa*, it acts as a photosensitizer that intercalates with DNA upon UVA exposure, used therapeutically for anti-psoriatic effects by targeting hyperproliferative skin cells. In *F. racemosa*, psoralen contributes to antifungal activity against pathogens like Curvularia sp. and Colletotrichum gloeosporioides, as isolated from methylene chloride-hexane fractions showing growth inhibition.[33,34]

Bergapten (5-methoxypsoralen)

Bergapten (5-methoxypsoralen) is a furanocoumarin with the molecular formula C12H8O4 and a molecular weight of 216.19 g/mol. Found in the stem bark and leaves of *Ficus racemosa* alongside psoralenes and other coumarins, it acts as a photosensitizer that binds to DNA under UVA light, contributing to therapeutic applications. Bergapten exhibits anti-inflammatory effects by inhibiting pro-inflammatory mediators.[1,48]

Ficusin (reported coumarin)

Ficusin is a reported coumarin derivative from *Ficus racemosa*, characterized by a C11–12 carbon skeleton. Isolated from the stem bark alongside racemosic acid, bergenin, tannin, kaempferol, rutin, bergapten, and phenolic glycosides, it contributes to the plant's antimicrobial activity against bacteria like Staphylococcus aureus. Ficusin also supports anti-inflammatory effects in extracts used traditionally for wounds and inflammation.[1,32]

Coumarin (simple coumarin)

Coumarin (simple coumarin) is a benzopyrone with the molecular formula C9H6O2 and a molecular weight of 146.14 g/mol. Extracted from the stem bark of *Ficus racemosa* using hot water methods alongside bergenin and kaempferol, it serves as an anticoagulant precursor by inhibiting vitamin K-dependent clotting factors. Coumarin also contributes fragrance notes to the plant and supports antimicrobial properties observed in bark extracts.[15]

Table 3: Pharmacological activity.

S. No.	Activity	Extract Type	Doses	Model	Key Outcome
1	Antidiuretic activity	Bark extract	250, 500, 1000 mg/kg	---	It began quickly within one hour, peaked after three hours, persisted for 5 hours, urine sodium ion level decreased, sodium/ potassium ratio decreased, urinary osmolality increased[49]
2	Renal anti-carcinogenic activity	*Ficus racemosa* extract	200 and 400 mg/kg	Potassium bromate (KBrO3) induced nephrotoxicity in rats	Lipid peroxidation decreased, xanthine oxidase decreased, gamma-glutamyl transpeptidase decreased, hydrogen peroxide generation decreased, renal glutathione content decreased by potassium bromate improved, antioxidant enzymes improved, augmentation of DNA synthesis reversed, blood urea nitrogen reversed, serum creatinine reversed, renal ornithine decarboxylase activity reversed.
3	Hepatoprotective activity	Methanol extract of the stem bark	----	Carbon tetrachloride (CCl4) induced hepatotoxicity in rats.	Aspartate aminotransferase increased by CCl4 reversed, alanine aminotransferase increased by CCl4 reversed, alkaline phosphatase increased by CCl4 reversed, total bilirubin decreased, hepatoprotective effect observed
4	Anthelmintic activity	Aqueous bark extract	50 mg/mL		Spontaneous motility (paralysis), no recovery seen with extract, worms recovered with piperazine citrate[15]
5	Hypotensive activity	Glycoside -rich fract ion of leaf extract		Dogs, isolated frog heart, isolated rabbit heart	Notable hypotensive and vasodilator effect, direct cardiac depressing effect, no change in behavioral activity, no acute toxic effect[50,51]
6	Antifertility **activity**	50% ethanolic bark extract	200 and 400 mg/kg	Proven fertile rats	Significant anovulatory activity, no significant changes in uterus structure when given alone, significant anti-estrogenic activity when given with ethinylestradiol[52,53]
7	Antifungal activity	50% methylene chloride in hexane leaf extract fraction	----	In vitro antifungal model	Psoralen identified as active compound, shown to be biodegradable, potential fungicide against crop pathogens[54,55,56]
8	Hypoglycemic activity	Ethanol extract, isolated beta-sitosterol	250 mg/kg/day	Alloxan-diabetic albino rats	Blood glucose level lowered within two weeks, beta-sitosterol showed potent hypoglycemic activity[57,58,59]
9	Anti-inflammatory activity	Ethanol extract of leaves; ethanol extract of stem bark	400 mg/kg; 100 mg/mL IC50	Carrageenan-induced rat paw edema, serotonin, histamine, dextran-induced models	Maximum anti-inflammatory effect (30.4%, 32.2%, 33.9%, 32%), cyclooxygenase-1 inhibited[60,61,62]

10	Antioxidant activity	Ethanol and water stem bark extract	—	Nanosecond pulse radiolysis, stopped-flow spectrophotometry, micronucleus assay in V79 cells	Potent free radical scavenging activity, ethanol extract showed higher antioxidant activity, radioprotective potential observed[15,25,63]
11	Antiulcer activity	50% ethanolic fruit extract	50, 100, 200 mg/kg twice daily	Ethanol-induced ulcer, pylorus ligation model, cold strain-induced ulcer	Ulcer inhibited in dose-dependent manner, reduced oxidative damage, inhibition of hydrogen/potassium ATPase enzyme and superoxide dismutase[64,65,66]
12	Gastro protective activity	50% ethanolic extract	50, 100, 200 mg/kg twice daily for 5 days	Ethanol-induced ulcers, cold-restraint stress ulcer	Significant gastroprotective activity, gastric defense factors involvement, phenolic constituents responsible[67,68,69]
13	Antimicrobial activity	Methanol extract, chloroform extract	1 mg/100 µL	Agar well diffusion method, MIC assay	*Ficus racemosa* inhibited Salmonella typhi; presence of alkaloids, tannins, saponins, flavonoids[70]
14	Anti-obesity activity	n-hexane and ethyl acetate extract	100, 500, 1000, 1500 mg/kg	Mouse anti-obesity model	Extract caused weight loss; optimal dose was 1500 mg/kg[71]
15	Wound healing activity	Ethanolic leaf extract purified fraction	—	Excision wound model in Wistar albino rats	Complete wound healing: 84.36% on day 17 with mupirocin, 81.30% on day 18 with extract[72]
16	Antipyretic activity	Methanol extract of stem bark	100, 200, 300 mg/kg	Yeast-induced pyrexia in rats	Significant dose-dependent reduction in body temperature up to 5 hours[73]
17	Antitussive activity	Methanol bark extract	200 mg/kg	Sulfur dioxide-induced cough in mice	Significant antitussive activity comparable to codeine phosphate; maximum activity at 90 minutes[74]
18	Antifilarial activity	Alcoholic and aqueous fruit extracts	50–350 µg/mL	Setaria cervi whole worm and nerve-muscle preparation	Inhibition of spontaneous motility, death of microfilariae; lethal concentration 50% = 21–27 ng/mL[72]
19	Chemo-preventive activity	*Ficus racemosa* extract	200 and 400 mg/kg	Fe-NTA induced chemotoxicity; potassium bromate-induced nephrotoxicity	Decrease in gamma-glutamyl transpeptidase, lipid peroxidation, xanthine oxidase, hydrogen peroxide generation, blood urea nitrogen, serum creatinine; recovery of glutathione and antioxidant enzymes; reversal of ornithine decarboxylase activity and DNA synthesis[15,75]
20	Hypolipidemic activity	Ethanolic bark extract; dietary fiber of fruit	100–500 mg/kg	Alloxan-induced diabetic rats; dietary fiber model	Hypocholesterolemic effect; increased excretion of cholesterol and bile acids; beta-sitosterol is responsible[76]
21	Analgesic activity	Ethanol extract of bark and leaves; decoction; petroleum ether extract	300 mg/kg	Hot plate, tail immersion, acetic acid writhing test, carrageenan-induced paw edema	Increased latency time, decreased writhes, analgesic effect due to friedelin, behenate, bergenin, lupeol, lupeol acetate; anti-edemic effect[15,76]
22	Toxicity studies	Ethanol, water, hydroalcoholic, methanol, petroleum ether extracts	up to 3.2 g/kg, up to 5 g/kg	Human skin fibroblasts, human hepatocyte carcinoma, human promyelocytic leukemia, brine shrimp lethality, mice acute toxicity	IC50 values are low but less toxic than aspirin and mercuric chloride; LC50 = 850 µg/mL; safe at high doses, no mortality or behavioral change[75,76]
23	Anti-diarrheal activity	Ethanolic extract of leaves of ficus racemose, bark also	400mg\kg-600mg\kg	Castor oil induced diarrhea,PGE2 induced	Decrease in fecal output and frequency of droppings, decrease in intestinal motility, decrease in

		used in some studies		entropooling, Gastrointestinal motility (charcoal meal test)	entropolling (fluid builds up) in PGE2 induced model[15]

Pharmacological activity of *Ficus racemosa*

Antidiuretic activity

The bark extract exhibited significant antidiuretic activity in a dose-dependent manner at doses of 250,500, and 1000 mg/kg.[49] This effect commenced rapidly, within one hour of administration, reached its peak effectiveness after three hours, and was sustained for up to five hours.[49] Concurrently, there was a measurable decrease in urinary sodium ion levels and a reduction in the urinary sodium-to-potassium ratio.[49] Furthermore, the urinary osmolality was observed to increase.[49]

Renal anti-carcinogenic activity

Studies have reported the renal anti-carcinogenic potential of *Ficus racemosa* extract at doses of 200 and 400 mg/kg in experimental models. The extract was evaluated against potassium bromate ($KBrO_3$)-induced nephrotoxicity in rats. Treatment with the extract significantly reduced lipid peroxidation, xanthine oxidase activity, gamma-glutamyl transpeptidase activity, and hydrogen peroxide generation. Potassium bromate–induced depletion of renal glutathione content was improved following extract administration. In addition, antioxidant enzyme levels were restored. The extract also reversed the augmentation of DNA synthesis, reduced elevated blood urea nitrogen and serum creatinine levels, and normalized renal ornithine decarboxylase activity. These findings suggest that *Ficus racemosa* possesses protective and potential anti-carcinogenic effects against chemically induced renal damage, mainly through its antioxidant and nephroprotective properties.

Hepatoprotective activity

The methanol extract of the stem bark of *Ficus racemosa* has been shown to exhibit significant hepatoprotective activity against carbon tetrachloride (CCl_4)-induced liver damage in experimental rat models. In CCl_4-treated animals, serum levels of liver function enzymes such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) were markedly elevated, indicating hepatic injury. Pretreatment with the methanol stem bark extract effectively reversed these elevated enzyme levels and also reduced total bilirubin concentrations, which were increased due to CCl_4 intoxication. These biochemical improvements reflect the ability of the extract to protect hepatocytes from toxic insult and restore normal liver function. Histopathological observations further confirmed the protective effect of the extract on liver tissue structure. Overall, these findings suggest that *Ficus racemosa* stem bark methanol extract possesses potent hepatoprotective properties, likely mediated through antioxidant and membrane-stabilizing mechanisms.[2]

Anti-helmintic activity

The aqueous bark extract demonstrated notable anthelmintic activity in in-vitro assays using adult earthworms. At a concentration of 50 mg/mL, the extract caused spontaneous paralysis of the worms, and no recovery was observed after treatment. In contrast, worms treated with the standard drug piperazine citrate exhibited paralysis but regained motility within five hours, highlighting the stronger or sustained immobilizing effect of the bark extract. These results indicate that the aqueous bark extract has a significant anthelmintic effect, likely through mechanisms that inhibit spontaneous motility and lead to sustained paralysis.[15]

Hypotensive activity

The glycoside-rich fraction of the leaf extract showed notable hypotensive and vasodilator effects in dogs, along with a direct cardiac-depressant effect in isolated frog and rabbit heart preparations, without any change in behavioral activity or acute toxic effects.[50,51]

Anti-fertility activity

The 50% ethanolic bark extract, administered at doses of 200 and 400 mg/kg to proven-fertile female rats, produced significant antifertility effects characterized by marked anovulatory activity and a significant anti-estrogenic effect when co-administered with ethinylestradiol, while no significant alterations in uterine structure were observed when the extract was given alone.[52,53]

Antifungal activity

The 50% methylene chloride-in-hexane leaf extract fraction exhibited significant antifungal activity in an in vitro antifungal model, with psoralen identified as the principal active compound; psoralen was shown to be biodegradable and to possess potential as a fungicide against a range of crop pathogens.[54,55,56]

Hypoglycemic activity

The ethanol extract containing isolated beta-sitosterol, administered at a dose of 250 mg/kg/day to alloxan-diabetic albino rats, produced a significant hypoglycemic effect, with blood glucose levels markedly lowered within two weeks of treatment, indicating that beta-sitosterol possesses potent hypoglycemic activity.[57,58,59]

Anti-inflammatory activity

The ethanol extract of leaves and stem bark of *Ficus racemosa* (dose 400 mg/kg orally, with an IC_{50} of 100 mg/mL in vitro) showed significant anti-inflammatory activity in carrageenan-, serotonin-, histamine-, and dextran-induced rat paw edema models, producing maximum edema inhibition of 30.4%, 32.2%, 33.9%, and 32.0%, respectively at the end of 3 hours; the extract also exhibited cyclooxygenase-1 (COX-1) inhibition, indicating a prostaglandin-mediated mechanism for its anti-inflammatory effect.[60,61,62]

Antioxidant activity

The ethanol and water stem bark extracts of *Ficus racemosa* were evaluated for antioxidant activity using nanosecond pulse radiolysis, stopped-flow spectrophotometry, and a micronucleus assay in V79 cells, and demonstrated potent free radical scavenging activity, with the ethanol extract showing significantly higher antioxidant capacity than the aqueous extract; the ethanol extract also exhibited a concentration-dependent radioprotective effect against radiation-induced micronuclei, indicating its potential as a natural radioprotector.[15,25,63]

Antiulcer activity

The 50% ethanolic fruit extract of *Ficus racemosa*, administered at doses of 50, 100, and 200 mg/kg twice daily, exhibited significant antiulcer activity against ethanol-induced, pylorus ligation-induced, and cold-restraint-induced gastric ulcer models in rats, with ulcer inhibition occurring in a dose-dependent manner; the extract also reduced oxidative damage and inhibited key enzymes such as hydrogen/potassium ATPase and superoxide dismutase, indicating a combined cytoprotective, antioxidant, and acid-suppressive mechanism of action.[64,65,66]

Gastroprotective activity

The 50% ethanolic extract of *Ficus racemosa* (syn. F. glomerata) fruit, administered orally at doses of 50, 100, and 200 mg/kg body weight twice daily for 5 days, exhibits significant gastroprotective activity against ethanol-induced gastric ulcers and cold-restraint stress (CRS)-induced ulcers in rat models. This effect is dose-dependent, reducing ulcer index through enhanced gastric defense factors such as increased gastric wall mucus and inhibition of H+/K+-ATPase (proton pump) activity in the ethanol model, alongside modulation of oxidative stress in CRS via boosted catalase levels, reduced superoxide dismutase, and blocked lipid peroxidation. Phenolic constituents like gallic acid (0.57% w/w) and ellagic acid (0.36% w/w), identified by HPTLC, are primarily responsible for these antioxidant and cytoprotective mechanisms, aligning with the plant's traditional use in herbal ulcer therapy.[67,68,69]

Antimicrobial activity

The methanol and chloroform extracts of *Ficus racemosa*, prepared at a concentration of 1 mg/100 µL, demonstrated notable antimicrobial activity against Salmonella typhi using the agar well diffusion method and MIC assay. These extracts effectively inhibited the growth of Salmonella typhi, with the methanol extract showing a particularly strong zone of inhibition (up to 20 mm). This activity is attributed to the presence of bioactive phytochemicals such as alkaloids, tannins, saponins, and flavonoids, which are known to disrupt bacterial cell membranes and inhibit pathogen proliferation in F. racemose.[70]

Anti-obesity activity

The n-hexane and ethyl acetate extracts of *Ficus racemosa* bark were evaluated for anti-obesity effects in a mouse model using oral doses of 100, 500, 1000, and 1500 mg/kg body weight. These extracts induced significant weight loss in obese mice, with the optimal dose identified at 1500 mg/kg, where the n-hexane extract reduced body weight by 0.33% and the ethyl acetate extract by 1.38% compared to controls. This activity aligns with the plant's rich profile of terpenoids and steroids, which contribute to its therapeutic potential, as further supported by isolation of bioactive compounds like β-amyrin acetate, showing 2.31% weight reduction at the same dose.[71]

Wound healing activity

In the excision wound model using Wistar albino rats, the purified fraction of the ethanolic leaf extract demonstrated notable wound healing activity. Complete wound healing reached 84.36% by day 17 with mupirocin as the standard treatment, while the extract achieved 81.30% healing by day 18, outperforming the control group's 62.22% on day 24. This indicates the extract's efficacy approaches that of the reference antibiotic ointment in promoting wound contraction and epithelialization.[72]

Antipyretic activity

The methanol extract of stem bark, administered at doses of 100, 200, and 300 mg/kg, exhibited significant antipyretic activity in the yeast-induced pyrexia model in rats. It produced a dose-dependent reduction in rectal temperature, sustaining the effect for up to 5 hours post-administration, comparable to standard antipyretic agents. This activity suggests potential inhibition of prostaglandin synthesis responsible for fever elevation.[73]

Antitussive activity

The methanol bark extract at a dose of 200 mg/kg demonstrated significant antitussive activity in the sulfur dioxide-induced cough model in mice. This effect was comparable to that of codeine phosphate, the standard reference drug. Maximum inhibition, reaching 56.9%, occurred 90 minutes after administration.[74]

Antifilarial activity

The alcoholic and aqueous fruit extracts exhibited potent anti-filarial activity against the whole worm and nerve-muscle preparation of Setaria cervi at concentrations ranging from 50–350 µg/mL. These extracts caused significant inhibition of spontaneous motility in adult worms and led to the death of microfilariae. The median lethal concentration (LC50) was determined to be 21–27 ng/mL, indicating high efficacy against filarial parasites.[72]

Chemo-preventive activity

Ficus racemosa extract, administered at doses of 200 and 400 mg/kg, demonstrated significant chemopreventive effects against Fe-NTA-induced chemotoxicity and potassium bromate-induced nephrotoxicity in experimental models. The extract markedly decreased levels of gamma-glutamyl transpeptidase, lipid peroxidation, xanthine oxidase, hydrogen peroxide generation, blood urea nitrogen, and serum creatinine, while promoting recovery of glutathione content and antioxidant enzymes. Additionally, it effectively reversed ornithine decarboxylase activity and renal DNA synthesis, suppressing tumor incidence and oxidative damage.[15,75]

Hypolipidemic activity

The ethanolic bark extract and dietary fiber of fruit from *Ficus racemosa*, administered at doses ranging from 100–500 mg/kg, exhibited significant hypolipidemic activity in alloxan-induced diabetic rats and a dietary fiber model. These interventions produced a pronounced hypocholesterolemic effect by increasing the fecal excretion of cholesterol and bile acids. The bioactive compound beta-sitosterol present in the extracts is primarily responsible for inhibiting endogenous lipid synthesis and restoring lipid profiles toward normal levels.[76]

Analgesic activity

The ethanol extract of bark and leaves, decoction, and petroleum ether extract of *Ficus racemosa* at 300 mg/kg showed potent analgesic effects in hot plate, tail immersion, and acetic acid-induced writhing tests in animal models. These extracts significantly increased latency time and reduced writhing responses, comparable to standard analgesics. The activity is attributed to bioactive compounds like friedelin, behenic acid, bergenin, lupeol, and lupeol acetate.[15,76]

Anti-diarrheal activity

The ethanolic extract of *Ficus racemosa* leaves (400-600 mg/kg), with bark extracts also showing activity in some studies, demonstrated significant anti-diarrheal effects in castor oil-induced diarrhea, PGE2-induced enteropooling, and gastrointestinal motility (charcoal meal) tests in animal models. It markedly decreased fecal output and frequency of droppings, reduced intestinal fluid accumulation in the PGE2 model, and inhibited gastrointestinal transit. These effects suggest inhibition of secretory mechanisms and propulsion, supporting traditional antidiarrheal uses of the plant.[15]

Toxicity studies

Various extracts of *Ficus racemosa*—including ethanol, water, hydroalcoholic, methanol, and petroleum ether—were evaluated for toxicity across multiple models such as human skin fibroblasts, human hepatocyte carcinoma, human

promyelocytic leukemia cells, brine shrimp lethality assay, and acute toxicity in mice at doses up to 3.2 g/kg and 5 g/kg. These extracts showed low IC50 values indicating moderate potency but were significantly less toxic than reference compounds like aspirin and mercuric chloride. In the brine shrimp assay, the LC50 was determined at 850 µg/mL, while in mice, no mortality, behavioral changes, or organ toxicity were observed even at high doses, confirming the plant's safety profile.[75,76]

Conclusion and future perspective

Ficus racemosa Linn. is an important medicinal plant that has been widely used for centuries in traditional systems of medicine such as Ayurveda, Siddha, and Unani. It contains a variety of phytochemicals, including flavonoids, tannins, sterols, triterpenoids, phenolic compounds, and glycosides, which together are responsible for its diverse therapeutic effects. Research studies have validated its traditional applications and shown that different parts of the plant, such as the bark, leaves, fruits, roots, and latex, possess notable pharmacological properties. These include antidiabetic, anti-inflammatory, antioxidant, hepatoprotective, antimicrobial, antiulcer, analgesic, wound-healing, hypolipidemic, and gastroprotective activities. Bioactive constituents such as β-sitosterol, lupeol, quercetin, gallic acid, and rutin play a key role in these medicinal effects. Further experimental evidence suggests that *Ficus racemosa* has strong potential in treating metabolic disorders, inflammatory diseases, infections, and gastrointestinal issues. Toxicological studies also indicate that the plant is relatively safe, even at higher doses, which supports its use in therapeutic applications. In conclusion, *Ficus racemosa* is a valuable natural source of bioactive compounds with considerable pharmacological importance. Nevertheless, more clinical research and proper standardization are required to confirm its effectiveness and safety, and to support its development into modern medicinal formulations.

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