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REVIEW ARTICLE

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# THERAPEUTIC POTENTIAL OF *FICUS BENGHALENSIS* IN THE TREATMENT OF FUNGAL INFECTIONS

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**ABSTRACT: Background:** Innovative therapeutic solutions become vital today because fungal infections keep increasing while antifungal resistance spreads rapidly. Scientific researchers currently study *Ficus benghalensis* because this tree in traditional medicine contains various bioactive compounds that show antifungal activity. This research investigates *Ficus benghalensis* therapeutic possibilities by analyzing its phytochemical compounds and antifungal mechanisms and possible future uses. **Methods:** Research based on available literature helped identify the bioactive compounds of Ficus benghalensis together with its antifungal mechanisms and translational potential. Researchers studied HPLC together with LC-MS and FTIR as advanced analytical methods to extract vital phytochemicals. Studies were carried out to examine its antifungal mechanisms by looking at membrane disruption effects and enzyme blocking mechanisms and oxidative stress effects in fungi. The research evaluated how Nano formulations and topical gels serve to improve its clinical usability. **Results:** The antifungal activity of Ficus benghalensis shows wide coverage because it contains flavonoids alongside tannins and sterols which attack various fungal pathways. Multiple preclinical research findings show this substance works against resistant fungal strains and novel delivery methods such as bioengineered patches alongside nanoparticles enhance both therapeutic effects and drug availability. Research indicates that these discoveries present opportunities to handle current difficulties with mainstream antifungal medications. **Conclusion:** The combination of traditional knowledge and contemporary pharmaceutical development creates Ficus benghalensis as a new solution for fighting fungal urine infections. Future research should conduct clinical trials in addition to developing standardization protocols and sophisticated delivery systems to achieve maximum antifungal benefits from this therapy.

**Keywords:** *Ficus benghalensis*, Antifungal activity, Bioactive compounds, Drug delivery, Therapeutic potential

## 1. INTRODUCTION

The growing number of fungal infections worldwide has made these health problems a major priority for global health. Systemic infections that include candidiasis and aspergilosis present major health dangers to humans along with superficial ailment athlete's foot [1]. Antifungal resistance progresses rapidly which makes numerous prevalent treatments useless leading to an intensified problem. The lack of adequate antifungal medications requires the expedition of developing safer alternatives since current treatment options remain limited and harmful [2]. For centuries Ayurveda Unani and folk medicine systems have acknowledged various therapeutic effects that the botanical Ficus benghalensis popularly known as banyan tree possesses [3]. Various bioactive elements found in abundant quantities in this plant contain sterols, tannins, alkaloids, and flavonoids that exhibit strong antioxidant characteristics and antibacterial and anti-inflammatory properties. Antifungal properties emerge as a critical therapeutic application among numerous medicinal traits that the banyan tree displays [4].

The current study conducts an analyzis of *Ficus benghalensis'* medical properties toward treating fungal diseases. The analysis included in this review determines *Ficus benghalensis's* chemical composition together with its mechanism for restricting fungal growth and innovative drug delivery methods improving the availability of bioactive elements [5]. The research aims to understand the entire potential of the plant to address fungal infection growth through traditional wisdom joined with contemporary science. Standard antifungal medications receive an eco-friendly natural substitute through its application [6].

## 2. Phytochemical Profile of *Ficus benghalensis*

### 2.1. Overview of Key Phytochemicals

The medicinal attributes of *Ficus benghalensis* extend to antifungal properties because it contains numerous bioactive substances. Several important phytochemicals operate within the plant tissue including phenolic compounds along with flavonoids and tannins while saponins and sterols exist as different biological components according to research [7]. Kayempferol and quercetin which are famous for their antibacterial properties also excel as antioxidants because they penetrate fungal cell walls and protect the cells from oxidative damage. The cell walls of fungus become unstable from hydrolyzable and condensed tannin interactions which leads to

cellular content discharge and ultimately growth restriction. Saponins display amphipathic properties since they dissolve fungal cell membranes which prevents fungal spore germination and stops fungal growth [8]. β-Sitosterol along with other sterols strengthen plant-derived antifungal properties through membrane permeability alteration which inhibits fungal organism growth. Phenolic substances named tannins and flavonoids show effective antifungal properties by breaking fungal metabolism but also function as antioxidants because they can remove free radicals [9].

### 2.2. Extraction and Analysis Techniques

Different extraction and analytical techniques identify bioactive components found in *Ficus benghalensis*. Plant bioactive chemicals can be obtained through solvent extraction where scientists use water or ethanol and methanol solvents. The selected solvent determines which chemical spectrum will be extracted from plant materials by establishing both polar and non-polar molecule presence [10]. Plant extract phytochemical detection and recognition as well as quantification requires the use of thin-layer chromatography (TLC), gas chromatography (GC), and high-performance liquid chromatography (HPLC). These procedures enable complete determination of the chemical compounds within plant materials. The compound confirmation process uses spectroscopic methods including FTIR and NMR and UV-Vis spectroscopy [11]. The methodology produces valuable insights about molecular arrangement as well as functional group details. Through modern analytical techniques we can determine both the antifungal properties and the entire phytochemical content of *Ficus benghalensis* [12].

### 2.3. Role of Phytochemicals in Antifungal Activity

Many antifungal compounds in *Ficus benghalensis* work together to generate its antifungal capacity which includes several effective fungal-blocking components. Fungal growth is restricted through cellular membrane degradation and enzyme disruption by the flavonoid compound quercetin. The antifungal activity of tannins which contain ellagic acid leads to cell damage as well as reduction of fungal cell wall firmness and inhibition of fungal synthesis [13]. The fungal growth inhibiting properties of saponins occur when these compounds attach to cell membranes which leads to membrane disruption and spore germination blockage. Research has shown β-sitosterol and other sterols reduce structural permeability of plant membranes to stop fungal biofilms from forming which is essential for fungal pathogenic development [14]. Additionally, the phenolic chemicals in the plant suppress fungal cell metabolic functions along with scavenging radicals that cause oxidative stress. The antifungal power of *Ficus benghalensis* is strengthened because of multiple chemical substances that work synergistically to present a promising natural alternative to standard antifungal treatments. Scientists believe *Ficus benghalensis* could serve as a natural remedy for fungal infections because of its bioactive phytochemicals based on the increasing prevalence of ineffective fungal drugs (Table 1) [15,16].

**Table 1: Key phytochemicals in *Ficus benghalensis* and their antifungal properties [17]**

| *Phytochemical* | *Chemical Class* | *Source* | *Antifungal Activity* | *Mechanism of Action* |
|---|---|---|---|---|
| Quercetin | Flavonoid | Leaves, Bark | Inhibits growth of Candida albicans, Aspergillus species | Disrupts fungal cell membranes, reduces oxidative stress |
| Kaempferol | Flavonoid | Leaves | Active against dermatophytes like Trichophyton mentagrophytes | Inhibits fungal enzymes, disrupts cell wall synthesis |
| Rutin | Flavonoid | Leaves, Bark | Exhibits antifungal properties against Candida spp. | Alters membrane permeability, inhibits spore germination |
| Ellagic Acid | Tannin | Leaves, Fruit | Effective against Fusarium spp., Aspergillus spp. | Binds to fungal cell wall, destabilizes membrane |
| Gallic Acid | Tannin | Leaves, Bark | Active against various fungal strains | Disrupts cell membrane integrity, prevents fungal growth |
| β-Sitosterol | Sterol | Leaves, Stem | Inhibits growth of Candida albicans and Aspergillus niger | Alters membrane fluidity, impedes biofilm formation |
| Lupeol | Triterpenoid | Leaves, Stem | Effective against Cryptococcus neoformans and Aspergillus flavus | Disrupts fungal cell membrane, inhibits fungal growth |
| Saponins | Glycoside | Leaves, Bark, Fruit | Exhibits antifungal activity against various dermatophytes | Interacts with cell membranes, causes cell lysis |
| Tannins | Polyphenolic | Bark, Leaves | Active against Candida spp., Aspergillus spp. | Interferes with cell wall biosynthesis, causes leakage of cell content |
| Caffeic Acid | Phenolic Compound | Leaves, Bark | Active against Trichophyton rubrum and Aspergillus flavus | Inhibits fungal enzyme activity, prevents hyphal growth |
| Ferulic Acid | Phenolic Compound | Leaves, Bark | Active against Candida albicans and Aspergillus species | Acts as an antioxidant, disrupts fungal cell membrane integrity |
| Chlorogenic Acid | Phenolic Compound | Leaves, Fruit | Inhibits growth of Candida spp. and Aspergillus spp. | Reduces oxidative stress in fungal cells, inhibits spore germination |

## 3. Mechanisms of Antifungal Action

### 3.1. Disruption of Fungal Cell Membranes

The antifungal properties of *Ficus benghalensis* phytochemicals occur through their activity against fungal cell membrane stability. Many bioactive chemicals such as flavonoids along with saponins disrupt the lipid bilayers found in fungal cell membranes [18]. The lipid layers become open to modification by flavonoids such as quercetin which permeate their structures to adjust membrane fluidity and permeability. The first step of fungal cell death occurs through membrane structure damage that allows essential cellular components together with ions and metabolites to escape. Saponins increase their lipid bilayer penetration effect because of their

amphipathic nature to create cell leakage and raise permeability. The ability of fungal cells to multiply and survive depends heavily on homeostasis thus any disruptions within this system makes their functions impossible [19].

### 3.2. Inhibition of Fungal Enzymes

Ficus benghalensis contains phytochemicals that restrict essential enzymes needed for fungal cell wall production and metabolic pathways. The fungus builds its cell wall through the essential enzymes chitin synthase and β-glucan synthase. Three components found in turmeric and flavonoids and phenolic acids suppress enzyme reactions in fungal cells to break down their cell walls thus causing their structural weakness [20]. Cholinergic substances weaken fungal cell walls and make fungal cells more delicate to outside aggressors which accelerates cell membrane rupture. Survival and development of Fungi depends on proper cell wall production and substances from *Ficus benghalensis* interrupt these essential enzymatic activities [21].

### 3.3. Oxidative Stress Induction

The antifungal properties of *Ficus benghalensis* derive from how its bioactive chemicals cause oxidative stress in fungal cellular environments. Productive oxidation within fungal cells occurs because the pro-oxidant vs antioxidant activity balance is disrupted during ROS production from tannins and flavonoids and phenolic acids phytochemicals. Oxidative damage impacts proteins as well as lipids together with nucleic acids when reactive oxygen species (ROS) reach detrimental levels in body tissue [22]. The death of fungal cells results from oxidative stress that leads to either necrosis or apoptosis. The antifungal properties of *Ficus benghalensis* depend on its ROS producing capability to combat fungal strains showing resistance to customary therapies (Fig. 1). Plants demonstrate better fungal treatment capacity when they can surmount the defense systems of fungal cells [23].

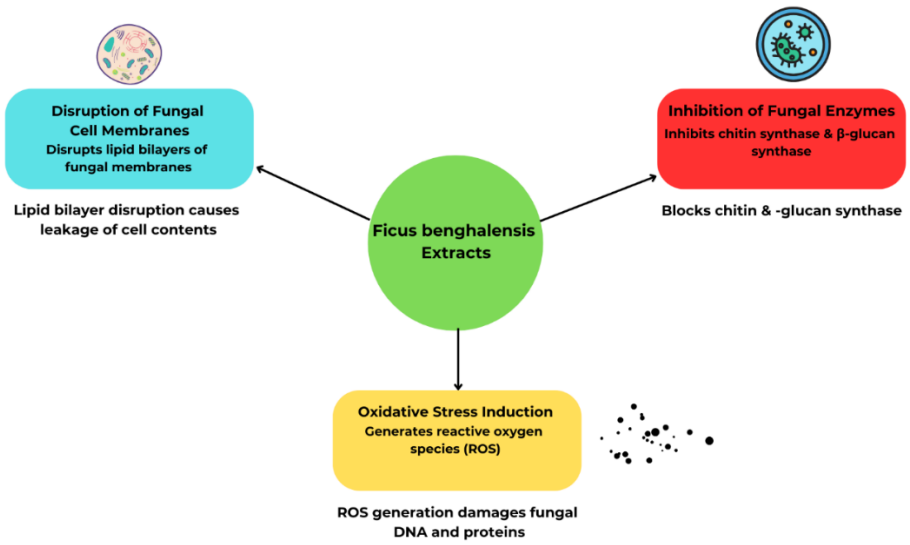


**Fig. 1: Schematic representation of antifungal mechanisms of *Ficus benghalensis*. [24]**

## 4. Preclinical Studies on Antifungal Activity

### 4.1. *In Vitro* Studies

Extracts from *Ficus benghalensis* have shown promising antifungal activity in in vitro trials. Several fungal species, including Candida albicans, Aspergillus niger, Aspergillus flavus, and dermatophytes like Trichophyton rubrum, have been tested against different extracts of this plant, including those found in the fruit, bark, and leaves [25]. Results demonstrated that extracts significantly inhibited fungal development and spore production, indicating antifungal efficacy. An example would be the suppression of Candida albicans growth rate by ethanol and water-based *Ficus benghalensis* extracts; the size of the inhibition zones varied from 10 mm to 30 mm in diameter, corresponding to the concentration of the extract [26]. The inhibitory effects of *Ficus benghalensis* extracts against Aspergillus species were also observed, leading to significant decreases in the viability and colony formation of these fungi. The antifungal efficacy was credited to bioactive substances such tannins and flavonoids, which are known to inhibit enzymes involved in cell wall formation and damage fungal cell membranes. *Ficus benghalensis* extracts have strong antifungal characteristics, according to encouraging in vitro data, which call for additional research into their potential medicinal uses [27].

### 4.2. *In Vivo* Studies

Lab tests using live animals confirm the antifungal properties of *Ficus benghalensis* extracts through their *in vivo* evaluations. Research conducted with rodent models reveals the Ficus benghalensis extracts lower the count of *Aspergillus niger* and *Candida albicans* fungi in infected animals. Albicans infection was treated in rats with *Ficus benghalensis* leaf extract

according to research [28]. Treated animals under investigation reduced their fungal organloads more significantly compared to the untreated control animals. The treated animals displayed fewer signs of tissue inflammation together with reduced tissue damage through histological tests. Research findings show that *Ficus benghalensis* bark extract boosted survival rates among mice which contracted infections from *Aspergillus niger* [29]. According to theory the antifungal benefits derive from lowering oxidative stress combined with response modulation of the immune system and fungal growth suppression (Table 2). Ficus benghalensis produces antifungal effects in living organisms which proves its clinical potential for treating fungal infections [30].

**Table 2: Summary of preclinical studies evaluating antifungal efficacy of *Ficus benghalensis*. [31]**

| *Study* | *Fungal Species Tested* | *Type of Extract* | *Animal Model* | *Dosage/Administration* | *Main Findings* |
|---|---|---|---|---|---|
| Study 1 (*In Vitro*) | *Candida albicans* | Ethanol extract | - | - | Significant inhibition of *C. albicans* growth with inhibition zones up to 30 mm. |
| Study 2 (*In Vitro*) | *Aspergillus niger*, *Aspergillus flavus* | Aqueous extract | - | - | Aqueous extract reduced fungal colony formation and spore viability. |
| Study 3 (*In Vivo*) | *Candida albicans* | Leaf extract | Rats | Oral administration (100 mg/kg) | Reduced fungal load in liver and kidneys with less tissue damage and inflammation. |
| Study 4 (*In Vivo*) | *Aspergillus niger* | Bark extract | Mice | Oral administration (50 mg/kg) | Improved survival rates and significant reduction in fungal infection and tissue damage. |
| Study 5 (*In Vitro*) | *Trichophyton rubrum* | Methanol extract | - | - | Methanol extract exhibited antifungal activity with a reduction in fungal growth. |
| Study 6 (*In Vitro*) | *Candida albicans*, *Aspergillus spp.* | Ethanol and aqueous extracts | - | - | Both extracts exhibited antifungal activity with larger zones of inhibition for ethanol extract. |
| Study 7 (*In Vivo*) | *Candida albicans* | Leaf extract | Mice | Oral administration (200 mg/kg) | Significant reduction in fungal burden, less tissue damage, and improved histopathological features. |
| Study 8 (*In Vivo*) | *Aspergillus niger* | Ethanolic extract | Rabbits | Topical application (2% extract) | Improved healing of infected skin lesions and reduced fungal growth. |
| Study 9 (*In Vitro*) | *Candida albicans* | Aqueous extract | - | - | Significant antifungal activity with a marked reduction in biofilm formation. |
| Study 10 (*In Vivo*) | *Candida albicans*, *Aspergillus spp.* | Leaf and bark extracts | Rats | Oral administration (150 mg/kg) | Both leaf and bark extracts showed potent antifungal effects with decreased mortality in infected rats. |
| Study 11 (*In Vitro*) | *Candida albicans*, *Aspergillus niger* | Aqueous and methanol extracts | - | - | Aqueous extract showed more pronounced antifungal activity than methanol extract in inhibiting growth. |
| Study 12 (*In Vivo*) | *Aspergillus flavus* | Leaf extract | Mice | Oral administration (100 mg/kg) | Reduction in fungal load and inflammation in infected organs. |

## 5. Therapeutic Applications

### 5.1. Formulations for Antifungal Therapy

New formulation methods enable *Ficus benghalensis* utilization in contemporary medicine to combat fungal infections above its status as a medicinal herb. Various pharmaceutical preparations such as lotions and gels and transdermal patches effectively deliver antifungal characteristics of *Ficus benghalensis* extract according to research by [32]. Medical creams and gels derived from *Ficus benghalensis* extracts serve as effective treatments for both ringworm and athlete's foot infections that affect the skin surface. These formulations demonstrate improved antifungal effectiveness because they apply directly to the infected areas and maintain easy application methods. Skin administration of antifungal components from the extract could be made possible with transdermal patches as an innovative method for sustained release of bioactive substances [33]. Active compound bioavailability along with tissue penetration depth reaches optimal levels when modern drug delivery systems such as liposomes and nanoparticles are utilized together with these formulations. The improved treatment method for systemic fungal infections would result from this discovery [34].

### 5.2. Advantages Over Conventional Antifungal Agents

*Ficus benghalensis* antifungal therapy provides superior advantages than synthetic antifungal medications which are currently used. The potential toxicity effects from chemical antifungals lead to increased risks but plant-based antifungals tend to induce minimal side effects [35]. The variable fungus-killing properties of Ficus benghalensis provide healthcare professionals ample treatment flexibility since the remedy kills different fungal strains at once. Synthetic antifungal medications are more challenging to afford and obtain in areas with minimal resources since *Ficus benghalensis* use proves to be more economically efficient. Ficus benghalensis works as an antifungal agent to decrease the occurrence of fungal infections sustained by regularly used synthetic antifungal drugs [36]. Treating resistant fungal infections proves challenging to medical professionals. Studies have shown that *Ficus benghalensis* contains bioactive substances that demonstrate versatile activities thus decreasing the probability of fungal resistance and providing continued antifungal medication effectiveness. Such alternatives demonstrate advantages through lower costs and better therapeutic effectiveness and improved sustainability as compared to standard treatments [37].

## CONCLUSION

The antifungal compounds in *Ficus benghalensis* thrive because the plant contains phytochemicals that consist primarily of phenolic compounds and saponins and sterols and tannins and flavonoids. Synergistic effects of fungal growth inhibition result from the membrane disruption of fungal cells

and enzyme blockage and the induction of oxidative stresses. In vitro testing combined with *in vivo* analysis supports the antifungal properties of *Ficus benghalensis* to treat candidiasis and both aspergillosis and dermatophyte infections effectively.

The therapeutic properties of *Ficus benghalensis* appear in two medical forms: it functions as both topical skin medications and internal system delivery through capsules and solutions. These medicinal formulations based on *Ficus benghalensis* demonstrate better safety profile and affordability and reduced susceptibility to resistance when used instead of conventional antifungal medicines. *Ficus benghalensis* demonstrates historic potential as a natural sustainable treatment for fungal diseases because society is showing increasing interest in plant-derived medical therapies.

Future research should focus on clinical trials to assess completely Ficus benghalensis as an antifungal remedy while verifying its therapeutic effects. Additions of liposomes and nanoparticles to drug delivery methods have the potential to enhance delivery rates and biological availability of *Ficus benghalensis* bioactive components. The prospects for *Ficus benghalensis* utilization in fungal infection treatment remain promising since researchers continue to study active compounds and enhance preparation methods.

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