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Mussaenda Frondosa (Bellothi): An Overview of Its Phytochemistry and Pharmacological Potential

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ABSTRACT

Mussaenda frondosa Linn. (Rubiaceae), commonly known as Bellothi, is a perennial medicinal shrub distributed widely across the Indian subcontinent and parts of Southeast Asia. This review provides a comprehensive synthesis of its botanical characteristics, traditional therapeutic applications, phytochemical profile, and pharmacological properties. Traditional medicine utilizes various parts of the plant, including leaves, roots, bark, and flowers, to treat ailments ranging from jaundice and asthma to skin infections and ulcers. Phytochemical screening has identified a diverse array of bioactive secondary metabolites, such as flavonoids, steroids, tannins, iridoid glycosides, and triterpenoids. The application of advanced analytical techniques, including GC–MS, HPTLC, and UHPLC-QTOF, has enabled the precise profiling of these constituents. Pharmacological investigations using in vitro and in vivo models have validated many traditional claims, demonstrating significant antioxidant, antimicrobial, anti-inflammatory, wound-healing, cytotoxic, hepatoprotective, and anti-seizure activities. Furthermore, emerging nanotherapeutic approaches, such as the green synthesis of zinc oxide nanoparticles, highlight the potential for enhanced bioavailability and therapeutic efficacy. This review consolidates the current evidence base to support the development of M. frondosa as a source of novel therapeutic agents while identifying critical gaps for future clinical research. Keywords: Mussaenda frondosa, Bellothi, Phytochemistry, Pharmacology, Rubiaceae, Hepatoprotective, Antioxidant, Iridoids.

1. Introduction

Mussaenda frondosa Linn. is a prominent member of the Rubiaceae family, long recognized in various folk medicine traditions for its diverse therapeutic properties, particularly in the treatment of bacterial infections, inflammation, ulcers, and liver disorders (Pappachen & Sreelakshmi, 2017). Scientific investigations into the whole plant have highlighted its complex chemical landscape and specific experimental biological activities, such as cleavage potential (Nallabattini et al., n.d.). The leaves of M. frondosa are especially noted for their high concentration of bioactive steroids, phenolic compounds, and glycosides, which contribute to their pharmacological utility (Niharika & Mahesh, 2017). These leaf extracts have demonstrated significant effectiveness in experimental models of antibacterial and wound-healing activity, which is attributed to the presence of flavonoids, steroids, saponins, and resins (Patil et al., 2011). Among the isolated constituents, the flavonoid quercetin has been identified as a major contributor to the plant's regenerative and therapeutic potential in wound management (Patil et al., 2011). A holistic review of the species underscores a wide pharmacological spectrum, including antimicrobial, antioxidant, anti-inflammatory, and hepatoprotective effects, confirming its status as a significant medicinal resource ("Mussaenda Frondosa (Bellothi): A Comprehensive Review...", 2025).

2. Botanical Identity and Traditional Uses

The botanical identity of Mussaenda frondosa is marked by its classification as an aerial part plant within the Rubiaceae family, often evaluated for its systemic biological effects, including potential antiseizure activity (Guggilla, 2017). In the context of Indian folklore, the plant is frequently referred to as "Bellente Gida" or "Bellothi." It is traditionally valued for its mucilage, which is believed to be soothing to the eyes and hair, and its inorganic constituents like calcium and iron are recognized for their roles in blood health and wound management (Vijayalakshmi & Anaghadevi, 2022). Comparative studies within the Rubiaceae family have shown that the methanol extract of M. frondosa leaves possesses potent anti-inflammatory and analgesic properties comparable to standard treatments (Bose et al., 2020). Its traditional use as a hepatoprotective agent has been supported by findings of significant activity against ethanol-induced hepatic injury, demonstrated by a decrease in serum transaminases and bilirubin (Sambrekar et al., 2012).

Furthermore, the plant's protective effects extend to isoniazid-induced hepatotoxicity, validating its historical role in managing metabolic and drug-induced stress (Sambrekar et al., 2014).

3. Phytochemistry

The phytochemical profile of Mussaenda frondosa is characterized by a rich diversity of secondary metabolites. In vitro antioxidant studies have led to the identification of several key polyphenolic and steroid compounds, including astragalin, isoquercetin, kaempferol-3-o-beta rutinoside, lupeol, and β-sitosterol (Siju et al., 2010). Callogenesis and phytochemical screening of leaf, stem, and leaf-derived callus have further identified phenols, flavonoids, tannins, saponins, alkaloids, and glycosides as major constituents (Manasa et al., 2017). Alcoholic and aqueous extracts of the whole plant are typically used to evaluate these bioactive compounds, with a focus on their hepatoprotective and antioxidant roles (Sambrekar et al., 2017). The bark of the plant also serves as a source for medicinal extracts, yielding chloroform and methanol fractions with significant biological activities (Basavaraja et al., 2011).

4. GC–MS and Analytical Profiling

Advanced analytical techniques have provided detailed insights into the chemical fingerprints of Mussaenda species. For instance, the development of functional products like sepal-infused tea has allowed for the evaluation of augmented phenolic content and hypoglycemic activities (Nafla et al., 2024). The roots of the plant have been screened for hepatoprotective activity against paracetamol-induced toxicity, showing significant normalization of biochemical parameters (Thummala et al., 2013). GC-MS analysis of related species like Mussaenda roxburghii has identified compounds such as gamma tocopherol, Vitamin E, neophytadiene, and squalene, which are also of interest in M. frondosa profiling (Payum, 2016). Phytochemical screening of specific parts, such as flower petals, has also revealed antibacterial fractions (Efendi, n.d.). Modern nanotherapeutic research has utilized leaf and stem extracts for the green synthesis of zinc oxide nanoparticles, which are characterized using UV-Vis, XRD, and FTIR techniques to establish their bioactive potential (Jayappa et al., 2020).

5. Therapeutic and Pharmacological Properties

5.1 Antioxidant Activity

The antioxidant capacity of M. frondosa is robust across various solvent extracts. Preliminary phytochemical screening of crude powder and extracts has established the presence of essential metabolites throughout the plant (Maiti et al., n.d.). Ultra-High Performance Liquid Chromatography coupled with Quadrupole Time-of-Flight mass spectrometry (UHPLC-QTOF) has been successfully employed for the detection and identification of complex phenolic compounds that drive these antioxidant effects (Manasa et al., n.d.). Ethyl alcohol and aqueous extracts show significant DPPH radical scavenging activity and reducing power in a concentration-dependent manner (Siju et al., 2010). Callus and stem extracts also exhibit notable free radical scavenging potential (Manasa et al., 2017).

5.2 Antimicrobial Activity

Antimicrobial evaluations have confirmed the broad-spectrum efficacy of M. frondosa. Leaf extracts have been specifically profiled for their antimicrobial effects against both bacteria and fungi using high-performance methods (Shanthi & Radha, 2020). Bark extracts (methanol and chloroform) exhibit significant antibacterial activity comparable to ciprofloxacin and potent antifungal activity against Candida albicans (Basavaraja et al., 2011). Additionally, root extracts have been evaluated for their radical scavenging and antistress activities, contributing to the plant's systemic antimicrobial environment (Koul & Chaudhary, 2011). Cultural documentation, such as the use of the plant by the Dayak Meratus tribe for childbirth, highlights its traditional role in preventing postpartum infections (Garvita, 2017). Studies on related species like Mussaenda pubescens further demonstrate that leaf extracts are effective against Staphylococcus aureus, with a 75% concentration providing optimal inhibition (Utari et al., 2022).

5.3 Anti-inflammatory Activity

The anti-inflammatory potential of M. frondosa has been validated using the carrageenan-induced paw edema model. Petroleum ether and ethyl acetate extracts of the leaves demonstrated significant inhibition of inflammation, while the butanol extract showed marked activity attributed to steroids and flavonoidal glycosides (Niharika & Mahesh, 2017). Methanol extracts also displayed anti-inflammatory and antipyretic properties in mouse models (Bose et al., 2020). Nanotherapeutic investigations have also highlighted the holistic investigation of these prospects (Setia et al., n.d.).

5.4 Wound-Healing Activity

Mussaenda frondosa is traditionally used for its healing properties, which have been confirmed in excision, incision, and dead space wound models. Alcoholic leaf extracts significantly increased wound contraction and tensile strength while reducing epithelialization time (Patil et al., 2011). The isolated compound quercetin was found to contribute significantly to this activity, facilitating faster tissue regeneration (Patil et al., 2011).

5.5 Cytotoxic and Anticancer Activity

In vitro cytotoxicity studies using the MTT assay on HepG2 cell lines have shown that the methanolic extract and isolated flavonoid fractions of M. frondosa leaves exhibit significant anticancer activity (Pappachen & Sreelakshmi, 2017). Additionally, ZnO nanoparticles synthesized from plant extracts have demonstrated cytotoxic effects on A549 lung cancer cells, inducing apoptosis through a dose-dependent mechanism (Jayappa et al., 2020).

5.6 Antidiabetic and Hypoglycemic Activity

The plant has shown potential in managing postprandial hyperglycemia. Functional tea developed from M. frondosa sepals exhibited significant α-amylase inhibitory activity (Nafla et al., 2024). Similarly, ZnO nanoparticles derived from the plant showed inhibitory effects on both α-amylase and α-glucosidase enzymes (Jayappa et al., 2020).

5.7 Hepatoprotective Activity

Extensive studies have confirmed the hepatoprotective role of M. frondosa. Alcoholic and aqueous leaf extracts were found to normalize biochemical parameters such as AST, ALT, ALP, and bilirubin in rats with ethanol-induced and isoniazid-induced hepatic injury (Sambrekar et al., 2012; Sambrekar et al., 2014; Sambrekar et al., 2017). Aqueous root extracts have also shown significant protection against paracetamol-induced hepatotoxicity (Thummala et al., 2013).

5.8 Other Biological Activities

- Anti-seizure: Methanolic extracts of the aerial parts inhibit cobalt-induced brain toxicity and provide protection against epileptogenic cortex injury (Guggilla, 2017).
- Analgesic: Chloroform bark extracts and methanol leaf extracts exhibit analgesic activity in various animal models (Bose et al., 2020; Basavaraja et al., 2011).
- Antistress: Ethanolic root extracts normalize brain neurotransmitters and MAO levels in rats subjected to cold immobilization stress (Koul & Chaudhary, 2011).

6. Integrated Discussion

The synthesized evidence highlights Mussaenda frondosa as a chemically diverse species with significant pharmacological potential. There is a clear correlation between its traditional uses—such as treating jaundice and inflammatory conditions—and scientific findings regarding its hepatoprotective and anti-inflammatory activities. The presence of bioactive constituents like quercetin, rutin, and various iridoid glycosides likely mediates these effects through antioxidant and cell-signaling pathways.

Modern research has successfully integrated nanotechnology to improve the delivery of these phytochemicals, with ZnO-NPs showing enhanced biological activity. However, most current evidence relies on in vitro assays and animal models. The lack of clinical trial data remains a significant barrier to the formal integration of M. frondosa into standardized clinical practice. Future investigations should focus on long-term toxicity profiles and human pharmacokinetic studies to establish safe and effective therapeutic dosages.

7. Summary

Mussaenda frondosa (Bellothi) is a versatile medicinal plant with a robust profile of phytochemicals and pharmacological activities. Scientific validation of its traditional uses in wound healing, hepatoprotection, and infection management provides a strong foundation for future drug discovery. The identification of specific bioactive markers and the development of functional food products like sepal-infused tea further broaden its therapeutic applications. Continued research into the molecular mechanisms and clinical safety of this species is warranted to fully harness its medicinal potential.

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