Review Article

Comprehensive review of pharmacological activities of *Coleus forskohlii*

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ABSTRACT

Coleus forskohlii (syn. Plectranthus barbatus) is a medicinally important herb belonging to the Lamiaceae family and is widely used in traditional Ayurvedic medicine for the management of cardiovascular, respiratory, digestive, and inflammatory disorders. Due to its broad therapeutic applications and increasing industrial demand, the plant has attracted considerable scientific interest in recent years. The present review comprehensively summarizes the botanical characteristics, geographical distribution, cultivation practices, phytochemical constituents, and pharmacological activities of *Coleus forskohlii*, with special emphasis on forskolin, its principal bioactive diterpenoid. Relevant scientific literature related to traditional uses, agronomy, phytochemistry, and pharmacological investigations was critically analysed to evaluate the medicinal significance and research progress associated with the plant. The review highlights that *Coleus forskohlii* contains a diverse range of secondary metabolites, including diterpenoids, triterpenoids, glycosides, flavonoids, and alkaloids, which contribute to its wide spectrum of biological activities. Among these compounds, forskolin has gained particular importance because of its unique ability to activate adenylate cyclase and increase intracellular cyclic AMP levels, thereby influencing multiple physiological pathways. Experimental and clinical studies demonstrate that forskolin and its derivatives exhibit antiglaucoma, bronchodilatory, antihypertensive, anti-inflammatory, antimicrobial, antioxidant, antidiabetic, hepatoprotective, antimetastatic, antidepressant, and cardiotonic properties. The review also discusses recent developments in cultivation methods, propagation techniques, biofertilizer application, and biological disease management approaches that enhance root yield and forskolin production. Furthermore, forskolin derivatives such as NKH477 and HIL568 have shown promising therapeutic potential in cardiovascular and ophthalmic applications. The collective findings presented in this review emphasize the growing pharmaceutical relevance and medicinal value of *Coleus forskohlii* and support the need for further advanced pharmacological and clinical investigations.

Key words: *Coleus forskohlii*, Forskolin, Phytochemicals, Pharmacological Actions, Medicinal Plants.

Coleus forskohlii (syn. Plectranthus barbatus) is a well-known medicinal plant belonging to the Lamiaceae family and is widely recognized for its therapeutic and pharmacological importance. The genus Coleus, comprising nearly 300 species globally, was described by De Loureiro, and its nomenclature is derived from the Greek word meaning “sheath,” referring to the floral structure. The species name forskohlii honors the Swedish botanist Forsskål [1]. In India, approximately eight species of Coleus have been identified, with *Coleus forskohlii* being the most economically and medicinally significant. Due to its diverse health benefits and increasing demand in the herbal and pharmaceutical industries, the plant has gained substantial importance in global trade and commerce [2].

Traditionally, it has been used in Ayurveda for managing various ailments, particularly those related to the cardiovascular, respiratory, and digestive systems. Phytochemically, *Coleus forskohlii* is rich in bioactive secondary metabolites such as alkaloids, isoflavonoids, and terpenoids [3]. Among these, forskolin, a labdane diterpenoid, is the principal active compound that has attracted worldwide scientific attention due to its unique ability to activate adenylate cyclase and increase intracellular cyclic AMP (cAMP) levels [4]. This biochemical property underlies many of its pharmacological effects. Studies have demonstrated that forskolin and its derivatives exhibit a wide range of biological activities, including inhibition of platelet aggregation, mast cell stabilization, vasodilation, regulation of insulin and thyroid hormone secretion, weight reduction, and enhancement of digestive enzyme activity and nutrient absorption [5].

Additionally, it has been utilized in the treatment of skin disorders as well as respiratory and cardiovascular diseases. From an anatomical perspective, the tubers of *Coleus forskohlii* contain specialized cytoplasmic vesicles within cork cells, which serve as storage sites for forskolin and other secondary metabolites. These vesicles exhibit distinct colouration ranging from yellowish-brown to reddish-brown,

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indicating the accumulation of bioactive compounds over time [6]. Considering its diverse pharmacological properties, traditional significance, and growing economic value, the present review aims to comprehensively summarize the botanical, phytochemical, pharmacological, and therapeutic aspects of *Coleus forskohlii*, highlighting its potential applications in modern medicine and future research prospects.

MATERIALS AND METHODS

This review was conducted using a structured literature survey approach to compile and analyse available information on *Coleus forskohlii*. A comprehensive search was carried out using electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar, covering publications up to 2024. The search strategy employed relevant keywords and Boolean combinations such as "*Coleus forskohlii*," "Plectranthus barbatus," "forskolin," "phytochemistry," "pharmacological activity," "medicinal plant," "therapeutic potential," "anti-inflammatory," "antimicrobial," and "clinical studies."

A total of 120 records were initially identified through database searching. After the removal of duplicate articles, 95 records remained for screening. Titles and abstracts were reviewed, leading to the exclusion of irrelevant studies. Subsequently, 60 full-text articles were assessed for eligibility, out of which 49 studies met the inclusion criteria and were included in the final review. The study selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, ensuring a transparent and systematic approach.

The included studies comprised various types of publications, including original research articles, review papers, in vitro and in vivo experimental studies, clinical studies, and ethnopharmacological reports. The included studies were articles focusing on *Coleus forskohlii* or its major bioactive compound forskolin, studies addressing botanical, phytochemical, pharmacological, or therapeutic aspects, peer-reviewed publications, and articles published in English. Duplicate records, studies not directly related to the topic, articles lacking sufficient scientific data, and non-peer-reviewed sources were excluded from the review.

Relevant data were extracted systematically from the selected studies, including details on plant parts used, types of extracts, identified phytochemicals, and reported pharmacological activities. The literature search and study selection process were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and reproducibility (Figure 1).

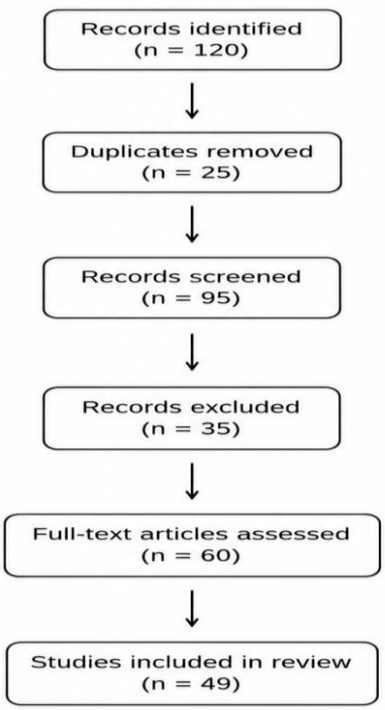

Figure 1: PRISMA flow diagram of the screening and selection process.

RESULTS

Table 1 shows the profile of *Coleus forskohlii*.

Parameter	Description
Scientific Name	*Coleus forskohlii*
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Lamiaceae
Genus	Coleus
Species	forskohlii
Ayurvedic Names	Makandi, Mayani

3.1 Botanical Description

Coleus forskohlii is a soft-stemmed, fragrant, and medicinal plant that belongs to the Lamiales order and family [8]. The plant has an erect stem with four branches, pubescence in nodal regions, and a height of 30 to 60 cm (Figure 2A, B). The leaf is 5 cm in breadth and 7.5 cm in length. The leaves are shaped like a teardrop and have a greenish colour. The middle of the leaf may be purple and have hairs on it (Figure 2C) [7]. The blooms have a hairy calyx, are cross-pollinated, and are either lilac or light purple in hue. The raceme inflorescence is between 2 and 2.5 cm in length (Figure 2D) [9]. Two lobes form on the stigma, while the ovary consists of four locules (Figure 2D). The main ecological characteristic of its root is that it is fasciculate, conical, golden brown, and measures 0.5 to 2.5 cm in width (Figure 2F) [10].

Figure 2: A. young *Coleus forskohlii* plant that is thriving in its native environment. B. Hairy stems. C. Hairy leaves. D. Flowers in various phases of growth. E. Mature plants. F. Roots of plants.

3.2 Geographical distribution

Coleus forskohlii is prevalent in several tropical and subtropical regions globally. This plant originates from India [11]. The countries of India, China, Nepal, Sri Lanka, Pakistan, Ethiopia, Egypt, Brazil, tropical East Africa, and Arabia are supposedly receiving it [7]. In India, it occurs naturally in the Himalayas, in the Shimla hills, Kumaon hills, Garhwal hills, as well as the Parasnath hills in Bihar, and the Western Ghats [12].

3.3 Cultivation Practices

Coleus forskohlii thrives in red sandy loam soil (pH 5.5–7), with temperatures of 10–25°C, 83–95% humidity, and 100–160 cm of annual rainfall [10]. It is mainly propagated through terminal stem cuttings (10–12 cm) that are transplanted at 60 cm spacing, with proper irrigation, weeding, and plant protection [13]. The crop grows well with organic and inorganic fertilisers. There is a need to use 140 kilos of organic manure on the 30th and 45th days after planting [14].

Growth and forskolin content may be enhanced by arbuscular mycorrhizal fungi such as Glomus bagyarajii [15]. Major pests include mealy bugs, root-knot nematodes, and leaf-eating caterpillars. Soil-borne diseases such as Fusarium chlamydosporum and root rot caused by Macrophomina phaseolina can be managed using bioagents like Trichoderma viride, Glomus mosseae, and Trichoderma harzianum combined with zinc sulphate [16,17]. Harvesting occurs after 4.5–5 months, yielding approximately 800–1000 kg/ha of dried roots, which may increase up to 2000–2200 kg/ha under optimal agronomic practices [13].

3.4 Phytochemical Properties

There are many chemicals derived from the parts of *Coleus forskohlii*, each with different uses. These are given in Table 2.

Table 2. Phytochemical properties of *Coleus forskohlii*

Compound/ Group	Type of Compound	Source (Plant Part / Extract)	Key Activity / Significance	Reference
Forskolin (coleonol)	Labdane diterpenoid	Root extract	Antiglaucoma, cardiotonic, widely studied bioactive compound	[18]
HIL 568	Forskolin derivative	Synthetic/derived compound	Antiglaucoma agent	[19]
NKH 477	Forskolin derivative	Synthetic/derived compound	Cardiovascular stimulant (cardiotonic)	[19]
α-Amyrin	Triterpenoid	Root extract	First isolated triterpenoid from a plant	[19]
Betulinic acid	Triterpenoid	Root extract	Bioactive triterpene with pharmacological potential	[19]
Forskoditerpenoside A & B	Labdane diterpene glycosides	Ethanol extract (whole plant)	Smooth muscle relaxant (guinea pig tracheal studies)	[20]
Forskoditerpenosides C, D & E	Labdane diterpene glycosides	Ethanol extract (whole plant)	Relaxant effect on tracheal smooth muscle	[21]
Forskoditerpene A	Labdane diterpene (spiro structure)	Whole plant extract	Novel spiro-labdane derivative, pharmacologically active	[21]

3.5 Pharmacological Profile

Coleus forskohlii has the potential to treat seizures, insomnia, excruciating urination, congestive heart failure, and high blood pressure [22]. It has also been shown to reduce inflammation [23].

In addition to supporting these traditional uses, clinical studies on the plant and its forskolin component show that it may help cure psoriasis, asthma, angina, and cancer metastases. Detail pharmacological activities have been described as follows;

3.5a. Antiglaucoma

1 percent suspension of forskolin prepared by using *Coleus forskohlii* can reduce intraocular pressure in humans, monkeys, and rabbits by lowering the synthesis of aqueous fluid [24].

3.5b Asthma

The active constituent of *Coleus forskohlii* is forskolin, which has been investigated as a bronchodilator in the treatment of asthma. It was discovered to inhibit the action of the histamine

and leukotrienes C-4- induced bronchospasm and bronchitis in guinea pigs [25].

3.5c Anti-obesity

The anti-obesity effects involved the use of *Coleus forskohlii* extracts, leading to weight loss, intake of food, and adipogenesis in ovariectomised rats that were used in the study [26].

3.5d Antimicrobial

Coleus forskohlii showed both bacteriostatic and bactericidal effects against Staphylococcus aureus, with minimum inhibitory concentration varying between 60 and 300 µg/ml [27].

3.5e Anti-inflammatory

Forskolin administered intraperitoneally (i.p.) to rats significantly and dose-dependently lowers paw swelling caused by carrageenan. Rats that had ear inflammation from croton oil and polyarthritis from an adjuvant had similar results [23].

3.5f Antihypertensive

Forskolin causes dogs, cats, and rodents with spontaneous hypertension and renal hypertension to have higher rates and lower blood pressure [28]. It was found that coleonol, a diastereoisomer of forskolin, which is produced as an extract of *Coleus forskohlii* using 50 percent ethanol, was effective in the relaxation of vascular smooth muscle. This resulted in a reduction of blood pressure in both spontaneously hypertensive rats and anaesthetised cats and rats [9].

3.5g Antimetastatic & Antiproliferative

In mice injected with cancerous cells, forskolin was shown to be a powerful inhibitor of cancer spread. Mice given as low as 82 mcg showed a 70% reduction in metastasis. In vitro, 13-epi-sclareol stopped the growth of uterine and breast cancer cells [29]. The A375 cell line was the most responsive when Coleon C's ability to stop the growth of cells was evaluated on eight human cancer cell lines [30].

It was determined that Coleon C might stop cancer cells from growing and spreading by causing apoptosis with very little harm to healthy cells. Barbatusin has been demonstrated to stop Lewis's lung cancer and lymphocytic leukaemia (P388) in mice [31].

3.5h Antidepressant

When rats are forced to swim, forskolin is shown to be a potent antidepressant. Like the effects of amitriptyline therapy, forskolin (0.01-0.1 mg/kg) reduced perceptions of immobility in a dose-dependent manner. Forskolin at a dosage of 0.01 mg/kg gave the most pronounced effects, so it is 150 times stronger than amitriptyline at 15 mg/kg [32].

3.5i Antidyspeptic

Coleus forskholii's aqueous extract prevents stress-induced stomach ulcers and reduces gastric output, suggesting an antidyspeptic action [33].

3.5j Antioxidant

Studies on the antioxidant properties of *Coleus forskohlii* have shown that, in addition to their health benefits, the tubers have a lot of potential as both enzymatic and non-enzymatic antioxidants. These antioxidants may help protect against oxidative damage and the harm caused by free radicals [34].

3.5k Antidiabetic

In vitro, forskolin increases insulin release triggered by glucose. This seems to indicate that forskolin generally stimulates adenylate cyclase activity, negating its applicability as a therapy for diabetes [35].

3.5l Antimycotic

Research on several fungi, including Aspergillus flavus, Trichoderma rubrum, and Microsporum gypseum, revealed that chloroform extract has the most inhibitory action [36].

3.5m Hepatoprotective

Forskohlii and 1,9-dideoxyforskolin help protect the liver by activating the PXR [37].

3.5n Immune System Enhancement

In several studies, forskolin significantly boosts the immune system (mostly by activating macrophages and lymphocytes) [38].

3.5o Psoriasis

Four psoriasis patients participated in clinical research, and it was shown that their psoriatic symptoms improved after they received forskolin. Forskolin's capacity to control Cyclic AMP levels in skin cells has been demonstrated to provide therapeutic value to psoriasis patients [39].

3.5p Urinary Tract Infection (UTI)

When mice were infected with the type 1 fimbriated uropathogenic Escherichia coli, their bladder epithelial cells were observed to exocytosis fusiform vesicles containing E. coli upon administration of forskolin either intravenously or intramuscularly. This allowed the antibiotics to reach the bacterium by reducing the amount of E. coli inside the cells [40].

3.5q Vasculogenic properties

Forskolin can be administered in addition to a typical three-agent pharmacotherapy for erectile dysfunction, according to research on the drug for vasculogenic impotence. Additional in vitro and in vivo research was conducted that suggests forskolin may be useful in treating this illness [29].

3.5r Cardiovascular action

NKH477 is the best water-soluble forskolin derivative until now. Research has been published describing the successful wearing of an infant after repair of a complex congenital heart defect, removed from cardiopulmonary bypass with the help of the continuous infusion of NKH477 [41,42].

DISCUSSION

The review of *Coleus forskohlii*, along with recent research developments, offers a comprehensive understanding of the plant's phytochemistry, cultivation methodologies, and extensive pharmacological potential.

From an agronomic perspective, innovative methodologies such as aeroponic cultivation have shown considerable potential in augmenting both the biomass and forskolin yield of *Coleus forskohlii*. This controlled, soil-less system presents an environmentally sustainable and resource-efficient approach to producing bioactive-rich plant material, thereby addressing the challenges associated with traditional soil cultivation and ensuring consistent phytochemical profiles. Metabolomic profiling further corroborates that such abiotic stress factors can positively influence secondary metabolite production, underscoring the importance of optimizing cultivation methods for the quality and sustainability of medicinal plants [43].

Phytochemically, *Coleus forskohlii* is characterized not only by the presence of forskolin but also by a diverse array of terpenoids and related diterpene glycosides, which contribute to its extensive range of pharmacological effects. The identification of a unique CytB5 (CfCytB5A) that enhances forskolin production in yeast highlights the potential for biotechnological production of plant specialized metabolites, which may eventually supplement or replace traditional plant cultivation sources [44].

Pharmacologically, the molecular activation of cAMP by forskolin mediates numerous physiological effects, including vasodilation, bronchodilation, anti-inflammatory and antimicrobial actions, metabolic regulation, and neuroprotection. Emerging evidence supports its benefits in glaucoma through the reduction of intraocular pressure, in cardiovascular diseases via vasculogenic and cardiac effects, and in anti-cancer activities by inhibiting proliferation and metastasis. Furthermore, innovative delivery systems, such as forskolin-loaded halloysite nanotubes incorporated into biomaterial scaffolds, demonstrate potential for regenerative medicine through osteoinductive effects, showcasing the expanding biomedical applicability of forskolin beyond traditional uses [45,46].

Despite these promising outcomes, several limitations must be acknowledged. A substantial proportion of the available studies are based on in vitro and animal models, while clinical evidence in humans remains limited. Key aspects such as pharmacokinetics, dosage optimization, long-term safety, and potential toxicity of *Coleus forskohlii* and forskolin require systematic clinical evaluation. In addition, phytochemical variability due to differences in geographical origin, cultivation conditions, and extraction methods presents challenges for standardization and reproducibility. Although nanoparticle-based formulations have demonstrated enhanced bioactivity, their clinical applicability remains uncertain due to limited data on biocompatibility and safety. Furthermore, the molecular mechanisms underlying several pharmacological effects, particularly anticancer and immunomodulatory activities, are not yet fully understood [43,47].

Future research should focus on addressing these gaps through well-designed clinical trials to establish the efficacy, safety, and optimal dosing of *Coleus forskohlii* extracts and forskolin derivatives in humans. Standardization strategies, including advanced cultivation techniques such as aeroponic systems and controlled abiotic stress conditions, may improve phytochemical consistency and yield. Additionally, detailed mechanistic studies using molecular pharmacology and systems biology approaches are needed to identify specific cellular targets and signalling pathways. Such efforts may facilitate the development of standardized, mechanism-based therapeutic formulations and support the integration of this medicinal plant into evidence-based clinical practice [48,49].

CONCLUSION

Coleus forskohlii is a highly effective medicinal plant with significant therapeutic potential and pharmacological effects.

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