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Analytical Techniques for Phytochemicals Screening and Bioactivities Of Some *Coleus* Species: A Review

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Abstract
Medicinal plants are of great significance to health of individuals and communities. Due to their great importance, demand of medicinal plants has increased in numerous fields. Among various plants of medicinal importance, plants of genus *Coleus* belonging to family Lamiaceae or Labiatae are well known for their biological activities. Flavonoids, glycosides, volatile constituents, phenolic and many other compounds have been reported as the active phytoconstituents of the *Coleus species.* These isolated and identified bioactive compounds have been analyzed by using phytochemical screening assays, chromatographic techniques (HPLC and TLC), NMR, UV spectroscopy as well as GC-MS. The fundamental aspiration of current review stems for the availability of literature on phytochemicals compounds and biochemical activities of the prominent species of the genus *Coleus*.
Key words: Metabolites, Constituents, Herb, Lamiaceae, *Coleus* species.

INTRODUCTION

Nature has been a source of medicinal agents for thousands of years. An impressive number of modern drugs have been isolated from natural sources that are based on their use in traditional medicine. The genus *Coleus* (family Lamiaceae) comprises a number of herbaceous medicinal plants which are particularly employed in home remedies for various ailments. The active constituents contributing to these protective effects are naturally occurring phytochemicals, vitamins and minerals that give plants their colour and flavor. Alkaloids, tannins, flavonoids, phenolic compounds and bioactivities like anti-inflammatory, antithrombotic, antioxidative and anticarcinogenic activities play a major role in preventing number of chronic diseases in human beings [1]. In the present scenario, medicines and drugs for clinical purposes contain natural products and their derivatives. According to WHO, 70% to 80% of the population in many developed countries have used some form of alternative or complementary medicine from traditional plant products. Therefore, it becomes necessary to explore active constituents from medicinal plants which are responsible for biochemical and pharmacological activities. The present review summarizes information available on the phytochemical compounds (Table 1) and biochemical activities (Table 2) of *Coleus* species.

PHYTOCHEMISTRY OF *COLEUS* SPECIES

Various phytochemicals or bioactive compounds occur in plant extracts as a combination of different polarities and their separation is a big challenge for the identification and characterization of these compounds. A number of different separation techniques such as TLC, column chromatography, flash chromatography, Sephadex chromatography and HPLC have been used to analyze the phytochemical compounds. These compounds are then used for the determination of structure and biological activity of different plant species.

Among different species of *Coleus, C. aromaticus* has the tremendous potential as a traditional medicine, probably due to presence of large number of bioactive compounds. Essential oil of *C. aromaticus* is rich in carvacrol, thymol, eugenol, chavicol, ethyl salicylate [2] and contains γ-terpinolene (3.75%), pinene (2.50%), β-caryophyllene (4.20%), methyl eugenol (2.10%), thymol (41.3%), 1,8-cineole (5.45%), eugenol (4.40%), carvacrol (13.25%) and phellandrene (1.90%) [3]. Haque [4] detected 15 components in the essential oil (0.1%) by dry steam distillation of the fresh stalk and leaves of *C. aromaticus*. Prudent et al. [5] identified some important constituents like (Z)-1, 3-hexadiene (0.1%); (Z)-3-hexenol (0.6%); (E,Z) farnesene (0.2%); (E,E) farnesene (0.2%) and murolene (0.2%) in *C. aromaticus*. On the other hand, volatile constituent of Mauritius's *C. aromaticus* were reported to contain camphor (39%) along with carvacrol (41.3%) [6]. Pino et al. [7] also characterized some volatile compounds from *C. aromaticus* leaf by steam distillation, hexane extraction, super critical CO_2 extraction and identified 26 components by GC/MS. Butylaniside; caryophyllene; carvacrol; 1-8-cineole; p-cymene; ethylsalicylate; eugenol; limonene; myrcene; pinenes; selenene; terpinene; terpinen-4-ol; thymol; verbenone (essential oil); apigenin; chrysoeriol; 5,4-dihydroxy-6,7-dimethoxy-flavone (cirsimaritin); eriodictyol; 6-methoxygenkawanin; luteolin; quercetin; salvigenin; taxifolin; oxaloacetic acid; crategolic; euscaphic; 2,3-dihydro-olean-12-en-28-oic; pomolic; oleanolic; tormentic; 2,3,19,23-tetrahydroxyurs-12-en-28-oic; sitosterol; D-glucoside were isolated from the leaves of the *C. aromaticus* by Chatterjee and Pakrash [8]. Rosmarinic acid was found as a major component and principally responsible for the radical scavenging activity of *C. aromaticus* [9]. Knab et al. [10] isolated eucalyptol from leaves of *C. aromaticus* by steam distillation and solid phase micro extraction (SPME) methods. Phenolic and polyphenol constituents namely carvacrol, flavonoids, rosmarinic acid, caffeic acid and chlorogenic acid are reported to be responsible for antioxidant activity of *C. aromaticus* [11-12]. Leaves of *C. aromaticus* contained flavones like salvigenin; 6-methoxygenkwanin; quercetin; chrysoeriol; luteolin and apigenin (fig. 1), as well as flavanone along with eriodyctol and flavanol (taxifolin; triterpenic acids; oleanolic acid; 2,3-dihydroxyoleanolic acid; crategolic acid; ursolic acid; pomolic acid; euscaphic acid; tormentic acid and 2,3,19,23-tetrahydroxyursolic acid) [13]. The GC and GC–MS analysis of *C. aromaticus* essential oil showed the presence of 28 compounds, of which 16 compounds were identified with thymol (94.3%) as a major constituent, followed by carvacrol (1.2%), 1,8-cineole (0.8%), p-cymene (0.3%), spathulenol (0.2%) and terpinen-4-ol (0.2%) as minor constituents [14]. Jasmine and Selvi [15] analyzed antibacterial activity of bioactive constituents from the acetone extract of *Coleus aromaticus* leaves by Gas chromatography-Mass spectrometery. Four major components 1,2-Benzene diol 4-(1,1 dimethyl ethyl), phytol, Squalene and Eudesma-4 (14),11- diene were identified.

Another species of *Coleus*, *C. forskohlii* was reported to contain diterpenoids *viz.,* deactylforskolin; 9–deoxyforskolin; 1,9-deoxyforskolin; 1,9-dideoxy-7-deacetylforskolin in addition to forskolin (7 β-acetoxy-8,13-epoxy-1α, 6 β, 9 α-trihydroxylabd-14-en-11-one) in tuber roots extract [16-22]. Forskolin was discovered in the year 1974 and was termed as coleonol [23-25]. However, after the identification of other coleonols and diterpenoids, the name of colenol was later changed to forskolin [16]. Misra et al. [26] reported the presence of 3-decanone, bornyl acetate, β-sesquiphellandrene and γ-endesmol as major constituents in essential oil from the roots of 10 genotypes of *C. forskohlii.* Chowdhury and Sharma [27] identified 18 important compounds from *C. forskohlii* of which 22% were hydrocarbons and 69% oxygenated compounds with α-fenchyl acetate and α-pinene as the major components. Xu et al. [28] obtained six compounds from the roots of *C. forskohlii* and identified their structures as 14-deoxycoleon U, demethylcryptojaponol, α -amyrin, betulic acid, α -cedrol and β -sitosterol. The compounds *viz.,* α-amyrin and betulic acid were first time isolated from *C. forskohlii*. Similarly 2 new diterpenoids forskolin I (1 α, 6 β-diacetoxy-7 β, 9 α-dihydroxy-8,13-epoxylabd-14-en-11- one) and J (1 α, 9 α-dihydroxy-6 β, 7 β- diacetoxy-8,13-epoxylabd-14-en-11-one) were isolated from *C. forskohlii* by Shen and Xu [29]. Bioactivity of root hexane extract of *C.forskohlii* was analyzed using Varian 4000 gas chromatography mass spectrometry (GC-MS-MS). Six major components α-cedrene, β- cadinene, citronellal, two labdane derivatives and ß-citronellol were identified. These components have been characterized and identified as a rich source of medical and other biological properties [30].

While Pino et al. [31] investigated the essential oil of *C. amboinicus* by using LSC, GLC and GC-MS technique and identified 20 components including 13 terpene hydrocarbons and 7 oxygenated compounds. Ragasa et al. [32] isolated three flavones: salvigenin, crisimaritin and chrysoeriol by silica gel chromatography from leaves of *C. amboinicus* using 1D and 2D NMR and UV spectroscopy. Chemical investigations of essential oil of *C. amboinicus* leaf by GC and GC-MS techniques by Singh et al. [14] indicated the presence of six components. The major component was thymol followed by carvacrol, 1, 8-cineole, p-cymene, spathulenol, terpine-4-ol and an unidentified component. Other species of *Coleus* such as *C. zeylanicus, C. laniniatus* and *C. parvifolius* also are reported to have valuable phytochemicals used for preparation of traditional medicine. Thoppil [33] reported the essential oil composition of *C. zeylanicus* and found α-terpineol and δ-cadinene as the major components. Thoppil and Jose [34] showed the presence of β-ionone, α-humulene in *C. laniniatus* and β-thujone, α-farnesene in *C. parviflorus*. Eighty compounds were detected with monoterpenes especially geraniol and nerol derivatives, hexane and octane derivatives as the main constituents by GC-FID, GC-MS and olfactoric evaluation in essential oil of the leaves of *C. zeylanicus* [35]. Yuenyongsawad and Tewtrakul [36] analyzed the essential oil of leaves of *Coleus parvifolius* Benth. (Labiatae) by gas chromatography and mass spectrometry (GC-MS) and identified (*E*)-phytol, followed by eicosatrienoate; *n*-tetradecanoic acid; octoil; 2-methyl-7-octadecyne; nonadecane (3.25%), germacrene-D and α-humulene (1.42%).

BIOLOGICAL ACTIVITIES

Antioxidant activities

Antioxidants from natural sources have received special attention owing to their health promoting effects. These naturally-occurring antioxidants can be synthesized to give nutraceuticals that can help to prevent oxidative damage occurring in the body [12]. Rao et al. [37] investigated the antioxidant, anticlastogenic and radioprotective effects of an hydroalcoholic extract of *C. aromaticus* (CAE) on Chinese hamster fibroblast cells (V 79) exposed to gamma radiations. A dose-dependent increase in radical scavenging ability was observed against various free radicals *viz.,* 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), superoxide anion, hydroxyl and nitric oxide generated *in vitro.* CAE also exhibited a moderate inhibition of lipid peroxidation *in vitro*. The extract also rendered protection against radiation induced DNA damage as evidenced by the significant ($P<0.05\%$) decrease in the percentage of radiation-induced micronucleated cells (MN) and frequency of micronuclei.

Kumaran and Karunakaran [38] investigated the antioxidant potency of freeze-dried aqueous extract of *C. aromaticus* (CAE) employing various established *in vitro* systems, such as the β-carotene-linoleate model system, 1, 1-diphenyl-2-picrylhydrazyl (DPPH)/ superoxide/ nitric oxide radical scavenging, reducing power and iron ion chelating activity. CAE showed notable inhibitory activity in the β-carotene-linoleate model system, a moderate concentration dependent inhibition of DPPH radical. CAE also showed significant reducing power, superoxide scavenging ability, nitric oxide-scavenging activity and ferrous ion chelating potency. The study clearly established the antioxidant potency of freeze-dried extract of *C. aromaticus* (CAE). Zakaria et al. [39] reported antioxidant activity of a group of Lamiaceae plants namely *C. blumei, Orthosiphon staminess, Ocimum basilicum* and *Mentha arvensis* using DPPH (2, 2-diphenyl-1-picrylhydrazyl radical) scavenging assay. Rasineni et al. [12] examined free radical quenching activity and polyphenols in three species of *Coleus viz*., *C. forskholii* Briq., *C. aromaticus* Benth. and *C. zeylanicus* Benth. Plant extracts of *C. forskholii* exhibited high amount of polyphenols and higher antioxidant activity as compared to *C. aromaticus* and *C. zeylanicus*.

Nugraheni et al. [40] studied antioxidant properties of *C. tuberosus* using the 1,1-diphenyl-2-picryl hydrazyl radical assay, antiproliferative activity using 3-(4,5-dimethylthiazol-2)-2,5-diphenyltetrazolium bromide assay. The results showed that ethanolic extract of flesh of *C. tuberosus* and ethanolic extract of peel of *C. tuberosus* might be used as a potential source of natural antioxidants and antiproliferative agents.

Khatun et al. [41] investigated antioxidative activity of various parts including roots, stem, leaves and tubers of *C. forskohlli*. For enzymatic antioxidant properties, activities of superoxide dismutase, peroxidase, polyphenol oxidase and catalase were observed to be significantly higher in tubers than in leaves, roots and stem. Jaslin et al. [42] estimated total flavonoid and reported the antioxidant potential of ethanolic extract of the aerial parts of *C. spicatus* by ferric reducing ability of plasma (FRAP) assay.

Antimicrobial activities

Various extracts and essential oils of *C. aromaticus* have great anti-microbial activities against various phytopathogenic microorganisms. Rao et al. [43] reported antimicrobial activity of *C. aromaticus* oil against pathogenic, nonpathogenic fungi and bacteria. In another study flavonoids, *viz.,* salvigenin and cirsimaritin isolated from *C. aromaticus* showed low antimicrobial activities against *Psedomonas aeruginosa*, *Bacillus subtilis*, *Escherichia coli*, *Staphylococcus aureus*, *Candida albicans*, *Tricophyton mentagrophytes* and *Aspergillus niger* [32]. Deena et al. [44] studied *in vitro* antimicrobial activity of the essential oils of *C. aromaticus* and *C. zeylanicus* against seven bacteria *viz., Bacillus megaterium, B. subtilis, Eschericha coli, Staphylococcus aureus, Proteus vulgaris, Pseudomonas arrugenisa* and *Xanthomonas campestris* and eight fungi *viz., Aspergillus niger, A. parasiticus, Rhizoctonia oryzar-sativae, R. oryzae, Colletotrichum musae, Fusarium solani, Candida albicans and Alternaria brassicicola.* In this comparative study, essential / volatile oil of *C. zeylanicus* was found to have slightly higher inhibitory effect than *C. aromaticus* against different bacteria and fungi used. Pritima and Pandian [45] studied antimicrobial activity of leaf discs of *C. aromaticus* against microbes of reproductive tract infection among women. *Candida kru*sei showed high zone of inhibition followed by *Candida albicans, Proteus mirablis, Escherichia coli, Staphylococcus aureus, Enterococcus faecalis, Klebsiella pneumoniae* and the least inhibition was observed for *Neisseria gonohorreae.*

The essential oil of aerial parts of *C. amboinicus* exhibited antibacterial activity against *Bacillus subtils* (gram positive) and *Pseudomonas fluorescens* (gram negative) and antifungal acitivity against *Cladosporium cucumerinum.* Bioassay-guided fractionation revealed that carvacrol and β-caryophyllene-4,5-oxide were the major contributors to the antimicrobial activity of the essential oil [46]. Perumal et al. [47] studied ethanolic extract of nine medicinal plants along with *C. aromaticus* for antifungal activity against *Aspergillus flavus, A. terreus* and *Mucor* species. Nilani et al. [48] found antifungal activity of extracts of *C. forskohlii, C. blumei* and *C. barbatus* by testing against pathogenic fungi like *Aspergillus niger, A. fumigates, A. ruantii, Proteus vulgaris* and *Canadida albicans*. The study showed that extract of *C. forskohlii* and *C. barbatus* exhibited significant antifungal activity against all selected organisms while extract of *C. blumei* did not show any significant effect. Discs of fresh leaves of *Coleus aromaticus* were found to be effective against microorganism's *viz., Candida albicans, C. krusei, Proteus mirabilis, Escherichia. coli, Staphylococcus aureus, Entereococcus feacalis, Klebsilla pnemoniae, Neiseri* and *Streptococcus mutans* [49]. Oils of *C. aromaticus* were also reported to be effective against yeast *Candida albicans*, *C. tropicalis*, *C. guilliermondi*i, *C. kruse*i and *C. stellatoide*a [50]. Methanolic extract of *C. aromaticus* showed activity against *Candida krusei*, *Leishmania chagasi* and *Leishmania amazonensis* [51].

Fresh leaves of *C. aromaticus* were observed to improve the seed germination percentage as well as the seedling vigor and ultimately the yield of okra apart from being antifungal [52]. Murthy et al. [53] observed that ochratoxin production from *Aspergillus ochraceus* was completely inhibited by the essential oil of *C. aromaticus.* Hydroalcohalic extract of *C. aromaticus* showed a great activity on methicillin resistant *Staphylococcus aureus* (MRSA) strains with minimum inhibitory concentration ranging from 18.7 to 9.3 mg/ml [54]. Saklani et al. [55] investigated antimicrobial activity of extract of *C. forskohlii* against bacteria *Staphylococcus aureus, Pseudomonas fluorescens, Sericea, Kelebsiella pneumonia, Bacillus pumilus* and fungi *Aspergillus flavus, Aspergillus parasiticus rubrum, Microsporum gypseum.* The study revealed the effectiveness of extracts of *C. forskohlii* in inhibiting the growth of microbes. Khattak et al. [56] investigated antifungal and antibacterial activity of *Coleus Spp* (*C. blumei, C. amboinicus , C. aromaticus*) leaves using macro dilution method against *viz., Bacillus subtils* and *Staphylociccus aureus* (gram positive) and *Escherichia coli* and *Pseudomonas aeruginosa* (gram negative) and disc diffusion method against *Candida albicans* (a fungi). Maximum inhibitory concentration (MIC) of all leaf extracts ranged from 1.0-2.0 mg/ml to inhibit the growth of *S. aureus, E. coli, P. aeruginosa* and *B. subtilis*. These results showed that *Coleus* leaves possessed anti-bacterial and anti-fungal activities. Revathi et al. [57] investigated antifungal activities of essential oils extracted from leaves of *C. aromaticus* against two fungal species *Candida albicans, Aspergillus niger*. The essential oil was reported to have maximum zone of inhibition against *C. albicans*. Mathur et al. [58] found antifungal activity of *C. barbatus* (Pathar choor) against *Aspergillus niger* and *Canadida albicans*. Hydro-alcoholic extracts of *C. barbatus* found to have maximum antifungal activity in comparison to hexane extracts. Crude water, crude alcohol, soxhlet water and soxhlet alcoholic extracts of *C. aromaticus* leaves were screened for antibacterial activity against five human pathogens isolated from sputum. Crude water extract was found to show the best activity for all the isolates. The results showed that zone of inhibition were maximum for *Pseudomonas aeruginosa* [59].

Anti-inflammatory activity

The anti-inflammatory effects of aqueous leaf extracts of *C. aromaticus* was evaluated using carrageenan induced rat paw edema. The study revealed extract at dose of 250 and 500 mg/kg produced significant reduction in the paw edema and exhibited potent anti-inflammation activity [52]. The extracts of *C. forskohlii* prepared by using *n*-hexane, chloroform, methanol, aqueous methanol (80% methanol) as solvents were screened for secondary metabolites and their *in vitro* anti-inflammatory activity. The study revealed the presence of alkaloids, phenols, tannins, proteins, carbohydrates, saponins, glycosides and cardiac glycosides in *C. forskohlii* [60].

Antiurolithiatic activity

Water extract of leaves of *C. aromaticus* was tested for antiurolithiatic activity against calcium oxalate stones in male albino rats. The water extract of *C. aromaticus* was found to be effective in reducing deposition of calcium oxalate. These results showed that *C. aromaticus* leaves were effective in the therapy of calcium oxalate stone in kidney and urinary tract [61]. Venkatesh et al. [62] investigated antiurolithiatic activity of *C. aromaticus* in ethylene glycol induced urolithiatic rats. The study revealed a significant increase in the levels of calcium oxalate crystals in the kidney as well as lipid levels in the blood serum. The results showed that treatment with hydro-alcoholic extract of *C. aromaticus* leaves (CALHAE) significantly reduced cholesterol levels and triglyceride levels in urolithiatic rats. Moreover, hydro-alcoholic extract of *C. aromaticus* leaves (CALHAE) showed potent *in vitro* antioxidant activity in DMPD, ABTS radicals.

Other activities

Fischman et al. [63] showed that water extract of *C. barbatus* produced mild stimulation of central nervous system, increased intestinal movement and reduced gastric secretion indicating an antidyspeptic activity. It has also shown protection against gastric ulcers induced by stress. Sur et al. [64] investigated the diuretic activity of *C. aromaticus* on rats. The study was carried out on normal rats by treating with furosemide and *C. aromaticus*. The results showed that urine output and electrolytes concentration were significantly increased.

Bioassay-guided fractionation of a methanolic extract of tubers of *C. tuberosus* afforded the isolation of active anti-tumor compounds which were identified as the triterpenoid 2α, 3β-dihydroxyolean-12-en-28-oic acid (maslinic acid, CT2) and a phytosterol mixture (CT1). CT1 consisted of stigmasterol (32%), β-sitosterol (40.3%), and campesterol (27.7%) as determined by capillary gas chromatography. CT1 and CT2 showed strong anti-tumor activities at IC_{50} 0.7 mg/ml and 0.1 mg/ml, respectively, in a convenient, short term *in vitro* assay, i.e., inhibition of Epstein Barr Virus (EBV) activation induced by phorbol 12-acetate (PMA) and sodium butyrate [65].

Prasenjit et al. [66] studied anthelmintic activity of alcoholic extracts of leaves, stems and roots of *C. amboinicus* against Indian earthworm (*Pheritima posthuma*) and antioxidant activity by DPPH free radical scavenging activity, hydrogen-peroxidant scavenging activity, nitric oxide scavenging activity and reducing power assay using ascorbic acid as standard. The results revealed that all extracts of *C. amboinicus* possessed significant anthelmintic acitivity in a dose dependent manner. Among the tested extracts, the leaf extract was found to be more promosing in comparison to stem and root extracts. *C. barbatus* extracts in different solvents were tested against some gastrointestinal pathogens. In the case of *Escherichia coli,* the inhibition was recorded by treatment of all types of extracts. *Staphylococcus aureus* was found to be resistant against hexane extract of *C. barbatus* while ethanol extract inhibited the growth of *S. aureus*. In case of *S. epidermidis*, water extract of *C. barbatus* has shown higher inhibition than other extracts [58]. Hullatti et al. [67] evaluated the anticonvulsant activity of leaf, stem and roots of *C. amboinicus* by maximal electric shock induced seizures (MES) and pentyenetetrazole (PTZ) induced seizures models in Swiss albino mice. All the extracts have shown significant anticonvulsant activity in both the models. The essential oil of *C. aromaticus* was extracted and tested against *Tribolium castaneum,* a storage grain insect. The E. Oils were found effective against *Tribolium castaneum* during *in vitro* as well as *in vivo* fumigant testing [68].

Nugraheni et al. [69] studied the resistant starch content and effects of consumption of *C. tuberosus* on lipid profile in rats with diabetes mellitus using the megazyme method. The study revealed that the treatment increased the levels of the resistant starch and lowered the lipid profile of Total Cholesterol (TC), Triglyceride (TG) and Low Density Lipoprotein (LDL) and increase High Density Lipoprotein (HDL) in experimental animals. The results showed that resistant starch contained in *C. tuberosus* affected the lipid profile of experimental animals with diabetes mellitus. Kumari et al. [70] evaluated the antiepileptic potential of the leaf juice of *C. amboinicus* by maximal electro shock and pentylenetetrazole models. *C. amboinicus* possessed significant dose dependent antiepileptic activity against MES and PTZ induced seizures and also significant increase in the brain of Na^+/K^+ and $Ca2^+$ ATPases and GABA.

Table 1. Summary of literature on different analytical techniques used for identification of phytoconstituents from *Coleus* spp.

Species	Phytochemicals	Isolation procedure	References
C. amboinicus	Thymol	GC, GC-MS	[14]
	Carvacrol	GC, GC-MS	
	1,8-cinenole	GC, GC-MS	
	p-cymene	GC, GC-MS	
	Spathulenol	GC, GC-MS	
	Terpinene-4-ol	GC, GC-MS	
	Salvigenin	Silica gel chromatography, UV spectroscopy	[32]
	Crisimaritin	Silica gel chromatography, UV spectroscopy	
	Chrysoeriol	Silica gel chromatography, UV spectroscopy	
C. aromaticus	Reducing Sugar	Fehling's test	[71-72]
	Flavonoids	Shinoda test	
	Steroids	Liebermann-Burchard test	
	Terpenoids	Liebermann-Burchard test	
	Tannins	Folin-denis method	[72]
	Coumarins	Phytochemical test	[71-72]
	Saponins	Phytochemical test	
	Antraquinone	Phytochemical test	[71-73]
	Glycosides	Keller-Killiani test	
	Fixed oils	Phytochemical test	
	Proteins	Bradford method	[72,74]
	Amino Acids	Phytochemical test	[72,75]
	Phenolic compounds	Phytochemical test	[72,73]
	Carbohydrates	Phytochemical test	
	Alkaloid	Phytochemical test	[72-74]
	Gum and resin	Phytochemical test	[72-73]
	Camphene	GC, GC-MS	[76]
	1-Octen-3-ol	GC, GC-MS	
	α-Terpinene	GC, GC-MS	[7,76]
	cis-Sabinene hydrate	GC, GC-MS	[76]
	Linalool	GC, GC-MS	
	Terpinen-4-ol	GC, GC-MS	[7,14,76]
	trans-Anthole	GC, GC-MS	[76]
	Thymol	GC, GC-MS	[2,3,7,14,76]
	Carvacrol	GC, GC-MS	[2,7,14,76]
	1,8-cineole	GC, GC-MS	[3,7,14,76]
	p-cymene	GC, GC-MS	[7,14,76]
	Spathulenol	GC, GC-MS	[14,76]
	Thymylacetate	GC, GC-MS	[76]
	Eugenol	GC, GC-MS	[2,3,7,76]
	Tetradecene	GC, GC-MS	[76]
	trans-Caryophyllene	GC, GC-MS	[7,76]
	Spathulenol	GC, GC-MS	[76]
	Caryophyllene oxide	GC, GC-MS	
	α-Cadinol	GC, GC-MS	
	Chavicol	GC, GC-MS	[2,3]
	Ethylsalicylate	GC, GC-MS	[2, 7]
	1,2-Benzene diol 4-(1,1 dimethyl ethyl)	GC-MS	[15]
	Phytol	GC-MS	
	Squalene	GC-MS	
	Eudesma-4 (14),11- diene	GC-MS	

Species	Phytochemicals	Isolation procedure	References
C. blumei	Rosmarinic acid	HPLC, GC	[77-79]
	Flavonoids	Phytochemical test	[80-81],
	Saponins	Phytochemical test	
	Tannins	Phytochemical test	
	Steroids	Phytochemical test	
	Hydrocarbon constituents	Phytochemical test	
C. forskohlii	Tannins	Phytochemical test	[82]
	Reducing Sugar	Fehling's test	
	Phlobatannins	Phytochemical test	
	Saponins	Phytochemical test	
	Flavonoids	Phytochemical test	
	Terpenoids	Salkowshi test	
	Cardiac glycosides	Keller-Killiani test	
	Alkanoids	Phytochemical test	
	Deactylforskolin	TLC, HPLC	[16-17]
	9–Deoxyforskolin	TLC, HPLC	
	1,9-Deoxyforskolin	TLC, HPLC	
	1,9-Dideoxy-7-Deacetylforskolin	TLC, HPLC	
	Lycopene	Spectroscopy	[41]
	β-Carotene	Spectroscopy	
	3-Decanone	GC	[26]
	Bornyl acetate	GC	
	β-Sesquiphellandrene	GC	
	γ-Endesmol	GC	
	α-Fenchyl acetate	GC	[27]
	α-Pinene	GC	
	14-Deoxycoleon U	GC	[28]
	Demethylcryptojaponol	GC	
	α-Amyrin	GC	
	Betulic acid	GC	
	α-Cedrol	GC	
	B-Sitosterol	GC	
	Forskolin	TLC, GLC, HPLC,GC	[16-22], [29], [83]
	α- Cedrene	GC–MS-MS	[30]
	γ- Cadinene	GC–MS-MS	
	Citronellal	GC–MS-MS	
	β- Citronellol	GC–MS-MS	
C. laciniatus	β-Thujone	GC	[34]
	α-Farnesene	GC	
C. parvifolius	(E)-Phytol	GC-MS	[36]
	Eicosatrienoate	GC-MS	
	n-Tetradecanoic acid	GC-MS	
	Octoil	GC-MS	
	2-Methyyl-7-octadecyne	GC-MS	
	Nonadecane	GC-MS	
	Germacrene-D	GC-MS	
	α-Humulene	GC-MS	
C. spicatus	Flavonoids	Phytochemical test	[42], [84]
	Diterpenes	Phytochemical test	[84-85]

Species	Phytochemicals	Isolation procedure	References
C. tuberosus	Oleanolic acid	HPLC, NMR	[40], [65]
	Ursolic acid	HPLC, NMR	
	Maslinic acid	HPLC, NMR	
	Phytosterol	HPLC, NMR	
	β-Sitosterol	HPLC, NMR	
	Stigmasterol	GC	[40], [69]
	Campesterol	GC	
	Augustic acid	GC, NMR	
	Eucalyptolic acid	NMR	
C. vettiveroides	Phenols	Phytochemical test	[86]
	Flavonoids	Phytochemical test	
C. zeylanicus	Geraniol	GC-FID, GC-MS	[35]
	Nerolderivatives	GC-FID, GC-MS	
	Hexane-derivative	GC-FID, GC-MS	
	Octane-derivatives	GC-FID, GC-MS	
	α-Terpineol	GC, GC-MS	[33]
	δ-Cadinene	GC, GC-MS	

Table. 2. Summary on literature different biochemical activities of some species of *Coleus*

Name of Species	Type of Bioactivity	References
C. aromaticus	Antimicrobial	[44-45], [56-57], [73], [87]
	Antioxidant	[37], [38]
	Anticlastogenic	[37]
	Radioprotective effects	
	Anthelminthic	[73]
	Insecticidal	[68]
	Antifungal	[56], [68]
	Anti-inflammtory	[52]
	Anti urolithiatic	[61-62]
	Anti hyperlipidemic	[62]
	Diuretic activity	[64]
C. amboinicus	Antimicrobial	[46], [56], [88]
	Antioxidant	[66]
	Anthelmintic	
	Antifungal	[56]
	Anti-convulsant	[67]
	Antiepileptic	[70]
C. barbatus	Antifungal	[48], [58]
	Antidyspetic	[63]
	Hepatoprotective	[89]
C. blumei	Antimutagenic	[56], [90]
	Antioxidative	[39], [90-91]
	Antifungal	[56], [90]
	Anti-inflammatory	
	Antiviral	
	Anthelmintic	[92]

Name of Species	**Type of Bioactivity**	**References**
C. forskohlii	Antimicrobial	[55], [92-94]
	Antioxidant	[56], [95]
	Antifungal	[48], [96-98]
	Anti-inflammatory	[60], [99-100]
	Antiviral	[96-98]
	Antispasmodic effects	[101]
	Positive intropic, lower hypertension	[17], [102]
	Lower blood pressure	[103-104]
	Adenylate cyclase activating properties	[105-107]
	Antimetastatic	[107]
	Anticancer	
	Antiasthmatic	[100], [109]
	Antiglaucoma	
	Positive chronotropic and hypotension	[110-111]
	Antithrombotic agent	[112]
	Antiplatelet aggregatory effects	
	Anti-HIV inhibition activity	[113]
	Antiaging	[114]
	Antisenescence	[115]
C. kilimandcharis	Antidrepanocytant	[116]
C. parvifolius	Antimicrobial	[36]
	Antifungal	
C. spicatus	Antioxidative	[42]
C. tuberosus	Antioxidative	[40]
	Antiproliferative	
	Apoptosis	
	Chemopreventive	[65], [69]
	Lipid profile of Alloxan	[69]
C. xanthanthus	Cytotoxic	[115]
	Antitumour	[116-117]
C. zeylanicus	Free radical quenching acitivity	[12]

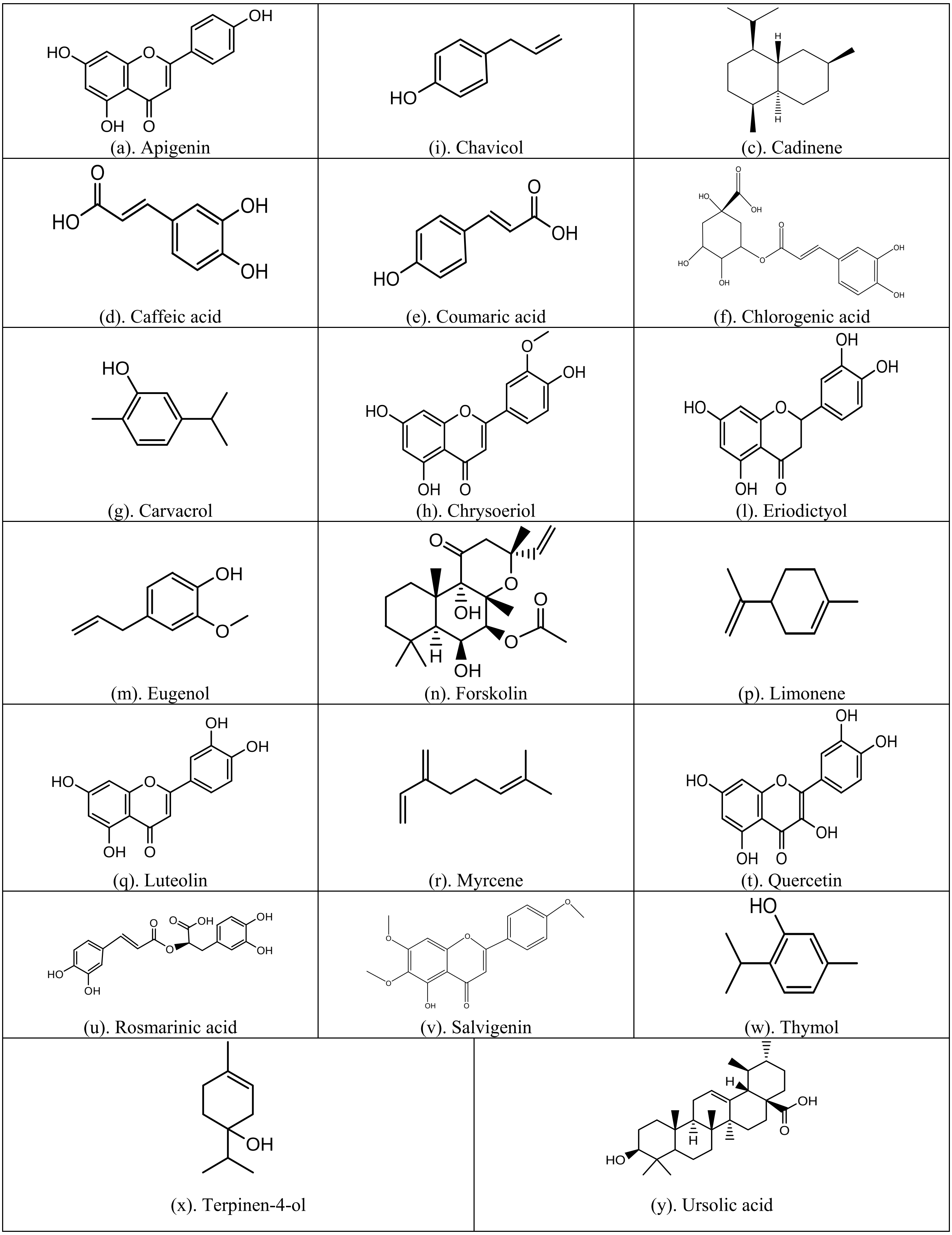

Fig.1. Structures of important compounds isolated from different *Coleus* Spp.

CONCLUSION

The members of the genus *Coleus* are of great importance acting as source of medicines, providing food and as ornamentals. Ayurvedic practitioners have been using *Coleus* species to treat various diseases including asthma, chronic cough, calculus, gonorrhea, piles, fever, heart disease, dyspepsia, respiratory problems etc. since ancient times. The different plant parts have been used as an ailment to treat many disorders. The isolated compounds have also been widely studied for their biochemical activitites like antioxidative, antimutagenic, anticarcinogenic, antigenotoxic etc. These components have been characterized and identified as a rich source of medical and other biological properties. The study pertains analytical methods for identification of phytoconstituents from *Coleus* species. The present review reveals that *Coleus* species are rich source of medicinally important chemical components such as rosmarinic acid, urolic acid, maslinic acid, forskolin etc and show many biochemical activities. Considering the easy availability of different *Coleus* species in all over the world, there still exist a scope for scientific studies to explore its applicability in medicinal field.

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