

Phytochemical Diversity and Therapeutic Horizons of Maidenhair Ferns (*Adiantum* Spp.)

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Abstract:

Adiantum species, also called maidenhair ferns, belong to the Pteridaceae family and have been utilised in traditional medicine across various cultures for treating respiratory ailments, skin disorders, inflammation, and more. This chapter reviews the biomedical sciences of key *Adiantum* species, focusing on their phytochemistry and validated pharmacological activities such as antimicrobial, antioxidant, anti-inflammatory, antidiabetic, and anticancer effects, as reported in recent studies up to 2025. Over 130 Active phytochemicals, including flavonoids. (rutin, quercetin, and luteolin), phenolic acids (chlorogenic acid and caffeic acid), and terpenoids, underpin these properties, with promising in vitro, in vivo, and in silico evidence. Despite low toxicity profiles, clinical trials remain scarce, highlighting the need for standardised extracts, mechanistic studies, and therapeutic formulations. Recent advancements in extraction techniques, like supercritical fluid extraction, enhance compound isolation for biomedical applications.

Keywords: *Adiantum*; fern; Western Ghats; Medicinal; Pteridophytes.

Botanical Overview

The genus *Adiantum* comprises about 200 species of ferns, distributed in tropical and temperate regions worldwide (Yumkham et al., 2018), thriving in moist, shaded environments such as riverbanks and cliffs (Rawat et al., 2025). Key medicinal species include *Adiantum capillus-veneris* (maidenhair fern) and *Adiantum philippense*, characterized by delicate, fan-shaped fronds on wiry black stipes arising from creeping rhizomes. These pteridophytes reproduce via spores and exhibit resilience to desiccation through adaptive leaf morphology. (Qadir et al., 2025; Rastogi et al., 2018)

Morphologically, *A. capillus-veneris* grows 15-75 cm tall with pinnate fronds 15-60 cm long, featuring round-oblong pinnae and marginal sori protected by reflexed edges. Traditional names vary: "Hansraj" in Ayurveda, "Pare-siavashan" in Iranian medicine, and "Shaar-ul-arz" in Arabic regions. Ethnopharmacologically, species treat cough, fever, wounds, hair loss, and digestive issues across Asia, Europe, and the Americas. (Mou et al., 2025; Pan et al., 2011; Rastogi et al. 2018)

Traditional Uses

Adiantum species feature prominently in folk medicine for respiratory disorders like cough, bronchitis, and asthma, often as expectorants and demulcents. In Iranian traditional medicine, *A. capillus-veneris* addresses irregular menstruation, jaundice, splenomegaly, and skin/hair conditions. Ayurvedic uses

include antiulcer, antidyenteric, and antitumor applications for *A. philippense* and others. (Pan et al., 2011; Akhter et al., 2023; Rastogi et al., 2018; Qadir et al., 2025)

Globally, decoctions treat diabetes, liver issues, microbial infections, and wounds; *A. capillus-veneris* promotes breastfeeding, renal function, and acts as an antiparasitic. Topical pastes manage dandruff and hair loss, while infusions serve as diuretics and febrifuges. These uses align with modern validations, bridging ethnomedicine and pharmacology. (Dehdari & Hajimehdipoor 2018; Rastogi et al., 2018; Mou et al., 2025)

Phytochemical Constituents

Adiantum species yield diverse metabolites: flavonoids (quercetin, rutin, luteolin, kaempferol, astragalin), phenolic acids (chlorogenic, caffeic, ferulic, p-coumaric), triterpenoids (ursolic acid, filic-3-ene epoxide), phenylpropanoids, coumarins, phytosterols, fatty acids (hexadecanoic, linoleic), and saponins. (Akhter et al., 2023; Rastogi et al., 2018; Qadir et al., 2025)

Essential oils from *A. capillus-veneris* feature carvone (33%), carvacrol (15%), thymol, and hexahydrofarnesyl acetone, analysed via GC-MS. HPLC-DAD-MS identifies high flavonoid content (4.66 mg CE/g DW), with quercetin-3-O-glucoside (949.5 µg/g), (Boukada et al., 2022) and 3,5-di-O-caffeoylquinic acid (769 µg/g). Minerals abound: K (17.95 mg/g), Ca (11.52 mg/g), Mg (2.90 mg/g). *A. philippense* shares quercetin, luteolin, and terpenoids like glycyrrhetic acid. (Rastogi et al., 2018; Akhter et al., 2023)

Boukada, Fadhela, et al. "CHEMICAL COMPOSITION, ANTIOXIDANT AND ANTIBACTERIAL ACTIVITY OF *Adiantum capillus-veneris* L. EXTRACT FROM ALGERIA." *Kragujevac journal of Science* 44 (2022).

Compound Class	Key Examples	Species	Concentration/Source
Flavonoids	Quercetin, Rutin, Luteolin, Kaempferol	<i>A. capillus-veneris</i> , <i>A. philippense</i>	Quercetin: 108.1 µg/g Rutin major
Phenolics	Chlorogenic acid, Caffeic acid, Ferulic acid	<i>A. capillus-veneris</i>	Chlorogenic: 60.9 µg/g; Ferulic: 183.8 µg/g
Terpenoids	Ursolic acid, Carvone, Filic-3-ene epoxide	Multiple	Carvone: 33% in EO
Fatty Acids	Hexadecanoic, Linoleic	<i>A. capillus-veneris</i>	7.02%
Minerals	K, Ca, Mg	<i>A. capillus-veneris</i>	K: 17.95 mg/g

These contribute to bioactivities via ROS scavenging and enzyme modulation. (Qadir et al., 2025; Rastogi et al., 2018)

Extraction Techniques

Modern methods optimise bioactive recovery: hydrodistillation yields essential oils (0.55% v/w); Soxhlet extracts polyphenols; ultrasound-assisted (UAE) and microwave-assisted (MAE) target phenolics/flavonoids efficiently at low temperatures. Supercritical fluid extraction (SFE) isolates volatiles greenly; RP-HPLC profiles carotenoids/chlorophylls. (Rastogi et al., 2018)

Method	Efficiency	Key Compounds	Advantages (Rastogi et al. 2018)
UAE	High	Saponins, Flavonoids	Short time, eco-friendly
MAE	Very High	Phenolics, Carotenoids	Fast, low solvent
SFE	Very High	Essential oils	Selective, green
Hydrodistillation	Moderate	Volatiles (carvone)	Traditional, simple

These surpass maceration, enabling scalable pharma applications. (Rastogi et al., 2018)

Pharmacological Activities

Antioxidant Effects

Extracts scavenge DPPH radicals potently (IC₅₀ 0.039 mg/mL for EO), suppress H₂O₂-induced ROS, attributed to flavonoids/phenolics. *A. philippense* shows in vitro/in vivo antioxidant activity via quercetin. Reduces lipid peroxidation in cancer models. (Viral et al., 2011; Mou et al., 2025; Akhter et al., 2023; Qadir et al., 2025; Rastogi et al., 2018)

Antimicrobial Activity

Methanolic extracts inhibit MDR bacteria (*S. aureus*, *E. coli*, *K. pneumoniae*) and fungi; highest against *S. aureus*/*Streptococcus*. Leaf methanolic fractions excel via membrane disruption (Singh et al., 2008; Jaafer et al., 2025; Qadir et al., 2025; Rastogi et al., 2018).

Anti-inflammatory and Analgesic

Inhibits LPS-induced cytokines (TNF- α , IL-6, CXCL2) at 0.1 μ g/mL; NF- κ B pathway modulation. Quercetin/luteolin dock COX-2 (-8.1/-8.0 kcal/mol) and are stable in MD simulations for *A. philippense* (Mou et al., 2025; Akhter et al., 2023; Qadir et al., 2025).

Anticancer Potential

Hexane fraction of *A. capillus-veneris* yields IC₅₀ 21-26 μ g/mL vs. HCT-116/A549/MCF-7; 82% EAC inhibition at 200 mg/kg. *A. venustum* reduces tumours via terpenoids/flavonoids. (Ayoub et al., 2020; Viral et al., 2011)

Other Activities

Antidiabetic (α -glucosidase inhibition); wound healing (pro-migratory in HaCaT); hepatoprotective. Photodynamic synergy accelerates healing. (Akhter et al. 2023; Mou et al., 2025; Qadir et al., 2025)

Toxicity and Safety

Studies show non-toxicity up to high doses; no histopathological changes in the liver/kidney. Subchronic trials confirm safety, though ALP monitoring is advised long-term. (Bemidinezhad et al., 2023; Rastogi et al., 2018)

Future Prospects

Standardised extracts, clinical trials, and nanoformulations (e.g., green synthesis) are needed. Molecular mechanisms, bioavailability studies, and combos with light therapy hold promise. *Adiantum* offers untapped biomedical potential against AMR, inflammation, and cancer.

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