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Eriocephalus africanus: A review of its medicinal uses, phytochemistry and biological activities

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Abstract

Eriocephalus africanus is a small shrub widely used as traditional medicine in South Africa. This study is aimed at providing a critical review of the botany, medicinal uses, phytochemistry and biological activities of *E. africanus*. Documented information on the botany, medicinal uses, phytochemistry and biological activities of E. africanus 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 *E. africanus* was gathered from pre-electronic sources such as book chapters, books, journal articles and scientific publications obtained from the University library. This study showed that the leaves, oil and stems of *E. africanus* are mainly used as aromatherapy, colic, cosmetic, diaphoretic, diuretic, haemostatic, and herbal medicine for headache, swellings, dropsy, flatulence, heart problems, menstrual problems, footbath and dandruff, pain, dermal problems, fever, gynaecological problems, respiratory problems and stomach problems. Phytochemical compounds that have been identified from the aerial parts, leaves and stems of *E. africanus* include essential oils, flavonoids, sesquiterpenoid lactones, tannins and triterpene steroids. Pharmacological research revealed that the leaf, root, stem and twig extracts of *E. africanus* and essential oils isolated from the species have analgesic, antibacterial, antimycobacterial, antifungal, anti-inflammatory, antioxidant, antipyretic and phytotoxic activities. There is need for experimental animal studies, randomized clinical trials and target-organ toxicity studies involving *E. africanus* crude extracts and compounds isolated from the species.

Keywords: Asteraceae, Compositae, *Eriocephalus africanus*, Ethnopharmacology, herbal medicine, indigenous pharmacopeia

INTRODUCTION

Eriocephalus africanus L. is a small multi-branched shrub belonging to the Asteraceae or Compositae family, commonly known as the aster, daisy or sunflower family. *Eriocephalus africanus* is an important source of essential oil which is widely used in perfumes, skin care preparations and as blend oil in beauty care products.[1] The leaves and stems of *E. africanus* are used in the development of commercial natural products sold locally in South Africa and abroad as tincture, oil, loose and ground sachets and cosmetics.[2] Therefore, *E. africanus* is widely cultivated in South Africa for its essential oils[3] and as an ornamental plant, particularly in coastal areas.[4] *Eriocephalus africanus* was therefore introduced as both an ornamental plant and source of essential oil in several countries around the Mediterranean sea such as Italy, Portugal, Spain, Dalmatia, Egypt, Tunisia, Morocco and southern France, as well as in England, the United States of America, Mexico and Australia.[5] *Eriocephalus africanus* is now naturalized and in some cases categorized as a weed in countries such as Australia, Egypt, Italy, Portugal and Spain.[6-12] In Portugal, *E. africanus* is widely used as traditional medicine and also cultivated in domestic gardens as an ornamental plant.[13] In South Africa, *E. africanus* is used as a rosemary (*Salvia rosmarinus* Spenn.) substitute for culinary flavouring purposes.[14] Dried or fresh leaves and young twigs of *E. africanus* are finely chopped and used in soups, salads, vegetables, meat and other foods.[5,6,11,15-17] *Eriocephalus africanus* is also used to flavour wines, vinegar, oil and butter.[5,11,18,19] *Eriocephalus africanus* is also cultivated in home gardens as traditional medicine in the Western Cape Province in South Africa.[20] Leaves and stems of *E. africanus* are also sold in informal herbal medicine markets in the Eastern Cape, Northern Cape and Western Cape provinces in South Africa as sources of traditional medicines.[21,22] *Eriocephalus africanus* is one of the important medicinal plants in South Africa and the species is 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.[23] Research by Van Wyk[24] and Van Wyk[25] showed that the leaves and essential oils of *E. africanus* have commercial potential as bitter tonics, inhalant, diaphoretic, diuretic and aromatherapy, and herbal medicines for digestive, stomach pain and fever in southern Africa. It is within this context that this review was undertaken aimed at reviewing the botany, medicinal uses, phytochemical and biological activities of *E. africanus* so as to provide the baseline data required in evaluating the therapeutic potential of the species.

Botanical profile of *Eriocephalus africanus*

The genus *Eriocephalus* L. consists of 34 species which are mostly sclerophyllous shrublets, with some species characterized by aromatic oils and small thorns or spines.[26,27] The genus name *Eriocephalus* is derived from two Greek words "*erion*" meaning "wool" and "*cephale*" meaning "head", and therefore, the genus name mean "woolly head".[28] The species name "*africanus*" means from Africa. Two infraspecific taxa are recognized, *E. africanus* var. *africanus* and *E. africanus* var. *paniculatus* (Cass.) M.A.N. Müll.,P.P.J. Herman & Kolberg. The var. *africanus* has spreading succulent leaves, confined to the Western Cape province in South Africa in coastal areas at an altitude ranging from sea level to 100 m above sea level while var. *paniculatus* is more erect in habit, lacking succulent leaves and distributed in the inland areas of the Eastern Cape, Northern Cape and Western Cape provinces

in clay or granite hillsides at an altitude ranging from 100 m to 3000 m above sea level.[29] The English common names of *E. africanus* are "African rosemary" and "wild rosemary" due to the superficial resemblance in general habit to the common Mediterranean rosemary (*Salvia rosmarinus*). Synonyms associated with the name *E. africanus* include *Achillea fasciculata* Burm.f., *E. corymbosus* Moench, *E. frutescens* R.Br., *E. racemosus* Gaertn., *E. septifer* Cass., *E. umbellulatus* Cass., *E. variifolius* Salisb. and *Monochlaena racemosa* Cass.[29] *Eriocephalus africanus* is a multi-branched woody shrub which can grow up to 1 metre in height.[23,26,29-31] The leaves are small, needle-shaped, silvery to bluish green in colour, felted or silky to glabrescent, alternate on flowering shoots or opposite on short-shoots or arranged in clusters along the branches. The leaves have minute silvery hairs that trap moisture and thus reduce transpiration.[26] The inflorescence consist of small brown and pale yellow heads borne in corymbs. The flowers consist of two or three showy white ray florets on the outside and purple disc florets in the centre. The fruits are covered in long white hairs and seed heads are fluffy and look like cotton wool or snow.[26]

Medicinal uses of *Eriocephalus africanus*

The leaves, oil and stems of *E. africanus* are mainly used as aromatherapy, colic, cosmetic, diaphoretic, diuretic, haemostatic, and herbal medicine for headache, swellings, dropsy, flatulence, heart problems, menstrual problems, footbath and dandruff, pain, dermal problems, fever, gynaecological problems, respiratory problems and stomach problems (Table 1, Figure 1). The leaves of *E. africanus* are mixed with those of *Rosmarinus officinalis* L. and used in footbath and against dandruffs.[14,23,27,32-35] The leaves of *E. africanus* are mixed with those of *Metalasia muricata* (L.) D. Don and used as a fumigant.[27]

Table 1: Medicinal uses of *Eriocephalus africanus*

Medicinal use	Parts used	References
Aromatherapy	Oil	Makunga et al.[2]; Van Wyk[25]; Njenga[27]; Lall and Kishore[36]; Mlungwana et al.[37]
Backache	Leaves	Hulley and Van Wyk[38]
Cancer	Leaves	Hulley and Van Wyk[38]
Colic	Leaves	Van der Walt[26]; Njenga[27]; Salie et al.[33]; Njenga et al.[34]; Mlungwana et al.[37]; Amabeoku et al.[39]
Cosmetic	Oil	Njenga[27]; Lall and Kishore[36]; Sagbo and Mbeng[40]
Dermal problems	Leaves	Njenga and Viljoen[1]; Merle et al.[6]; Mohamed et al.[9]; Catarino et al.[11]; Njenga[27]; Njenga et al.[34]; Lall and Kishore[36]; Behiry et al.[41]
Diaphoretic	Leaves	Njenga and Viljoen[1]; Catarino[8]; Mohamed et al.[9]; Catarino et al.[11]; Mohamed et al.[12]; Van Wyk[24]; Van der Walt[26]; Njenga[27]; Watt and Breyer-Brandwijk[32]; Njenga et al.[34]; Roberts[42]; Scott et al.[43]; Seaman[44]; Scott and Hewett[45]; Van Wyk[46]
Diuretic	Leaves	Njenga and Viljoen[1]; Catarino[8]; Mohamed et al.[9]; Catarino et al.[11]; Mohamed et al.[12]; Van Wyk[24]; Van der Walt[26]; Njenga[27]; Watt and Breyer-Brandwijk[32]; Amabeoku et al.[39]; Roberts[42]; Seaman[44]; Scott and Hewett[45]; Van Wyk[46]; Philander[47]
Dropsy	Leaves	Lall and Kishore[36]; Njenga[27]; Van Wyk[46]; Van Wyk and Gorelik[48]
Fever	Leaves	Catarino[8]; Mohamed et al.[9]; Catarino et al.[11]; Mohamed et al.[12]; Van Wyk[25]; Hulley and Van Wyk[38]; Amabeoku et al.[39]; Philander[47]
Flatulence	Leaves	Van der Walt[26]; Njenga[27]; Salie et al.[33]; Njenga et al.[34]
Footbath and dandruff	Leaves mixed with those of *Rosmarinus officinalis* L.	Dyson[14]; Van Wyk et al.[23]; Njenga[27]; Watt and Breyer-Brandwijk[32]; Salie et al.[33]; Njenga et al.[34]; Van Wyk and Gericke[35]
Fumigant	Leaves mixed with those of *Metalasia muricata* (L.) D. Don	Njenga et al.[34]
Gout	Leaves	Hulley and Van Wyk[38]
Gynaecological problems	Leaves	Njenga and Viljoen[1]; Njenga[27]; Njenga et al.[34]; Lall and Kishore[36]; Mlungwana et al.[37]; Hulley and Van Wyk[38]; Scott et al.[43]; Scott and Hewett[45]
Haemostatic	Leaves	Scott et al.[43]; Scott and Hewett[45]
Headache	Leaves	Hulley and Van Wyk[38]; Philander[47]
Heart problems	Leaves	Njenga[27]; Njenga et al.[34]; Hulley and Van Wyk[38]; Philander[47]
High blood pressure	Leaves	Balogun and Ashafa[49]
Kidney problems	Leaves	Hulley and Van Wyk[38]
Menstrual problems	Leaves	Njenga[27]; Njenga et al.[34]; Lall and Kishore[36]; Scott et al.[43]
Pain	Leaves	Catarino[8]; Mohamed et al.[9]; Catarino et al.[11]; Mohamed et al.[12]; Hulley and Van Wyk[38]; Amabeoku et al.[39]; Njenga et al.[34]
Perfume	Oil	Lall and Kishore[36]
Respiratory problems (asthma, chest complaints, colds, cough, influenza and tuberculosis)	Leaves	Makunga et al.[2]; Catarino[8]; Mohamed et al.[9]; Catarino et al.[11]; Mohamed et al.[12]; Van der Walt[26]; Njenga[27]; Salie et al.[33]; Njenga et al.[34]; Lall and Kishore[36]; Mlungwana et al.[37]; Hulley and Van Wyk[38]; Van Wyk[46]; Van Wyk and Gorelik[48]
Stomach problems	Leaves	Njenga and Viljoen[1]; Makunga et al.[2]; Merle et al.[6]; Catarino[8]; Mohamed et al.[9]; Catarino et al.[11]; Mohamed et al.[12]; Van Wyk[24]; Van Wyk[25]; Njenga et al.[34]; Mlungwana et al.[37]; Hulley and Van Wyk[38]; Scott et al.[43]; Van Wyk[46]; Philander[47]; Van Wyk and Gorelik[48]
Swellings	Leaves	Njenga et al.[34]; Lall and Kishore[36]; Scott et al.[43]
Ulcers	Leaves	Scott and Hewett[45]
Urinary problems	Leaves	Hulley and Van Wyk[38]
Venereal diseases	Leaves and stems	Ellis[16]

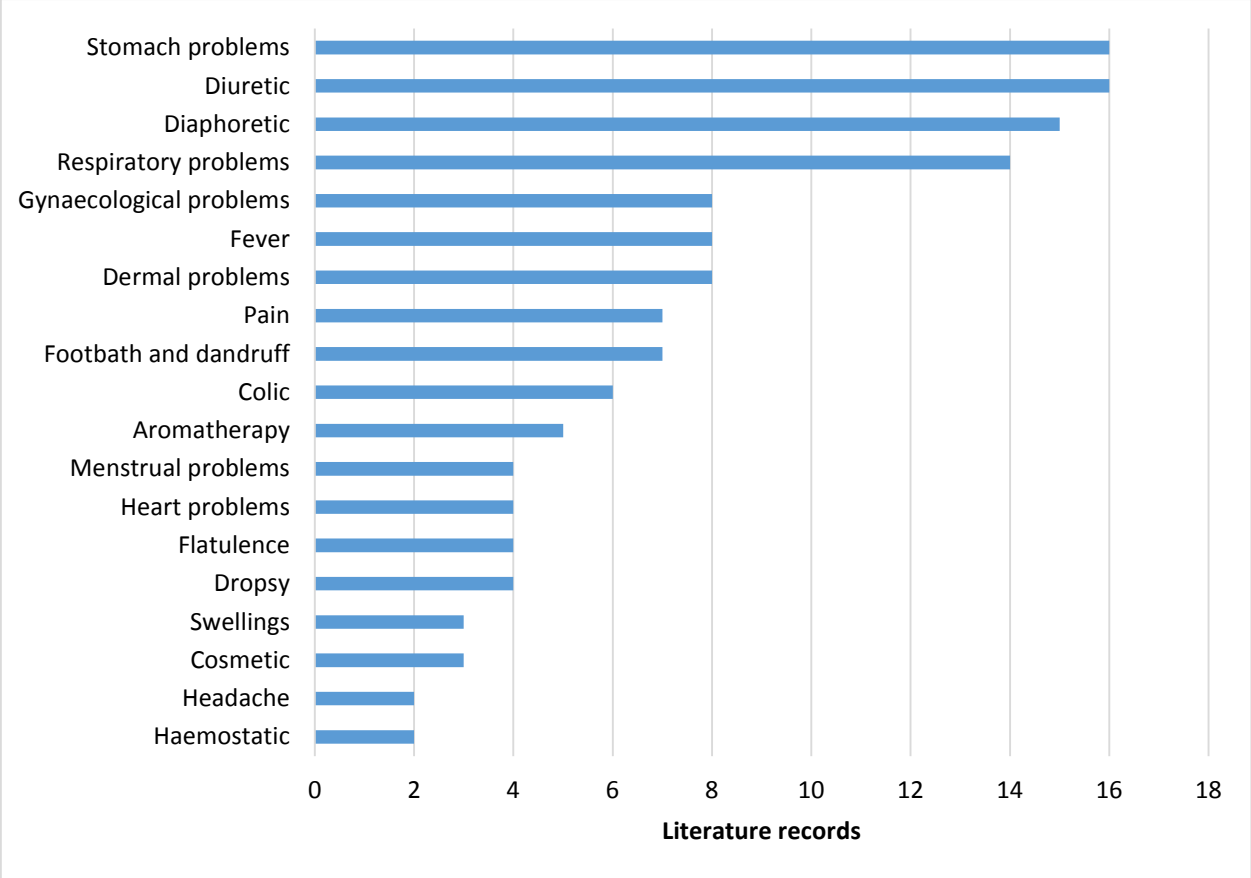

Figure 1. Medicinal applications of *Eriocephalus africanus* derived from literature records

Phytochemistry of *Eriocephalus africanus*

The aerial parts, leaves and stems of *E. africanus* contain essential oils, flavonoids, sesquiterpenoid lactones, tannins and triterpene steroids (Table 2).[6-8,11,12,27,33,41,43,50-53] The composition of essential oils appears to vary with geographical origin of the specimens as shown in Table 2. The major compounds that have been identified from the species include artemisia ketone (4.5 – 77.9%), bicyclogermacrene (0.7 – 15.6%), borneol (0.05 – 10.0%), camphor (0.3 – 12.1%), carvacrol (11.5%), caryophyllene oxide (0.3 – 10.1%), chrysanthenone (18.5%), 1,8-cineole (0.06 – 23.6%), eudesm-7(11)-en-4-ol (0.3 – 17.7%), intermedeol (9.1 – 11.6%), ledol (19.9%), piperitone (0.4 – 17.2%), santolina alcohol (29.9%) and spathulenol (0.4 – 40.0%).[6,7,12,27,41,53] Future research should focus on evaluating the biological activities of the isolated compounds.

Table 2: Phytochemical compounds identified from aerial parts, leaves and stems of *Eriocephalus africanus*

Phytochemical	Value	Reference
14-Acetoxy-5α-hydroperoxyisoalantolactone	-	Zdero et al.[50]
14-Acetoxy-11α,13-dihydrodesoxyivangustin	-	Zdero et al.[50]
14-Acetoxy-5α-hydroperoxy-11α,13-dihydroisoalantolactone	-	Zdero et al.[50]
allo-Aromadendrene (%)	0.02 – 6	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
allo-Aromadendrene epoxide (%)	0.5 – 9.0	Mohamed et al.[12]
Apigenin-O-glucoronide	-	Saraiva et al.[51]
Artemesia alcohol (%)	1.5 – 4.6	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Artemisia ketone (%)	4.5 – 77.9	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]; Njenga[27]; Behiry et al.[41]; El-Ahmady[53]
Artemisia ketone isomer (%)	0.4 – 0.7	Merle et al.[6]; Verdeguer et al.[7]
Artemisia triene (%)	0.2 – 0.3	Merle et al.[6]; Verdeguer et al.[7]
Benzaldehyde (%)	0.03 – 0.05	Merle et al.[6]; Verdeguer et al.[7]
Bicyclogermacrene (%)	0.7 – 15.6	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]; Njenga[27]
Borneol (%)	0.05 – 10.0	Merle et al.[6]; Njenga[27]
Butyl acetate (%)	0.04 – 0.05	Merle et al.[6]; Verdeguer et al.[7]
α-Cadinol (%)	0.6 – 8.4	Mohamed et al.[12]; Njenga[27]
δ-Cadinene (%)	0.2 – 9.0	Merle et al.[6]; Verdeguer et al.[7]; Njenga[27]
tau-Cadinol (%)	0.04 – 0.05	Merle et al.[6]; Verdeguer et al.[7]

Phytochemical	Value	Reference
Caffeic acid (mg/100 mg dry weight)	0.04 – 0.05	Mohamed et al.[9]
Caffeic acid derivatives	-	Saraiva et al.[51]
3-Caffeoylquinic acid (mg/g)	6.9 – 7.3	Catarino[8]; Catarino et al.[11]
Caffeoyl-hexuronide derivative (mg/g)	1.1 -1.6	Catarino[8]; Catarino et al.[11]
Caffeoxylquinic acid	-	Catarino et al.[52]
di-Caffeoxylquinic acid	-	Catarino et al.[52]
Chamazulen (%)	1.1 – 2.4	Njenga[27]
Camphene (%)	0.04 – 1.6	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Camphor (%)	0.3 – 12.1	Mohamed et al.[12]; Njenga[27]
Carvacrol (%)	11.5	El-Ahmady[53]
Caryophylla-4,8-dien-5-ol (%)	0.6 – 1.0	Merle et al.[6]; Verdeguer et al.[7]
Caryophyllene (%)	0.3 – 2.5	Mohamed et al.[12]
β-Caryophyllene (%)	0.6 – 5.1	Merle et al.[6]; Verdeguer et al.[7]; Njenga[27]; Behiry et al.[41]
Caryophyllene oxide (%)	0.3 – 10.1	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]; Njenga[27]
Caryophyllenol (%)	0.08 – 0.1	Merle et al.[6]; Verdeguer et al.[7]
Catechin (mg/100 mg dry weight)	1.7 – 5.1	Mohamed et al.[9]
Chrysanthenone (%)	18.5	Njenga[27]
1,8-Cineole (%)	0.06 – 23.6	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]; Njenga[27]
Chlorogenic acid (mg/100 mg)	1.1 – 3.6	Mohamed et al.[9]
α-Copaene (%)	0.05 – 1.5	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
β-Copaen-4-α-ol (%)	0.06 – 1.3	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
α-Cubebene (%)	0.2 – 1.5	Mohamed et al.[12]
1-epi-Cubenol (%)	0.02 – 0.05	Merle et al.[6]; Verdeguer et al.[7]
p-Cymene (%)	0.5 – 7.4	Merle et al.[6]; Verdeguer et al.[7]; Njenga[27]
1,4-Dicaffeoylquinic acid (mg/g)	3.7 – 5.4	Catarino[8]; Catarino et al.[11]
3,4-Dicaffeoylquinic acid (mg/g)	4.0 - 5.6	Catarino[8]; Catarino et al.[11]
3,5-Dicaffeoylquinic acid (mg/g)	16.3 – 19.4	Catarino[8]; Catarino et al.[11]
En-in-dicycloether (%)	2.3	Njenga[27]
Dihydromyrcene (%)	0.2	Behiry et al.[41]
Elemol (%)	0.8 - 1.1	Merle et al.[6]; Verdeguer et al.[7]
Eriodictyol (mg/g)	0.2	Catarino[8]
Eriodictyol-O-hexuronide (mg/g)	1.6 – 7.8	Catarino et al.[11]; Catarino et al.[52]
Eudesm-7(11)-en-4-ol (%)	0.3 – 17.7	Mohamed et al.[12]; El-Ahmady[53]
α-Eudesmol (%)	0.05 – 0.7	Merle et al.[6]; Verdeguer et al.[7]; Behiry et al.[41]
β-Eudesmol (%)	0.03 – 6.0	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]; Njenga[27]
γ-Eudesmol (%)	0.02 – 5.6	Merle et al.[6]; Verdeguer et al.[7]
T-Eudesmol (%)	9.1	El-Ahmady[53]
10-epi-γ-Eudesmol (%)	0.02 – 1.9	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Eriodictyol (mg/g)	0.2	Catarino et al.[11]
Eriodictyol-O-glucoronide	-	Saraiva et al.[51]
Eriodictiol-O-hexuronide (mg/g)	1.6 – 7.8	Catarino[8]; Catarino et al.[11]
Ferulic acid derivative (mg/g)	1.5	Catarino[8]; Catarino et al.[11]
Gallic acid (mg/100 mg dry weight)	0.02 – 0.03	Mohamed et al.[9]
Geranyl acetate (%)	0.05 – 1.2	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Germacrene-ɒ-4-ol (%)	0.04 – 0.05	Merle et al.[6]; Verdeguer et al.[7]
Globulol (%)	2.2 – 8.3	Mohamed et al.[12]
cis-β-Guaiene (%)	0.3 – 0.9	Mohamed et al.[12]
Guaiol (%)	0.09 – 1.4	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Hexanal (%)	0.04 - 0.05	Merle et al.[6]; Verdeguer et al.[7]
cis-3-Hexenyl acetate (%)	0.04 – 0.1	Merle et al.[6]; Verdeguer et al.[7]
α-Humulene (%)	0.03 – 1.0	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
5α-Hydroperoxyasperilin	-	Zdero et al.[50]
5β-Hydroxyasperilin	-	Zdero et al.[50]
11-Hydroxy-4,5-seco-eudesmane-4,5- dione	-	Zdero et al.[50]
14-Hydroxydexoxyivangustin	-	Zdero et al.[50]
14-Hydroxy-5α-hydroperoxyisoalantolactone	-	Zdero et al.[50]
Intermedeol (%)	9.1 – 11.6	Merle et al.[6]; Verdeguer et al.[7]
Kaempferol (mg/100 mg dry weight)	0.01 – 0.06	Mohamed et al.[9]
Kessane (%)	0.7 – 1.0	Merle et al.[6]; Verdeguer et al.[7]
Ledol (%)	19.9	Behiry et al.[41]

Phytochemical	Value	Reference
Liguloxide (%)	1.1 – 1.4	Merle et al.[6]; Verdeguer et al.[7]
Liguloxide isomer (%)	0.09 – 0.2	Merle et al.[6]; Verdeguer et al.[7]
Limonene (%)	0.04 – 0.05	Merle et al.[6]; Verdeguer et al.[7]
Limonene dioxide 2 (%)	0.1	Behiry et al.[41]
Longipinenepoxide (%)	0.1	Behiry et al.[41]
α-Longipinene (%)	0.6 – 3.7	Njenga[27]
9-(1-Methylethylidene)-bicyclo[6.1.0]nonane (%)	0.5	Behiry et al.[41]
τ-Muurolol (%)	0.3 – 8.4	Merle et al.[6]; Verdeguer et al.[7]; Njenga[27]
Myrtenal (%)	0.05 – 0.5	Merle et al.[6]; Verdeguer et al.[7]
Myrcene (%)	0.08 – 0.1	Merle et al.[6]; Verdeguer et al.[7]
Myrtenol (%)	0.04 – 0.7	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Nerol oxide (%)	<0.05	Merle et al.[6]
Neryl acetone (%)	5.7	Njenga[27]
1-Nonene (%)	0.04 – 0.06	Merle et al.[6]; Verdeguer et al.[7]
3-Octanone (%)	0.08 – 0.1	Merle et al.[6]; Verdeguer et al.[7]
1-Octen-3-ol (%)	0.04 – 0.05	Merle et al.[6]; Verdeguer et al.[7]
1-Octene (%)	0.07 - 0.08	Merle et al.[6]; Verdeguer et al.[7]
7-Methyl-1-octene (%)	0.2 – 0.3	Merle et al.[6]; Verdeguer et al.[7]
Phytol (%)	0.04 – 0.9	Verdeguer et al.[7]; Mohamed et al.[12]
α-Pinene (%)	0.5 – 7.5	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]; Njenga[27]
β-Pinene (%)	0.08 – 1.7	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Pinocarvone (%)	0.6 – 1.8	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Trans-pinocarveol (%)	0.4 – 1.2	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Piperitone (%)	0.4 – 17.2	Njenga[27]
Protocatechuic-acid-4-glucoside (mg/g)	0.4	Catarino[8]; Catarino et al.[11]
Quercetin (mg/100 mg dry weight)	0.01 – 0.07	Mohamed et al.[9]
Sabinene (%)	0.02 – 8.4	Merle et al.[6]; Verdeguer et al.[7]; Njenga[27]
Santolina alcohol (%)	29.9	Njenga[27]
Santolina triene (%)	0.2 – 0.3	Merle et al.[6]; Verdeguer et al.[7]
Selin-11-en-4-α-ol (%)	0.03 – 0.1	Merle et al.[6]; Verdeguer et al.[7]
Selina-3,7(11)-diene (%)	0.3 – 2.3	Mohamed et al.[12]
7-epi-α-Selinene (%)	0.2 – 0.3	Merle et al.[6]; Verdeguer et al.[7]
α-Selinene (%)	0.5 – 2.4	Mohamed et al.[12]
β-Selinene (%)	0.4 – 1.5	Mohamed et al.[12]
Spathulenol (%)	0.4 – 40.0	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]; Njenga[27]
Terpinen-4-ol (%)	0.03 – 0.05	Merle et al.[6]; Verdeguer et al.[7]
γ-Terpinene (%)	0.04 – 0.05	Merle et al.[6]; Verdeguer et al.[7]
4-Terpineol (%)	0.3 – 7.3	Njenga[27]
13-Tetradec-11-yn-1-ol (%)	0.3	Behiry et al.[41]
α-Thujene (%)	3.4	El-Ahmady[53]
Total flavonoid content (mg CE/g)	1.5 – 3.0	Mlungwana et al.[37]
Total phenolic content (mg GAE/g)	7.0 – 17.0	Mlungwana et al.[37]
Viridiflorol (%)	0.04 – 1.4	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]
Yomogi alcohol (%)	0.3 – 3.4	Merle et al.[6]; Verdeguer et al.[7]; Mohamed et al.[12]; Njenga[27]; Behiry et al.[41]

Biological activities of *Eriocephalus africanus*

The following biological activities have been reported from the leaf, root, stem and twig extracts of *E. africanus* and essential oils isolated from the species: analgesic,[39] antibacterial,[27,33,34,41,44] antimycobacterial,[44] antifungal,[27,33,34,44] anti-inflammatory,[1,8,27], antioxidants,[1,8,9,27,33,51] antipyretic[39] and phytotoxic[7,54] activities.

Analgesic activities

Amabeoku et al.[39] evaluated the analgesic activities of water leaf extracts of *E. africanus* by using the acetic acid writhing in mice and hot-plate test in mice assays with paracetamol as a positive control. The writhing induced by acetic acid was attenuated by 50 mg/kg, i.p. to 200 mg/kg, i.p. of the extract. Similarly, the pain produced by the hot-plate was antagonized by 50 mg/kg, i.p. to 100 mg/kg, i.p. of the extract. Paracetamol at 500 mg/kg, i.p. produced similar effect to that of the extract on acetic acid-induced writhes but did not affect the pain and the fever produced by the hot-plate.[39]

Antibacterial activities

Salie et al.[33] evaluated the antibacterial activities of petroleum ether, chloroform, ethanol, methanol and water leaf, root and stem extracts of *E. africanus* against

Staphylococcus aureus, Pseudomonas aeruginosa and *Mycobacterium smegmatis* using agar dilution method with ciprofloxacin (40 µg/disc) as a positive control. The petroleum ether stem extract exhibited weak activities with zone of inhibition of <3mm against >15 mm exhibited by the positive control. But the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values of methanol root extracts against Staphylococcus aureus was 10.0 mg/ml.[33] Njenga[27] evaluated the antibacterial activities of acetone leaf extracts of *E. africanus* and essential oil isolated from the species against *Bacillus cereus, Yersinia enterocolitica, Bacillus subtilis, Salmonella typhimurium, Enterococcus faecalis, Salmonella enteriditis, Escherichia coli, Staphylococcus aureus, Proteus vulgaris, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus epidermidis* and *Serratia odorifera* using disc diffusion assay and micro-titre plate dilution method with ciprofloxacin (0.01 mg/ml) as a positive control. The essential oil exhibited activities against most of the pathogens with the exception of *Salmonella typhimurium* with the zone of inhibition ranging from <1.0 mm to 5.5 mm. The acetone extract exhibited activities against *Bacillus cereus, Bacillus subtilis, Staphylococcus aureus* and *Pseudomonas aeruginosa* with the zone of inhibition ranging from <1.0 mm to 2.0 mm. The MIC values of essential oil against *Bacillus cereus, Escherichia coli* and *Staphylococcus aureus* ranged from 8.0 mg/ml to 32.0 mg/ml.[27] Njenga et al.[34] evaluated the antibacterial activities of the essential oil isolated from *E. africanus* using the disc diffusion assay against *Bacillus cereus, Bacillus subtilis, Staphylococcus aureus, Staphylococcus epidermidis, Klebsiella pneumoniae, Escherichia coli, Pseudomonas aeruginosa, Yersinia enterocolitica, Salmonella typhimurium, Salmonella enteriditis, Proteus vulgaris, Serratia odorifera* and *Enterococcus faecalis* with neomycin (30 µg) as a positive control. The essential oil exhibited activities against *Bacillus cereus, Bacillus subtilis, Staphylococcus aureus, Klebsiella pneumoniae* and *Escherichia coli* with zone of inhibition ranging from <1.0 mm to 6.0 mm which was comparable to 2.0 mm to 8.0 mm exhibited by the positive control. The MIC values against *Bacillus cereus, Staphylococcus aureus* and *Escherichia coli* ranged between 8.0 mg/ml to 32.0 mg/ml.[34] Seaman[44] evaluated the antibacterial activities of acetone and methanol leaf extracts of *E. africanus* against *Staphylococcus aureus, Enterococcus faecalis, Bacilus cereus, Pseudomonas aeruginosa, Klebsiella pneumoniae, Serratia odorifera* and *Moraxella catarrhalis* using broth microdilution method with neomycin and ciprofloxacin as positive controls. The extracts showed activities against tested pathogens with MIC values ranging from 0.5 mg/ml to >16.0 mg/ml.[44] Behiry et al.[41] evaluated the antibacterial activities of the essential oil isolated from *E. africanus* against *Agrobacterium tumefaciens, Dickeya solani, Erwinia amylovora, Pseudomonas cichorii* and *Serratia plymuthica* using the disc diffusion and serial dilution methods. The essential oil exhibited activities against *Agrobacterium tumefaciens, Dickeya solani, Erwinia amylovora* and *Pseudomonas cichorii* with zone of inhibition ranging from 5.7 mm to 18.3 mm and MIC values against these pathogens ranging from 100.0 µg/mL to 2000.0 µg/mL. The strain *Serratia plymuthica* was resistant to the oil but its growth inhibition was reported with a MIC value of 100 µg/mL.[41]

Antimycobacterial activities

Seaman[44] evaluated the antimycobacterial activities of acetone and water leaf extracts of *E. africanus* against *Mycobacterium smegmatis* and *Mycobacterium aurum* using broth microdilution technique and *Mycobacterium tuberculosis* using BACTEC susceptibility testing with rifampicin and ciprofloxacin as positive controls. The extracts exhibited activities with MIC values ranging from 0.3 mg/ml to 4.0 mg/ml.[44]

Antifungal activities

Salie et al.[33] evaluated antifungal activities of petroleum ether, chloroform, ethanol, methanol and water leaf, root and stem extracts of *E. africanus* against *Candida albicans* using agar dilution method with amphotericin B (25 µg/disc) as a positive control. The chloroform and petroleum ether leaf extracts exhibited weak activities with zone of inhibition of <3mm against 6mm to 9 mm exhibited by the positive control.[33] Njenga[27] evaluated antifungal activities of acetone leaf extracts of *E. africanus* and essential oil isolated from the species against *Cryptococcus neoformans* and *Candida albicans* using disc diffusion assay and micro-titre plate dilution methods with amphotericin B (0.01 mg/ml) as a positive control. The essential oil exhibited activities against both species with the zone of inhibition ranging from <1.0 mm to 2.0 mm. The acetone extract exhibited activities against *Cryptococcus neoformans* with the zone of inhibition of 2.0 mm. The MIC value of essential oil against both pathogens was 4.0 mg/ml.[27] Njenga et al.[34] evaluated the antifungal activities of the essential oil isolated from E. africanus using the disc diffusion assay against *Cryptococcus neoformans, Candida albicans* and *Alternaria alternata* with nystatin (100 IU) as a positive control. The essential oil exhibited activities against *Cryptococcus neoformans* and *Candida albicans* with zone of inhibition ranging from 1.0 mm to 8.0 mm which was comparable to 7.0 mm to 11.0 mm exhibited by the positive control. The MIC values against both *Cryptococcus neoformans* and *Candida albicans* was 4.0 mg/ml.[34] Seaman[44] evaluated the antibacterial activities of methanol and acetone leaf extracts of *E. africanus* against *Candida albicans* using the broth microdilution method with nystatin as a positive control. The acetone and methanol extracts exhibited activities with MIC values of 2.0 mg/ml and 4.0 mg/ml, respectively.[44]

Anti-inflammatory activities

Njenga[27] evaluated anti-inflammatory activities of essential oil isolated from the leaves of *E. africanus* using the 5-lipoxygenase (5-LOX) enzyme assay with nordihydroguaiaretic acid (NDGA) as a reference drug. The essential oil exhibited activities with half maximal inhibitory concentration (IC_{50}) values ranging from 19.0

µg/ml to 32.8 µg/ml against IC_{50} value of 5.0 µg/ml exhibited by the positive control.[27] Njenga and Viljoen[1] evaluated anti-inflammatory activities of essential oils isolated from the leaves of E. africanus using the 5-LOX enzyme assay with NDGA as a positive control. The essential oil exhibited activities with IC_{50} values ranging from 19.0 µg/ml to 32.8 µg/ml against 5.0 µg/ml exhibited by the positive control.[1] Catarino[8] evaluated anti-inflammatory activities of hydroethanolic leaf and stem extracts of *E. africanus* using the 5-LOX enzyme assay with ascorbic acid (75 µg/mL) as the standard compound. The stem extract exhibited weak 5-LOX inhibitory activities. At a concentration of 75 µg/mL, the stem extract was able to inhibit the 5-LOX activity in 29.7% in comparison to 70.9% exhibited by the standard drug.[8]

Antioxidants activities

Njenga[27] evaluated antioxidant activities of acetone leaf extracts of E. africanus and essential oil isolated from the species using the 2,2, diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay with vitamin C as the positive control. The essential oil did not show any activity but the acetone extract exhibited IC_{50} values ranging from 38.1 µg/ml to 49.9 µg/ml.[27] Njenga and Viljoen[1] evaluated antioxidant activities of acetone leaf extracts of *E. africanus* and the essential oil isolated from the species using the DPPH free radical scavenging assay with vitamin C as a positive control. The essential oil did not show any activities but the leaf extract exhibited activities with IC_{50} values ranging from 37.4 µg/ml to 49.9 µg/ml against 2.9 µg/ml exhibited by the positive control.[1] Saraiva et al.[51] evaluated the antioxidant activities of ethanolic leaf extract of *E. africanus* using DPPH free radical scavenging, ferric reducing antioxidant power and lipid peroxidation inhibition capacity assays. The extract exhibited activities with half maximal effective concentration (EC_{50}) values of 9.1 µg/mL, 0.05 mg/mL and 0.7 mg/mL for the DPPH, reducing power and lipid peroxidation assays, respectively (Saraiva et al., 2013).[51] Catarino[8] evaluated antioxidants activities of hydroethanolic leaf and stem extracts of *E. africanus* using DPPH free radical scavenging, 2,2-azino-bis(3-ethylbenzothiazoline)-6-sulfonic acid (ABTS) decolorization assay, hydroxyl (OH) scavenging assay, ferric reducing antioxidant power (FRAP) assay, lipid peroxidation inhibition capacity (TBARS) assays, oxygen radical absorbance capacity (ORAC) assay and chemical NO scavenging assay with ascorbic acid, butylated hydroxyanisole (BHA), mannitol and trolox as reference drugs. The extracts exhibited activities with DPPH exhibiting IC_{50} values of 17.0 µg/mL and 28.0 µg/mL, ABTS (15.0 µg/mL and 17.0 µg/mL), OH (150.0 µg/mL and 225.0 µg/mL), FRAP (57.0 µg/mL and 96.0 µg/mL), TBARS (333.0 µg/mL and 418.0 µg/mL), ORAC (1.2 µM TE and 4.0 µM TE and chemical NO scavenging (526.4 µg/mL and 538.6 µg/mL).[8] Mohamed et al.[9] evaluated the antioxidant activities of *in vitro* produced *E. africanus* and in vivo grown plants using the DDPH free radical scavenging assay. Extracts from both *in vitro* and *in vivo* produced plants that exhibited antioxidant activities ranging from 81.0% to 78.6%.[9] Catarino et al.[11] evaluated antioxidant activities of hydroethanolic leaf and stem extracts of *E. africanus* using DPPH free radical scavenging, ferric reducing antioxidant power and lipid peroxidation inhibition capacity assays with ascorbic acid, BHA and trolox as reference drugs. The extracts exhibited activities with DPPH exhibiting IC_{50} values of 17.0 µg/mL and 28.0 µg/mL, reducing power assay (57.0 µg/mL and 96.0 µg/mL) and lipid peroxidation inhibition capacity (333.0 µg/mL and 418.0 µg/mL).[11]

Antipyretic activities

Amabeoku et al.[39] evaluated the antipyretic activities of water leaf extracts of *E. africanus* by assessing fever produced by lipopolysaccharide in male albino mice with paracetamol as a positive control. The extract at 100 mg/kg, i.p. to 200 mg/kg, i.p. attenuated the fever produced by the bacterial endotoxin at lipopolysaccharide, 50 µg/kg, i.m. Paracetamol at 500 mg/kg, i.p. produced similar effect to that of the extract on the fever produced by the lipopolysaccharide.[39]

Phytotoxic activities

Verdeguer et al.[7] evaluated phytotoxic activities of the essential oil isolated from *E. africanus* against *Amaranthus hybridus* L. and *Portulaca oleracea* L. The essential oil showed phytotoxic effects against *Amaranthus hybridus* seeds, blocking their germination at all the concentrations applied, while reducing *Portulaca oleracea* germination at the highest concentrations of 0.5 µl/ml and 1.0 µl/ml. Both concentrations decreased *Portulaca oleracea* germination by 23% and 24%, respectively.[7] In another study, Verdeguer et al. (2009b) evaluated the allelopathic potential of aqueous leaf extracts of E. africanus using bioassays in the greenhouse and in field conditions. In greenhouse assays, the extract showed herbicidal activities exhibiting 52.5% inhibition while under field conditions, the extract exhibited 68.9% inhibition respectively.[54]

CONCLUSION

The present review summarizes the botany, medicinal uses, phytochemistry and pharmacological properties of *E. africanus*. In the past 30 years, *E. africanus* has been the subject of phytochemical and pharmacological research but there is not yet enough data correlating the ethnomedicinal uses of the species with its phytochemical and pharmacological properties. Detailed studies on the pharmacokinetics, *in vivo* and clinical research involving both extracts and compounds isolated from the species are required. Therefore, future research should focus on the molecular modes or mechanisms of action, pharmacokinetics and physiological pathways for specific extracts of the species including identification of the bioactive compounds of the species and their associated pharmacological activities.

Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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