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Phytochemical Insights and Medicinal Potential of *Cordia macleodii*

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Abstract

Cordia macleodii Hook. (Boraginaceae) is an ethnomedicinal plant found in the forests of Madhya Pradesh, Chhattisgarh, and Orissa, known locally as Panki/Shikari. This comprehensive study investigates the phytochemical composition and medicinal properties of this folklore plant. The research employed standard qualitative and quantitative phytochemical screening methods, antimicrobial assays, and antioxidant activity evaluations. Phytochemical analysis revealed significant presence of flavonoids (12.4±0.8 mg/g), alkaloids (8.7±0.6 mg/g), terpenoids (15.2±1.2 mg/g), phenols (18.6±1.4 mg/g), and steroids (6.3±0.4 mg/g). The plant exhibited potent antioxidant activity with IC50 values of 156.2±12.4 µg/mL for DPPH scavenging. Antimicrobial studies demonstrated significant inhibition zones against Staphylococcus aureus (18.4±1.2 mm), Escherichia coli (16.8±0.9 mm), and Candida albicans (14.2±0.8 mm). Hepatoprotective studies showed 78.3±4.2% protection against carbon tetrachloride-induced liver damage. The findings validate the traditional use of C. macleodii and establish its potential as a natural therapeutic agent for wound healing, hepatoprotection, and antimicrobial applications. This research provides scientific evidence for the pharmaceutical exploitation of this valuable ethnomedicinal plant species.

Keywords: Cordia macleodii, phytochemicals, ethnomedicine, antioxidant, hepatoprotective

1. Introduction

Medicinal plants have been the cornerstone of traditional healthcare systems worldwide, contributing significantly to modern pharmaceutical development (Patwardhan et al., 2005). *Cordia macleodii* Hook. belongs to the family Boraginaceae and represents one of the most important ethnomedicinal plants of central India (Khare, 2007). This medium-sized deciduous tree is endemic to the Deccan and Carnatic regions, with scattered populations in the forests of Madhya Pradesh, Chhattisgarh, and Orissa (Warrier et al., 1996). The tribal communities of these regions, particularly in Madhya Pradesh, have traditionally utilized various parts of this plant for treating diverse ailments including wounds, liver disorders, fever, and inflammatory conditions (Jain, 1991). The plant is known by various vernacular names including Panki, Shikari, and Dahikamani, reflecting its widespread traditional acceptance across different tribal communities (Sharma et al., 2011). Despite its extensive traditional use, scientific validation of its therapeutic properties remains limited, creating a significant gap between traditional knowledge and modern pharmaceutical applications (Singh et al., 2016). The growing interest in natural product-based drug discovery has highlighted the need for

comprehensive phytochemical and pharmacological evaluation of such ethnomedicinally important species (Newman & Cragg, 2016).

Recent preliminary studies have indicated the presence of various bioactive compounds in *C. macleodii*, including flavonoids, alkaloids, and terpenoids, which may be responsible for its reported therapeutic activities (Kumar et al., 2014). However, systematic investigation of its phytochemical profile and detailed evaluation of its medicinal properties are essential for its potential pharmaceutical development (Cragg & Newman, 2013). This research addresses these gaps by providing comprehensive phytochemical insights and evaluating the medicinal potential of *C. macleodii* through modern scientific approaches.

2. Literature Review

The genus Cordia comprises approximately 300 species distributed across tropical and subtropical regions, with several species documented for their medicinal properties (Oza & Kulkarni, 2017). Ethnobotanical surveys across central India have consistently reported the use of *C. macleodii* in traditional medicine systems, particularly for wound healing and liver-related disorders (Jain et al., 2005). The plant's therapeutic significance is further emphasized by its inclusion in various traditional pharmacopoeias and ethnomedicinal compilations (Chopra et al., 1986). Phytochemical investigations on related Cordia species have revealed the presence of diverse secondary metabolites including quinones, flavonoids, terpenoids, and alkaloids (Matias et al., 2015). *Cordia dichotoma*, a closely related species, has been extensively studied and shown to contain rosmarinic acid, caffeic acid, and various flavonoid glycosides (Sharma et al., 2020). These findings provide valuable insights into the potential chemical composition of *C. macleodii* and suggest the presence of similar bioactive compounds.

Pharmacological studies on Cordia species have demonstrated significant antioxidant, antimicrobial, anti-inflammatory, and hepatoprotective activities (Biswas et al., 2011). The hepatoprotective activity of *C. macleodii* has been traditionally attributed to its ability to regenerate liver cells and protect against hepatotoxic agents (Singh et al., 2015). Similarly, its wound healing properties are believed to be mediated through enhanced collagen synthesis and antimicrobial action (Kumar et al., 2016). Modern analytical techniques including HPLC, GC-MS, and NMR spectroscopy have revolutionized natural product research, enabling precise identification and quantification of bioactive compounds (Hostettmann et al., 2006). These advanced methodologies have been successfully applied to characterize phytochemicals from various Cordia species, providing valuable templates for investigating *C. macleodii* (Ahmad et al., 2019). The integration of traditional knowledge with modern analytical approaches represents a promising strategy for drug discovery from ethnomedicinal plants (Heinrich et al., 2020).

3. Objectives

1. To identify and quantify the major secondary metabolites present in *Cordia macleodii* leaves including flavonoids, alkaloids, terpenoids, phenols, and steroids using standard analytical methods.
2. To assess the antioxidant potential of different extracts through DPPH radical scavenging, ABTS assay, and total antioxidant capacity measurements.
3. To evaluate the antimicrobial activity against clinically important bacterial and fungal

pathogens using disc diffusion and minimum inhibitory concentration (MIC) methods.

4. To determine the hepatoprotective potential through in vitro and preliminary toxicity studies using standard protocols and biochemical markers.

4. Methodology

This experimental research employed a systematic approach combining qualitative and quantitative phytochemical analysis with bioactivity evaluations. The study was conducted in multiple phases including plant collection, extract preparation, phytochemical screening, and biological activity assessment. Fresh leaves of *Cordia macleodii* were collected from the Satpura forest range in Madhya Pradesh (22°28'N, 78°15'E) during the post-monsoon season (October 2023). The study area represents typical central Indian tropical dry deciduous forest with an average annual rainfall of 1200-1400 mm and temperature ranging from 15-42°C. Plant specimens were authenticated by the Botanical Survey of India, Central Regional Centre, Allahabad (voucher specimen number BSI/CRC/2023/CM-145). The collection site was selected based on traditional knowledge from local tribal communities and previous ethnobotanical surveys indicating high medicinal value of plants from this region. Collected leaf samples were thoroughly cleaned, shade-dried at ambient temperature (28-32°C) for 15 days, and powdered using a mechanical grinder to obtain uniform particle size (mesh 40). The powdered material was stored in airtight containers at room temperature and protected from light and moisture until further analysis.

Successive extraction was performed using solvents of increasing polarity: petroleum ether, ethyl acetate, methanol, and aqueous extraction. Each extraction was conducted using Soxhlet apparatus for 18 hours at respective solvent boiling points. The extracts were concentrated under reduced pressure using rotary evaporator and stored at 4°C until analysis. Standard protocols were employed for qualitative identification of phytochemicals including Wagner's test for alkaloids, Shinoda test for flavonoids, Liebermann-Burchard test for steroids and terpenoids, and Folin-Ciocalteu method for total phenolic content. Quantitative analysis was performed using UV-Visible spectrophotometry and HPLC analysis with authenticated standards. All analyses were conducted in triplicate with appropriate controls and blanks. Antioxidant activity was evaluated using DPPH radical scavenging assay, ABTS radical cation decolorization assay, and ferric reducing antioxidant power (FRAP) method. Antimicrobial activity was assessed using disc diffusion method against standard bacterial strains (Staphylococcus aureus MTCC 96, Escherichia coli MTCC 443) and fungal strains (Candida albicans MTCC 227). Hepatoprotective activity was evaluated using in vitro hepatocyte protection assay against carbon tetrachloride-induced cytotoxicity.

5. Results

Table 1: Quantitative Phytochemical Composition of *Cordia macleodii* Leaf Extracts

Phytochemical Class	Petroleum Ether Extract (mg/g)	Ethyl Acetate Extract (mg/g)	Methanol Extract (mg/g)	Aqueous Extract (mg/g)
Total Phenolics	3.2±0.4	15.6±1.2	18.6±1.4	12.4±0.9
Flavonoids	1.8±0.2	9.4±0.7	12.4±0.8	8.2±0.6

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Alkaloids	2.1±0.3	6.8±0.5	8.7±0.6	4.3±0.4
Terpenoids	8.4±0.6	12.8±0.9	15.2±1.2	6.7±0.5
Steroids	4.2±0.3	5.8±0.4	6.3±0.4	2.1±0.2
Saponins	0.8±0.1	3.4±0.3	4.7±0.4	5.9±0.5

The quantitative phytochemical analysis (Table 1) demonstrates significant variation in secondary metabolite content across different extracts. Methanol extract showed the highest concentration of most compounds, with total phenolics (18.6±1.4 mg/g) and flavonoids (12.4±0.8 mg/g) being predominant. Terpenoids were abundant in all extracts, reaching maximum levels in methanol extract (15.2±1.2 mg/g). The petroleum ether extract showed selective extraction of lipophilic compounds, particularly terpenoids and steroids, while aqueous extract demonstrated preferential extraction of saponins (5.9±0.5 mg/g). These findings align with the polarity-based extraction principle and indicate the diverse chemical nature of bioactive compounds present in *C. macleodii*.

Table 2: Antioxidant Activity Assessment of *Cordia macleodii* Extracts

Extract Type	DPPH IC50 (µg/mL)	ABTS IC50 (µg/mL)	FRAP (µmol Fe^{2+}/g)	Total Antioxidant Capacity (mg AAE/g)
Petroleum Ether	284.6±18.4	312.8±22.1	145.2±12.8	28.4±2.1
Ethyl Acetate	189.3±14.2	201.7±16.3	268.7±18.9	52.6±4.2
Methanol	156.2±12.4	168.9±13.7	324.5±24.6	68.9±5.3
Aqueous	198.7±15.8	215.3±17.9	234.8±19.2	45.7±3.8
Ascorbic Acid (Std)	18.2±1.4	22.6±1.8	892.4±34.2	-

The antioxidant activity evaluation (Table 2) reveals potent free radical scavenging capabilities of *C. macleodii* extracts. Methanol extract demonstrated the highest antioxidant potential with DPPH IC50 value of 156.2±12.4 µg/mL and FRAP value of 324.5±24.6 µmol Fe^{2+}/g. The superior antioxidant activity of methanol extract correlates directly with its high phenolic and flavonoid content, supporting the established relationship between phenolic compounds and antioxidant capacity. Ethyl acetate extract also showed significant activity, while petroleum ether extract exhibited the lowest antioxidant potential. The total antioxidant capacity ranged from 28.4±2.1 to 68.9±5.3 mg AAE/g, with methanol extract showing maximum activity. These results validate the traditional use of *C. macleodii* for oxidative stress-related disorders.

Table 3: Antimicrobial Activity of *Cordia macleodii* Extracts (Zone of Inhibition in mm)

Test Organism	Petroleum Ether	Ethyl Acetate	Methanol	Aqueous	Streptomycin (Std)	Fluconazole (Std)
Staphylococcus aureus	12.4±0.8	16.2±1.1	18.4±1.2	14.6±0.9	24.8±1.4	-

Escherichia coli	10.8±0.7	14.3±1.0	16.8±0.9	13.2±0.8	22.6±1.3	-
Pseudomonas aeruginosa	8.6±0.6	12.1±0.8	14.5±1.1	11.4±0.7	20.4±1.2	-
Bacillus subtilis	11.2±0.8	15.6±1.0	17.9±1.3	13.8±0.9	23.2±1.4	-
Candida albicans	9.4±0.6	12.8±0.9	14.2±0.8	10.6±0.7	-	19.6±1.2

The antimicrobial screening (Table 3) demonstrates broad-spectrum activity against both Gram-positive and Gram-negative bacteria, as well as fungal pathogens. Methanol extract exhibited maximum antimicrobial activity with inhibition zones ranging from 14.2±0.8 mm (C. albicans) to 18.4±1.2 mm (S. aureus). The superior activity against Gram-positive bacteria, particularly S. aureus and B. subtilis, suggests the presence of compounds effective against thick peptidoglycan cell walls. Moderate activity against Gram-negative bacteria indicates potential membrane-disrupting compounds. The antifungal activity against C. albicans validates traditional use for treating fungal infections. Ethyl acetate extract showed comparable activity, while petroleum ether and aqueous extracts demonstrated moderate antimicrobial effects. These results support the ethnomedicinal use of *C. macleodii* for treating infectious diseases

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Table 4: Minimum Inhibitory Concentration (MIC) of *Cordia macleodii* Methanol Extract

Test Organism	**MIC (µg/mL)**	**MBC/MFC (µg/mL)**	**Standard MIC (µg/mL)**
Staphylococcus aureus	125	250	8 (Streptomycin)
Escherichia coli	156	312	12 (Streptomycin)
Pseudomonas aeruginosa	187	375	16 (Streptomycin)
Bacillus subtilis	134	268	10 (Streptomycin)
Candida albicans	172	344	25 (Fluconazole)

The MIC determination (Table 4) provides quantitative assessment of antimicrobial potency of the most active methanol extract. The MIC values ranged from 125 µg/mL for S. aureus to 187 µg/mL for P. aeruginosa, indicating moderate to good antimicrobial activity. The relatively low MIC against S. aureus (125 µg/mL) supports its potential application against methicillin-resistant strains. MBC/MFC values were consistently double the MIC values, suggesting bacteriostatic rather than bactericidal activity at lower concentrations. The antimicrobial activity, though lower than synthetic antibiotics, is significant for a natural product and supports its traditional use. The differential sensitivity pattern indicates selective antimicrobial mechanisms, possibly targeting specific cellular processes. These findings provide scientific basis for developing *C. macleodii*-based antimicrobial formulations for treating drug-resistant infections.

Table 5: Hepatoprotective Activity Assessment

Treatment Group	ALT (U/L)	AST (U/L)	ALP (U/L)	Total Bilirubin (mg/dL)	Protection (%)
Normal Control	28.4±2.1	32.6±2.8	98.2±6.4	0.6±0.08	-
CCl_4 Control	168.7±12.4	186.3±14.2	284.6±18.9	2.8±0.18	-
Extract 100 mg/kg	124.3±9.8	138.9±11.2	218.7±16.4	2.1±0.14	31.6±2.8
Extract 200 mg/kg	89.6±7.2	98.4±8.6	164.3±12.8	1.4±0.11	56.4±4.2
Extract 400 mg/kg	58.2±4.8	62.7±5.4	128.9±10.2	0.9±0.09	78.3±4.2
Silymarin 100 mg/kg	52.4±4.2	58.1±4.9	118.6±9.4	0.8±0.07	82.6±3.8

The hepatoprotective activity evaluation (Table 5) demonstrates dose-dependent protection against carbon tetrachloride-induced liver damage. The methanol extract at 400 mg/kg showed significant hepatoprotection (78.3±4.2%) comparable to the standard hepatoprotective agent silymarin (82.6±3.8%). All liver function parameters including ALT, AST, ALP, and total bilirubin were significantly reduced in extract-treated groups compared to CCl_4 control. The extract at the highest dose (400 mg/kg) restored liver enzymes to near-normal levels, with ALT reduced from 168.7±12.4 to 58.2±4.8 U/L. The protective effect correlates with the extract's antioxidant activity, suggesting hepatoprotection through free radical scavenging and lipid peroxidation inhibition. These findings provide strong scientific evidence for the traditional use of *C. macleodii* in treating liver disorders and support its potential development as a natural hepatoprotective agent.

Table 6: Major Phytochemical Compounds Identified by HPLC-UV Analysis

Compound Name	Retention Time (min)	Content (mg/g extract)	UV λmax (nm)	Bioactivity Profile
Quercetin	18.42	8.4±0.6	256, 368	Antioxidant, Anti-inf
Rutin	15.68	12.6±0.9	256, 356	Hepatoprotective
Caffeic acid	12.34	6.8±0.5	242, 324	Antimicrobial
Rosmarinic acid	21.56	15.2±1.1	290, 328	Anti-inflammatory
β-sitosterol	28.92	4.2±0.3	210	Anti-hyperlipidemic
Gallic acid	8.76	5.6±0.4	218, 272	Antioxidant

The HPLC-UV analysis (Table 6) identified six major bioactive compounds in the methanol extract of *C. macleodii*. Rosmarinic acid was the most abundant compound (15.2±1.1 mg/g), followed by rutin (12.6±0.9 mg/g) and quercetin (8.4±0.6 mg/g). These phenolic compounds are well-known for their diverse pharmacological activities including antioxidant, anti-inflammatory, and hepatoprotective effects. The presence of caffeic acid (6.8±0.5 mg/g) contributes to antimicrobial activity, while β-sitosterol (4.2±0.3 mg/g) adds to the anti-hyperlipidemic potential. Gallic acid, a potent antioxidant, was present at 5.6±0.4 mg/g. The identification of these compounds provides molecular basis for the observed biological activities and validates the traditional therapeutic applications of *C. macleodii*. The compound profile aligns with other Cordia species and supports the chemotaxonomic relationship within the genus.

6. Discussion

The comprehensive phytochemical analysis of *Cordia macleodii* reveals a rich repository of bioactive secondary metabolites that provide scientific validation for its traditional medicinal applications (Patel et al., 2018). The predominance of phenolic compounds, particularly in the methanol extract, aligns with the established relationship between phenolic content and therapeutic activities in medicinal plants (Tungmunnithum et al., 2018). The quantitative phytochemical composition demonstrates selective extraction efficiency, with polar solvents extracting higher concentrations of phenolics and flavonoids, while non-polar solvents preferentially extracted terpenoids and steroids, supporting the traditional practice of using different extraction methods for specific therapeutic applications. The antioxidant activity evaluation reveals significant free radical scavenging potential, with IC_{50} values comparable to other well-studied antioxidant plants (Kedare & Singh, 2011). The strong positive correlation between total phenolic content and antioxidant activity ($r = 0.87$, $p < 0.01$) confirms the contribution of phenolic compounds to the plant's therapeutic efficacy. The identification of specific antioxidant compounds like quercetin, rutin, and gallic acid through HPLC analysis provides molecular evidence for the observed activities and supports the potential application of *C. macleodii* in managing oxidative stress-related disorders (Sharma et al., 2021).

The broad-spectrum antimicrobial activity against both Gram-positive and Gram-negative bacteria, as well as fungal pathogens, validates the traditional use of *C. macleodii* for treating infectious diseases (Ahmad et al., 2018). The superior activity against Gram-positive bacteria suggests the presence of compounds that effectively target peptidoglycan synthesis or cell wall integrity. The presence of caffeic acid and rosmarinic acid, known for their antimicrobial properties, provides mechanistic insights into the observed activities (Ramos et al., 2019). The moderate MIC values, while higher than synthetic antibiotics, are significant for natural products and suggest potential for combination therapies or topical applications. The hepatoprotective activity assessment demonstrates significant protection against chemical-induced liver damage, supporting the traditional use of *C. macleodii* for liver disorders (Singh et al., 2017). The dose-dependent response and restoration of liver enzyme levels to near-normal values indicate genuine hepatoprotective potential. The mechanism likely involves multiple pathways including antioxidant activity, anti-inflammatory effects, and direct hepatocyte protection. The presence of rutin and quercetin, well-documented hepatoprotective compounds, provides molecular basis for the observed effects (Enogieru et al., 2018).

7. Conclusion

This comprehensive investigation of *Cordia macleodii* provides substantial scientific validation for its traditional medicinal applications and establishes its potential as a valuable source of natural therapeutic compounds. The quantitative phytochemical analysis revealed significant concentrations of bioactive secondary metabolites, with methanol extract showing the highest content of phenolics, flavonoids, and terpenoids. The plant demonstrated potent antioxidant activity with DPPH IC_{50} value of 156.2±12.4 µg/mL, broad-spectrum antimicrobial activity against clinically important pathogens, and significant hepatoprotective effects with 78.3±4.2% protection at 400 mg/kg dose. HPLC analysis identified key

bioactive compounds including rosmarinic acid, rutin, quercetin, and caffeic acid, providing molecular basis for the observed biological activities. These findings establish *C. macleodii* as a promising candidate for pharmaceutical development and support its sustainable utilization in modern healthcare systems. Future research should focus on isolation and characterization of novel compounds, mechanism of action studies, and clinical evaluation to fully realize the therapeutic potential of this valuable ethnomedicinal plant.

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