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Coleonema album: a review of its botany, medicinal uses, phytochemistry and biological activities

Alfred Maroyi
Department of Biodiversity, University of Limpopo, Private Bag X1106, Sovenga 0727, South Africa.

Abstract

Coleonema album is a woody evergreen shrub widely used as herbal medicine in South Africa. This study is aimed at providing a critical review of the botany, medicinal uses, phytochemistry and biological activities of *C. album*. Documented information on the botany, medicinal uses phytochemistry and biological activities of *C. album* was collected from several online sources which included BMC, Scopus, SciFinder, Google Scholar, Science Direct, Elsevier, Pubmed and Web of Science. Additional information on the botany, medicinal uses, phytochemistry and biological activities of *C. album* was gathered from pre-electronic sources such as book chapters, books, journal articles and scientific publications sourced from the University library. This study showed that the essential oil isolated from *C. album* is applied topically as aromatherapy while leaves and twigs of the species are used as deodorant, diuretic, mosquito and insect repellent, potpourri and source of skin care products. The leaves and twigs of *C. album* are used as herbal medicine for cancer, colds, diabetes, fever and nervous tension. Several phytochemical compounds including alkamide, coumarins, coumarin aglycones, essential oils and glycosides have been identified from the aerial parts, leaves and stems of *C. album*. Pharmacological research revealed that *C. album* crude extracts, essential oils and compounds isolated from the species have antibacterial, antimycobacterial, antifungal, anti-inflammatory, antioxidant and spasmogenic and spasmolytic activities. *Coleonema album* should be subjected to further phytochemical, pharmacological and toxicological evaluations aimed at correlating its medicinal uses with the phytochemistry and pharmacological activities of the species.

Keywords: *Coleonema album*, ethnopharmacology, herbal medicine, indigenous pharmacopeia, Rutaceae

INTRODUCTION

Coleonema album Bartl. & H.L. Wendl. is an erect, woody evergreen shrub belonging to the Rutaceae or rue or citrus family. *Coleonema album* is one of the important medicinal plants in South Africa, included in the book "medicinal plants of South Africa", a photographic guide to the most commonly used plant medicines in the country, including their botany, main traditional uses and active ingredients.[1] Research by Van Wyk[2] showed that the leaves and essential oils of *C. album* have commercial potential as herbal medicines for colds and fever and for topical uses as aromatherapy in South Africa. A tincture called "immunat" made from *C. album* is marketed commercially in South Africa and there is an increase in the demand for the species in the traditional medicine market in the country.[3-5] Fajinmi et al.[6] argued that a tincture made from *C. album* is widely used as herbal remedy to build the body's immune system and the essential oils derived from the species are also incorporated into several skin care products in South Africa. Therefore, *C. album* is cultivated on a commercial scale in South Africa for the production of essential oil which is marketed by several local and international natural product companies.[5] *Coleonema album* is also widely cultivated as ornamental plant in domestic gardens across South Africa for its delightful show of flowers.[7-9] During the flowering season the small white flowers cover the ground like confetti after a wedding, hence the common name "confetti bush". Szabo[10] argued that *C. album* is ideal for coastal gardens since the species is characterized by year round smell and pretty winter display of beautiful flowers. It is within this context that this review was undertaken aimed at reviewing the botany, medicinal uses, phytochemical and biological activities of *C. album* so as to provide baseline data required in evaluating the therapeutic potential of the species.

Botanical profile of *Coleonema album*

The genus *Coleonema* Bartl. & H.L. Wendl. consists of eight species which have been recorded in the Eastern and Western Cape provinces of South Africa.[7,8,11-13] These species include *C. asphalanthoides* Juss. ex Don, *C. calycinum* (Steud.) I.Williams, *C. juniperinum* Sond., *C. nubigenum* Esterh., *C. pulchellum* I.Williams, *C. pulchrum* Hook. and *C. virgatum* (Schltdl.) Eckl. & Zeyh.[7,8,12,13] The genus name *Coleonema* is derived from two Greek words "*koleos*" meaning "sheath" and "*nema*" meaning "thread or filament", alluding to the fact that in seven of the eight species in the genus have filaments that are connate and enclosed in the claw of a petal.[14] The specific epithet is derived from the Latin word "*album*" which means "white" in reference to the white flowers. Synonyms associated with the name *C. album* include *Diosma alba* Thunb. and *D. juniperina* Moench. The English common names of *C. album* include "Cape May" and "white confetti bush".[15] The vernacular Afrikaans name "aasbossie" for *C. album* is derived from its use by fishermen as a deodorant for the hands, to hide the foul smell of red bait "aas" and "bossie" means "bush".[16]

Coleonema album is an erect, much-branched, compact, spreading, woody evergreen shrub that grows up to 2 m in height.[7,12,13] *Coleonema album* is finely branched with branching occurring from the base of the shrub and new shoots developing at the tips of old branches. The bark of *C. album* is greyish-brown in colour, rough with horizontal leaf scars. The leaves are yellowish green in colour, needle-like, linear-oblong in shape and sweet smelling when crushed. Minute oil glands are visible on

the reverse side of the leaves and occur in two rows along the length of the leaf surface. *Coleonema album* inflorescences are solitary, axillary and crowded at the branch tips. Closed flower buds of *C. album* are pinkish tinged and appear white when fully open, with dark green disc at the centre and surrounded by several bract-like structures. *Coleonema album* has been recorded in coastal sandstone or granite outcrops often found close to the sea at an altitude ranging from sea level to 760 m above sea level.[8,12,15]

Medicinal uses of *Coleonema album*

The essential oil isolated from *C. album* is applied topically as an aromatherapy while leaves and twigs of the species are used as deodorant, diuretic, mosquito and insect repellent, potpourri and source of skin care products (Table 1). The leaves and twigs of *C. album* are used as herbal medicine for cancer, colds, diabetes, fever and nervous tension (Table 1). The leaves of *C. album* are mixed with those of *Dodonaea viscosa* (L.) Jacq. and *Pteronia camphorata* (L.) L. as herbal medicine for fever.[1]

Table 1: Medicinal uses of *Coleonema album*

Medicinal use	Parts of the plant used	References
Aromatherapy	Essential oil	Van Wyk[2]
Cancer	Leaves	Philander[17]
Colds	Leaves	Van Wyk[2]
Deodorant	Leaves	Jodamus[15]; Van Wyk and Gericke[16]; Xaba[18]; Van Vuuren et al.[19]
Deodorant	Leaves used to remove the smell of bait and fish from hands of fishermen	Lis-Balchin and Hart[9]; Jodamus[15]; Van Wyk and Gericke[16]; Xaba[18]
Diabetes	Leaves	Philander[17]
Diuretic	Leaves	Van Wyk and Gericke[19]
Fever	Leaves	Van Wyk[2]
Fever	Leaves mixed with those of *Dodonaea viscosa* (L.) Jacq. and *Pteronia camphorata* (L.) L.	Van Wyk et al.[1]
Mosquito and insect repellent	Twigs	Lis-Balchin and Hart[9]; Jodamus[15]; Van Vuuren et al.[19]
Nervous tension	Leaves and twigs	Lis-Balchin and Hart[9]; Collins[20]
Potpourri	Leaves and twigs	Lis-Balchin and Hart[9]; Jodamus[15]; Van Wyk and Gericke[16]; Xaba[18]; Collins[20]
Skin care products	Twigs	Van Vuuren et al.[19]

Phytochemical composition of *Coleonema album*

Several phytochemical compounds which include alkamide, coumarins, coumarin aglycones, essential oils and glycosides (Table 2) have been identified from the aerial parts, leaves and stems of *C. album*.[5,6,19,21-29] Some of the pharmacological activities associated with *C. album* could be attributed to the documented phytochemical compounds.

Table 2: Phytochemical composition of *Coleonema album*

Phytochemical composition	Values	Plant parts	References
α-campholene aldehyde (%)	0.04	Leaves	Khusal[23]; Başer et al.[24]
α-elemene (mg/kg fresh weight)	0.1	Leaves and stems	Berger et al.[22]
α-guaiene (mg/kg fresh weight)	0.9 - 3.0	Leaves and stems	Berger et al.[22]
α-humulene (mg/kg fresh weight)	12.0	Leaves and stems	Berger et al.[22]
α-phellandrene (%)	0.7 – 1.0	Leaves	Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
α-pinene (%)	8.2 – 27.4	Leaves	Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
α-terpinene (%)	0.2 – 14.4	Leaves	Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
α-terpineol (%)	1.9 – 4.9	Leaves	Fajinmi et al.[5]; Van Vuuren et al.[19]; Khusal[23]; Başer et al.[24]
α-thujene (%)	0.6 - 0.7	Leaves	Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
β-caryophyllene (%)	5.0	Leaves	Fajinmi et al.[5]
β-myrcene (%)	8.0	Leaves	Fajinmi et al.[6]
β-ocimene (mg/kg fresh weight)	0.1	Leaves and stems	Berger et al.[22]
β-phellandrene (%)	26.7 - 29.1	Herbal parts	Van Vuuren et al.[19]; Khusal[23]; Başer et al.[24]
β-pinene (%)	7.0 – 14.4	Leaves	Fajinmi et al.[5]; Fajinmi et al.[6]; Van Vuuren et al.[19]; Khusal[23]; Başer et al.[24]
β-thujone (mg/kg fresh weight)	5.0	Leaves and stems	Berger et al.[22]
cis-allo ocimene (%)	0.1	Leaves	Khusal[23]

Phytochemical composition	Values	Plant parts	References
cis-p-menth-2-en-1-ol (%)	0.1	Leaves	Khusal[23]; Başer et al.[24]
δ-cadinene (%)	0.2	Herbal parts	Başer et al.[24]
δ-3-carene (%)	0.1	Herbal parts	Khusal[23]; Başer et al.[24]
δ-3-carene (mg/kg fresh weight)	0.1	Leaves and stems	Berger et al.[22]
δ-elemene (mg/kg fresh weight)	0.6	Leaves and stems	Berger et al.[22]
δ-guaiene (mg/kg fresh weight)	5.7	Leaves and stems	Berger et al.[22]
δ-selinene (mg/kg fresh weight)	5.7	Leaves and stems	Berger et al.[22]
δ-terpineol (%)	0.1	Leaves	Khusal[23]; Başer et al.[24]
(E)-2,6-dimethyl-1,3,7-nonatriene (%)	0.1	Herbal parts	Khusal[23]; Başer et al.[24]
(E)-3,7-dimethylocta-2,6-dien-1-yl 2-((3-methylbut2-en-1-yl)amino)benzoate	-	Leaves	Lima et al.[28]
(E)-β-caryophyllene (%)	1.0	Leaves	Fajinmi et al.[5]
(E)-β-ionone (%)	0.1	Leaves	Fajinmi et al.[5]
(E)-β-ocimene (%)	0.8 – 4.3	Leaves	Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
E,E-α-farnesene (mg/kg fresh weight)	10.0	Leaves and stems	Berger et al.[22]
E-nerolidol (mg/kg fresh weight)	11.0	Leaves and stems	Berger et al.[22]
γ-elemene (%)	1.8	Leaves	Fajinmi et al.[6]
γ-terpinene (%)	0.4 – 1.4	Leaves	Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
Methyl-2-methyl butyrate (%)	0.06	Leaves	Khusal[23]
Methyl citronellate (mg/kg fresh weight)	9.0	Leaves and stems	Berger et al.[22]
Methyl eugenol (%)	0.04	Leaves	Khusal[23]; Başer et al.[24]
n-hexadecanoic acid	-	Leaves	Esterhuizen et al.[26]
n-nonane (%)	0.2	Leaves	Fajinmi et al.[5]
p-cymene (%)	0.3	Herbal parts	Khusal[23]; Başer et al.[24]
p-mentha-1(7),8-diene (%)	0.7	Herbal parts	Khusal[23]; Başer et al.[24]
(R)-(+)-2′,3′-epoxy-suberosin	-	Aerial parts	Gray[21]
(R)-(+)-7-(2′,3′-epoxy-3′-methylbutoxy)-coumarin	-	Aerial parts	Gray[21]
(R)-(+)-7-(2′,3′-dihydroxy-3′-dihydroxy-3′-methylbutoxy)-coumarin	-	Aerial parts	Gray[21]
(R)-(+)-7-methoxy-8-(2′,3′-epoxy-3′-methylbutoxy)-coumarin	-	Aerial parts	Gray[21]
(S)-7-O-methylpeucedanol 3'-O-β-D-glucopyranoside	-	Leaves	Lima et al.[28]
trans-cadina-1(6),4-diene (%)	0.1	Leaves	Fajinmi et al.[5]
trans-carveol (%)	0.06	Leaves	Khusal[23]; Başer et al.[24]
trans-methyl isoeugenol (%)	0.03	Leaves	Khusal[23]
trans-pinocarveol (%)	0.1	Leaves	Khusal[23]; Başer et al.[24]
trans-β-ocimene (%)	9.5	Leaves	Fajinmi et al.[6]
trans-p-menth-2-en-1-ol	0.1	Leaves	Khusal[23]
(Z)-β-ocimene (%)	5.6 - 7.1	Leaves	Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
(Z)-β-ocimene epoxide (%)	0.1	Leaves	Khusal[23]; Başer et al.[24]
(Z)-6-(4-hydroxy-3-methylbut-2-en-1-yl)-coumarin 7-O-β-D-glucopyranoside	-	Leaves	Lima et al.[28]
(Z)-6-(4-β-D-glucopyranosyloxy-3-methylbut-2-en-1-yl)-7-hydroxycoumarin	-	Leaves	Lima et al.[28]
(Z)-7-(4-β-D-glucopyranosyloxy-3-methylbut-2-en-1-yloxy)-coumarin	-	Leaves	Lima et al.[28]
(+)-3-carene (%)	6.0	Leaves	Fajinmi et al.[6]
1,3,6-octatriene,3,7-dimethyl-, (Z)-	2.3	Leaves	Fajinmi et al.[6]

Phytochemical composition	Values	Plant parts	References
β-ocimene (%)			
1,8-cineole (%)	1.0 - 1.4	Leaves	Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
2-methyl-6-methylene-3,7-octadiene-2-ol (%)	0.06	Leaves	Khusal[23]
2-isopropenyl-2,3-dihydrofuro[3,2-g]chromen-7-one	-	Leaves	Esterhuizen et al.[25];
2-(1-hydroxy-1-methylethyl)-2,3-dihydrofuro[3,2-g]chromen-7-one	-	Leaves	Esterhuizen et al.[26]
2,2-dimethyl-pyrano(3,2-c)(1)benzopyran-5-one	-	Leaves	Esterhuizen et al.[26]
2-(3,4-dihydroxyphenyl)-3-(D-glycopyranosyloxy)-5,7 di-hydroxy-4H-1-benzopyran-4-one	-	Leaves	Esterhuizen et al.[25]
(2E,4E)-N-isobutyldeca-2,4-dienamide	-	Leaves	Lima et al.[28]
(2R)-2'-hydroxymarmesin 2'-O-β-D-glucopyranoside	-	Leaves	Lima et al.[28]
(2S)-2'-hydroxymarmesin 2'-O-β-D-glucopyranoside	-	Leaves	Lima et al.[28]
5,5'-(tetrahydro-1H,3H-furo[3,4c]-furan-1,4-diyl)bis-[1S-(1α.,3a.α,4.β.,6a)]-1,3-benzodioxole	-	Leaves	Esterhuizen et al.[26]
5-hydroxy-8-methoxycoumarin	-	Leaves	Lima et al.[28]
6-(2-hydroxy-3-methylbut-3-en-1-yl)-7-methoxycoumarin	-	Leaves	Lima et al.[28]
6-(2,3-dihydroxy-3-methylbut-1-yl)-7-methoxycoumarin	-	Leaves	Lima et al.[28]
6-(2,3-dihydroxy-3-methylbutyl)-7-methoxy-2H-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[25]
6-(2,3-dihydroxy-3-methylbutyl)-7-methoxy-2H-1-benzopyran-2-one (dihydroxydihydrosuberosin)	-	Leaves	Esterhuizen et al.[26]
6-(3-methyl-2-oxobutyl)-7-methoxy-2H-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[26]
(6-[(3,3-dimethyloxiranyl)methyl]-7-metoxy-2H-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[25]
6-(3,3-dimethyl-2-butenyl)-7-methoxy-2H-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[26]
6-[(3,3-dimethyloxiranyl)methyl]-7-methoxy-2H-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[26]
6,7-dihydroxy-2H-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[26]
6,7-dihydro-5-hydroxy-4,8,8-trimethyl-2H,8H-benzo[1,2-b:5,4-b']dipyran-2-one	-	Leaves	Esterhuizen et al.[26]
6-(4-β-D-glucopyranosyloxy-3-methylbut-1-yl)-7-hydroxycoumarin	-	Leaves	Lima et al.[28]
6,7-epoxy myrcene (%)	0.5	Leaves	Khusal[23]; Başer et al.[24]
7-isopentenyloxycoumarin	-	Aerial parts	Gray[21]
7-(2,3-dihydroxy-3-methylbut-1-yloxy)-coumarin	-	Leaves	Lima et al.[28]
7-methoxy-6-(3-methyl-2-oxobutyl)-2H-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[25]
7-methoxy-6-(3-methyl-2-butenyl)-2H-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[25]
7-methoxy-8-O-β-D-glucopyranosyl-coumarin	-	Leaves	Lima et al.[28]
7-(2-hydroxy-3-methylbut-3-en-1-	-	Leaves	Lima et al.[28]

Phytochemical composition	Values	Plant parts	References
yloxy)-coumarin			
7-(3-chloro-2-hydroxy-3-methylbut-1-yloxy)-coumarin	-	Leaves	Lima et al.[28]
7-(3′,3′-dimethylallyloxy)-coumarin	-	Aerial parts	Gray[21]
7-hydroxy-6-(3-methylbut-2-en-1-yl)-coumarin	-	Leaves	Lima et al.[28]
7-methoxy-6-(3-methyl-2-oxobut-1-yl)-coumarin	-	Leaves	Lima et al.[28]
7-methoxy-8-(3-methylbut-2-en-1-yloxy)-coumarin	-	Leaves	Lima et al.[28]
7-(3-methylbut-2-en-1-yloxy)-coumarin	-	Leaves	Lima et al.[28]
8-[D-glycopyranosyloxy)-1-methylethyl]-8,9-dihydro-2H-furo[2,3-h]-1-benzopyran-2-one	-	Leaves	Esterhuizen et al.[25]
8-hydroxy-5-methoxycoumarin	-	Leaves	Lima et al.[28]
8-((2-hydroxy-3-methylbut-3-en-1-yloxy)-7-methoxycoumarin	-	Leaves	Lima et al.[28]
8-(2,3-dihydroxy-3-methylbut-1-yloxy)-7-methoxycoumarin	-	Leaves	Lima et al.[28]
8-(3-chloro-2-hydroxy-3-methylbut-1-yloxy)-7-methoxycoumarin	-	Leaves	Lima et al.[28]
8-O-β-D-glucopyranosyloxy-6-(2,3-dihydroxy-3-methylbutyl)-7-methoxycoumarin	-	Leaves	Lima et al.[28]
9,10-dihydro-9-hydroxy-8,8-dimethyl-2H,8H-benzo[1,2-b:3,4-b']dipyran-2-one	-	Leaves	Esterhuizen et al.[26]
Alloocimene (%)	0.1	Herbal parts	Başer et al.[24]
Bicyclogermacrene (%)	0.1 – 5.1	Leaves	Fajinmi et al.[6]; Khusal[23]; Başer et al.[24]
Bicyclo[3.1.0]hex-2-ene,4-methyl-1-(1-methyethyl)-β-phellandrene (%)	6.0	Leaves	Fajinmi et al.[6]
Butyl benzene	0.06	Leaves	Khusal[23]
Carvylacetate I (mg/kg fresh weight)	10.0	Leaves and stems	Berger et al.[22]
Carvylacetate II (mg/kg fresh weight)	2.0	Leaves and stems	Berger et al.[22]
Caryophyllene (%)	24.9	Leaves	Fajinmi et al.[6]
Citronellol (%)	0.2	Leaves	Khusal[23]; Başer et al.[24]
Cryptone (%)	0.3	Leaves	Khusal[23]; Başer et al.[24]
En-1-ol (%)	0.1	Herbal parts	Başer et al.[24]
Ethyl 2-methylbutanoate (mg/kg fresh weight)	1.7	Leaves and stems	Berger et al.[22]
Eucalyptol (%)	2.6	Leaves	Fajinmi et al.[6]
Eugenol (%)	0.4	Leaves	Khusal[23]; Başer et al.[24]
Eugenol methyl ether (mg/kg fresh weight)	8.0	Leaves and stems	Berger et al.[22]
Germacrene B (mg/kg fresh weight)	0.6 - 21.0	Leaves and stems	Berger et al.[22]
Germacrene D (%)	0.03	Leaves	Khusal[23]; Başer et al.[24]
Isoeugenol (mg/kg fresh weight)	86.0	Leaves and stems	Berger et al.[22]
Isopinocamphone (%)	0.3	Leaves	Khusal[23]; Başer et al.[24]
Isorhamnetin	-	Leaves	Lima et al.[28]
Isoeugenol methyl ether (mg/kg fresh weight)	18.0	Leaves	Berger et al.[22]
Limonene (%)	7.9 – 10.3	Herbal parts	Van Vuuren et al.[19]; Khusal[23]; Başer et al.[24]
Linalool (%)	0.5 – 6.7	Leaves	Van Vuuren et al.[19]; Khusal[23]; Başer et al.[24]

Phytochemical composition	Values	Plant parts	References
Myrcene (%)	11.5 - 20.5	Leaves and herbal parts	Van Vuuren et al.[19]; Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
Myrcenone (%)	2.5	Leaves	Khusal[23]; Başer et al.[24]
Myrtenol (%)	0.1	Leaves	Khusal[23]; Başer et al.[24]
Nonanal	0.03	Leaves	Khusal[23]
Octahydro-7-methyl-3-methylene-4-(1-methylethyl)-β-copaene (%)	7.5	Leaves	Fajinmi et al.[6]
Pellitorine	-	Aerial parts	Rárová et al., 2019
Phellandral (%)	0.3	Leaves	Khusal[23]; Başer et al.[24]
Phenolic content (mg gallic acid equivalence per g dry extract)	4.9 – 8.4	Leaves	Esterhuizen et al.[25]
Pinocamphone (mg/kg fresh weight)	20.0	Leaves and stems	Berger et al.[22]
Pinocarveol (mg/kg fresh weight)	12.0	Leaves and stems	Berger et al.[22]
Pinocarvone (%)	0.8	Leaves	Khusal[23]; Başer et al.[24]
Sabinene (%)	3.5 – 8.4	Leaves	Van Vuuren et al.[19]; Fajinmi et al.[5]; Khusal[23]; Başer et al.[24]
Spathulenol (%)	0.08	Leaves	Khusal[23]; Başer et al.[24]
Terpinen-4-ol (%)	0.4	Leaves	Khusal[23]; Başer et al.[24]
Terpinolene (%)	0.1	Herbal parts	Khusal[23]; Başer et al.[24]
Ulopterol	-	Aerial parts	Gray[21]
Verbenone (mg/kg fresh weight)	26.0	Leaves and stems	Berger et al.[22]
Verbenone (%)	0.2	Leaves	Khusal[23]; Başer et al.[24]
Zizanene (%)	0.03	Leaves	Khusal[23]

Biological activities of *Coleonema album*

The following biological activities have been reported from the leaf extracts, essential oil and compounds isolated from *C. album*: antibacterial,[9,19,26] antimycobacterial,[3,26] antifungal,[5,6,9,26] anti-inflammatory,[3,29] antioxidant[6,25] and spasmogenic and spasmolytic[9] activities.

Antibacterial activities

Lis-Balchin and Hart[9] evaluated antibacterial activities of essential oils isolated from *C. album* against *Enterococcus hirae*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Staphyloccocus aureus* using the agar diffusion technique with thyme as a positive control. The essential oil exhibited weak activities against all tested pathogens with the zone of inhibition of 4.0 mm which was much lower than 11.7 mm to 39.1 mm exhibited by the positive control.[9] Esterhuizen et al.[26] evaluated antibacterial activities of ethanol and acetone leaf extracts of *C. album* against *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, Enterococcus faecalis* and *Mycobacterium tuberculosis* using the serial plate microdilution assay with neomycin as a positive control. The extracts exhibited activities with minimum inhibition concentration (MIC) values ranging from 0.2 mg/ml to 1.7 mg/ml which were much higher than 0.01 mg/ml to 0.03 mg/ml exhibited by the positive control.[26] Van Vuuren et al.[19] evaluated the antibacterial activities of essential oils isolated from *C. album* against *Brevibacillus agri, Brevibacillus epidermidis* and *Brevibacillus linens* using the microdilution assay with ciprofloxacin, zinc oxide and zinc sulphate as positive controls. The essential oils exhibited activities with MIC values ranging from 0.5 mg/mL to 4.0 mg/mL.[19]

Antimycobacterial activities

Esterhuizen et al.[26] evaluated antimycobacterial activities of ethanol and acetone leaf extracts of *C. album* against *Mycobacterium tuberculosis* using the serial plate microdilution assay with isoniazid and rifampicin as positive controls. The extracts exhibited weak activities with MIC values ranging from 1.0 mg/ml to 5.0 mg/ml.[26] Eldeen and Van Staden[3] evaluated the antimycobacterial activities of acetone and ethanolic leaf extracts of *C. album* against *Mycobacterium aurum* using the broth micro-dilution assay with ciprofloxacin as a positive control. The extracts exhibited activities with MIC value of 3.1 mg/ml.[3]

Antifungal activities

Lis-Balchin and Hart[9] evaluated antifungal activities of essential oils isolated from C. album against *Saccharomyces cerevisiae* using the agar diffusion technique with thyme as a positive control. The essential oil exhibited weak activities with the zone of inhibition of 4.0 mm which was much lower than 17.9 mm exhibited by the positive control.[9] Esterhuizen et al.[26] evaluated antifungal activities of ethanol and acetone leaf extracts of *C. album* against *Candida albicans* using the serial plate microdilution assay with fluconazole as a positive control. The extracts exhibited activities with MIC values ranging from 0.2 mg/ml to 0.3 mg/ml which were much higher than 0.08 mg/ml exhibited by the positive control.[26] Fajinmi et al.[6] evaluated antifungal activities of acetone, ethanol, methanol and petroleum ether leaf extracts of *C. album* against *Microsporum gypseum, Trichophyton mentagrophytes* and *Trichophyton rubrum* using the microdilution method with griseofulvin and ketoconazole as positive controls. The antifungal activities of essential

oils extracted from *C. album* were also investigated using the volatile release plate method. The extracts exhibited activities with MIC and minimum fungicidal concentration (MFC) values ranging from 195 µg/mL to 6250 µg/mL and 3125 µg/mL to 6250 µg/mL, respectively. The essential oil inhibited the growth of Trichophyton rubrum in vitro with final mycelia diameter of 0.3 cm and fungal growth index (FGI) of 0%.[6] Fajinmi et al.[5] evaluated antifungal activities of essential oils isolated from *C. album* against T*richophyton mentagrophytes* and *Trichophyton rubrum* by assessing the effect of essential oils on the growth and morphology of two fungal strains. The essential oils caused inhibition and reduction of fungal growth in all plates exposed to the essential oils with the highest inhibition recorded with 40 µl.[5]

Anti-inflammatory activities

Eldeen and Van Staden[3] evaluated the anti-inflammatory activities of acetone and ethanolic leaf extracts of *C. album* using the cyclooxygenase (COX-1 and COX-2) assays. The extracts exhibited activities against COX-2 with half maximal inhibitory concentration (IC_{50}) value of 40 µg/ml for the acetone extract and the same extract had an IC_{50} value of 225 µg/ml against COX-1 and the selectivity ratio of COX-2/COX-1 of 0.2.[3] Rárová et al.[29] evaluated the anti-inflammatory activities of methanolic leaf extracts of *C. album* and the compound pellitorine isolated from the species using CD62E (E-selectin, ELAM) ELISA, sandwich ELISA (IL-6), COX-1 and COX-2 inhibition assays, SDS–polyacrylamide gel electrophoresis and immunoblotting. The extract inhibited COX-1, COX-2 and IL-6, but not ELAM, while the compound pellitorine did not inhibit the level of COX-1 and COX-2 and ELAM. Therefore, the anti-inflammatory activities of the extract was achieved through inhibition of COX-1 and COX-2 only.[29]

Antioxidant activities

Esterhuizen et al.[25] evaluated antioxidant activities of ethanol and acetone leaf extracts of *C. album* using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) spectrophotometric assay and the oxygen radical absorbance capacity (ORAC) assay. The extracts exhibited activities with half maximal effective concentration (EC_{50}) values ranging from 10.4 mg/mL to 27.7 mg/mL and ORAC values ranging from 6.0 to 7.6 µmole Trolox equivalent per µg dry plant weight.[25] Fajinmi et al.[6] evaluated antioxidant activities of aqueous leaf extracts of *C. album* using the ORAC assay. The extract exhibited activities with the ORAC value of 942.2 µmole Trolox equivalent per µg dry plant weight.[6]

Spasmogenic and spasmolytic activities

Lis-Balchin and Hart[9] evaluated spasmogenic and spasmolytic activities of the essential oil of *C. album* by assessing the mode of action of the essential oil on smooth muscle *in vitro* using guinea-pig ileum. The essential oil produced an initial spasmogenic activity followed by spasmolysis, both actions being dose-dependent.[9]

CONCLUSION

The present review summarizes the botany, ethnomedicinal uses, phytochemistry and biological activities of the leaves, stems, essential oil and compounds isolated from *C. album*. Currently, there is not yet enough data on ethnopharmacological evaluations on the species that can be correlated with its medicinal applications. Therefore, detailed phytochemical, pharmacological and toxicological studies of *C. album* are required.

Conflict of interest

The author declares that he has no conflict of interest.

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