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Arctopus echinatus (Apiaceae): medicinal uses, phytochemistry and biological activities

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Abstract

Arctopus echinatus is a valuable perennial geophyte widely used as herbal medicine in South Africa. This study reviewed medicinal uses, phytochemical and pharmacological properties of *A. echinatus*. Relevant information on the medicinal uses, phytochemistry and pharmacological properties of *A. echinatus* was collected from electronic scientific databases such as ScienceDirect, SciFinder, PubMed, Google Scholar, Medline, and SCOPUS. Pre-electronic literature search of conference papers, scientific articles, books, book chapters, dissertations and theses was carried out at the University library. Literature search revealed that *A. echinatus* is used as blood purifier, demulcent, diuretic, sedative and general medicine, and herbal medicine for cough, ringworm, tuberculosis, bladder problems, skin irritations, epilepsy and venereal diseases. Phytochemical compounds identified from the species include amino acids, diterpenes and phenolic acids. Pharmacological studies revealed that *A. echinatus* extracts have antibacterial, antifungal and $GABA_A$ benzodiazepine receptor-binding activities. *Arctopus echinatus* should be subjected to detailed phytochemical, pharmacological and toxicological evaluations aimed at correlating its medicinal uses with its phytochemistry and pharmacological activities.

Keywords: Apiaceae, Arctopus echinatus, South Africa, traditional knowledge, Umbelliferae

INTRODUCTION

Arctopus echinatus L. is an acaulescent perennial geophyte which belongs to Apiaceae or Umbelliferae, commonly known as the carrot (*Daucus carota* L.), celery (*Apium graveolens* L.,) or parsley (*Petroselium crispum* (Mill.) Fuss family. Sayed-Ahmad et al.[1] argued that species belonging to the family Apiaceae have been utilized as sources of food, flavouring agents, sources of fragrance and herbal medicines since antiquity. Several species of the family are used as herbal medicines to treat and manage various illnesses related to digestive, endocrine, reproductive and respiratory systems.[1-3] The family is also rich in phytochemical and secondary metabolites such as terpenoids, triterpenoid saponins, flavonoids, coumarins, polyacetylenes and steroids.[1] Ethnopharmacological research revealed that extracts or compounds isolated from species belong to the Apiaceae family exhibited biological activities such as anti-tumor, antifungal, antiviral, anti-inflammatory, analgesic, radical scavenging, apoptosis, antibacterial, hepatoprotective, vaso-relaxant, cyclooxygenase inhibitory, diuretic, gastrointestinal and anti-obesity properties.[1,2,4] Olivier et al.[5] isolated phenolic acids including (R)-3'-O-β-D-glucopyranosylrosmarinic acid from the roots of Apiaceae species belonging to two closely related genera *Alepidea* F. Delaroche and *Arctopus* L. The compound (R)-3'-O-β-D-glucopyranosylrosmarinic acid is now considered a chemotaxonomic marker for the subfamily Saniculoideae of the Apiaceae family.[5,6] Recent research utilizing molecular data revealed that genera *Alepidea* and *Arctopus* appear to be the first two earliest lineages within the phylogeny of Saniculoideae subfamily. Species of both genera are widely used as herbal medicines throughout their geographical distributions with their roots characterized by kaurene-type diterpenoids,[7] a compound known to have antimicrobial, anti-parasitic and anti-inflammatory activities.[5,8] The species *Alepidea amatymbica* Eckl. & Zeyh., for example, is characterized by kaurene-type diterpenoids and their derivatives like ent-9, (11)-dehydro-16-kauren-19-oic acid, ent-16-kauren-19-oic acid, wedelia seco-kaurenolide, and 313-acetoxy which are believed to constitute up to 11.8% of rhizome and root dry mass.[9] These compounds could be responsible for biological activities associated with the species which include anti-inflammatory, antibacterial, antifungal, antiviral, antihelmintic, antimalarial, antihypertensive, cardiovascular, cytotoxicity and diuretic activities.[9-14] Moreover, *A. amatymbica* is used as herbal medicine against malaria, diarrhoea, colds, coughs, influenza, chest complaints and wounds to complex uses such as asthma and rheumatism.[15-21] Similarly, *A. echinatus* is one of the valuable medicinal plant species in South Africa, and the species is included in the book "medicinal plants of South Africa," a photographic guide to the most commonly used herbal medicines in the country, including its botany, major medicinal applications and active phytochemical compounds.[22] Due to the popularity of *A. echinatus* as traditional medicine, the tuberous root of the species is sold as traditional medicine in the informal herbal medicine markets in the Eastern Cape and Western Cape provinces in South Africa.[23-26] It is within this context that this review was undertaken aimed at reviewing the botany, medicinal uses and biological activities of *A. echinatus* so as to provide baseline data required in evaluating the therapeutic potential of the species.

Botanical profile of *Arctopus echinatus*

The genus name "*Arctopus*" means 'bear's foot' in reference to the broad and simple leaves that are characteristic of the plant group.[27] The specific epithet "*echinatus*" means "prickly"[28] in reference to the leaves of the species that are armed with large recurved thorns. The vernacular name of *A. echinatus* in Afrikaans is "sieketroos" which is derived from the medicinal value of the tuberous rootstock which brings comfort, that is,

"troos" in Afrikaans, to the sick, "sieke" in Afrikaans, translating to "comfort to the sick" in English.[22,23,27] The genus *Arctopus* is divided into three species namely *A. dregei* Sond., *A. echinatus* and *A. monacanthus* Carmich. ex Sond., based on the differences in their reproductive morphologies, being easily distinguishable by the large involucral bracteoles that surround the female pseudanthia.[29]

Arctopus echinatus is an easily recognizable, stemless, flat-growing, summer-deciduous perennial geophyte which can grow up to 10 cm in height and 60 cm in diameter.[29-31] The roots are relatively large, tuberous and exude a sticky resin when broken. The leaves are large, simple, prostrate, ovate to rhomboidal in outline, with spiny and conspicuously toothed margins and sharp recurved thorns between the leaf divisions. Male and female flowers are formed on different plants. The male flowers are small, white in colour and are borne on long stalks.[23,32] The female flowers are inconspicuous greenish-yellow in colour and borne in dense, stalkless, thorny clusters in the middle of the rosettes.[33] Fruits are dry, brown in colour and spiny. The prickly fruits are dispersed by sticking onto the fur or feet of animals or to human feet.[29] *Arctopus echinatus* has been recorded in winter rainfall region of South Africa in the Eastern Cape and Western Cape provinces, usually on seasonally moist sandy soils, granite flats and slopes at an altitude ranging from 50 m to 1700 m above sea level.[29-33]

Medicinal uses of *Arctopus echinatus*

The tuberous root of *A. echinatus* is mainly used as blood purifier, demulcent, diuretic, general medicine, sedative, and herbal medicine for cough, ringworm, tuberculosis, bladder problems, skin irritations, epilepsy and venereal diseases (Table 1, Figure 1).[5,22,23,27,31,34-53] The roots of *A. echinatus* are mixed with potassium nitrate as remedy for epilepsy.[35] The roots of *A. echinatus* are mixed with roots of *Pelargonium reniforme* Curtis and *P. sidoides* DC. as remedy for syphilis.[51]

Table 1: Medicinal uses of *Arctopus echinatus* in South Africa

Medicinal use	Parts used	References
Bladder problems	Roots	Van Wyk et al.[22]; Magee et al.[27]; Philander[46]; Hulley and Van Wyk[52]
Blood purifier	Roots	Van Wyk and Gericke[23]; Magee et al.[27]; Forbes[37]; Van Wyk[45]; Van Wyk and Gorelik[51]; Hulley and Van Wyk[52]
Cancer	Roots	Philander[46]
Cough	Roots	Van Wyk and Gericke[23]; Hulley and Van Wyk[52]
Demulcent	Roots	Van Wyk et al.[22]; Van Wyk and Gericke[23]; Magee et al.[27]; Musselman[40]; Van Wyk[45]; Van Wyk and Gorelik[51]
Diabetes	Roots	Philander[46]
Diuretic	Roots	Van Wyk et al.[22]; Magee et al.[27]; Musselman[40]; Digby[42]; Van Wyk[45]; Van Wyk and Gorelik[51]
Epilepsy	Roots mixed with potassium nitrate	Watt[35]
Epilepsy	Roots	Olivier et al.[5]; Van Wyk et al.[22]; Van Wyk and Gericke[23]; Watt[35]; Sobiecki[39]; Stafford et al.[41]; Stafford et al.[44]; Philander[46]
General medicine	Roots	Van Wyk[45]; Van Wyk and Gorelik[51]
Kidney problems	Roots	Hulley and Van Wyk[52]
Purgative	Roots	Van Wyk et al.[22]
Ringworm	Roots	Van Wyk and Gericke[23]; Hulley and Van Wyk[52]
Sedative	Roots	Olivier et al.[5]; Van Wyk and Gericke[23]; Sobiecki[39]; Stafford et al.[41]; Masondo et al.[53]
Skin irritations	Roots	Van Wyk et al.[22]; Magee et al.[27]; Watt and Breyer-Brandwijk[34]; Digby[42]; Mabona[47]; Mabona and Van Vuuren[48]; Twilley and Lall[49]
Sores	Roots	Van Wyk and Gericke[23]
Stomach ulcers	Roots	Philander[46]
Syphilis	Roots mixed with roots of Pelargonium reniforme Curtis and P. sidoides DC.	Van Wyk and Gorelik[51]
Tonic	Roots	Hulley and Van Wyk[52]
Tuberculosis	Roots	Van Wyk and Gericke[23]; Bapela[38]
Ulcers	Roots	Van Wyk and Gericke[23]
Venereal diseases (gonorrhoea and syphilis)	Roots	Van Wyk et al.[22]; Van Wyk and Gericke[23]; Magee et al.[27]; Lariushin[31]; Watt and Breyer-Brandwijk[34]; Theodore[36]; Forbes[37]; Scott and Hewett[43]; Van Wyk[45]; Philander[46]; Du Preez and Dronfield[50]; Van Wyk and Gorelik[51]

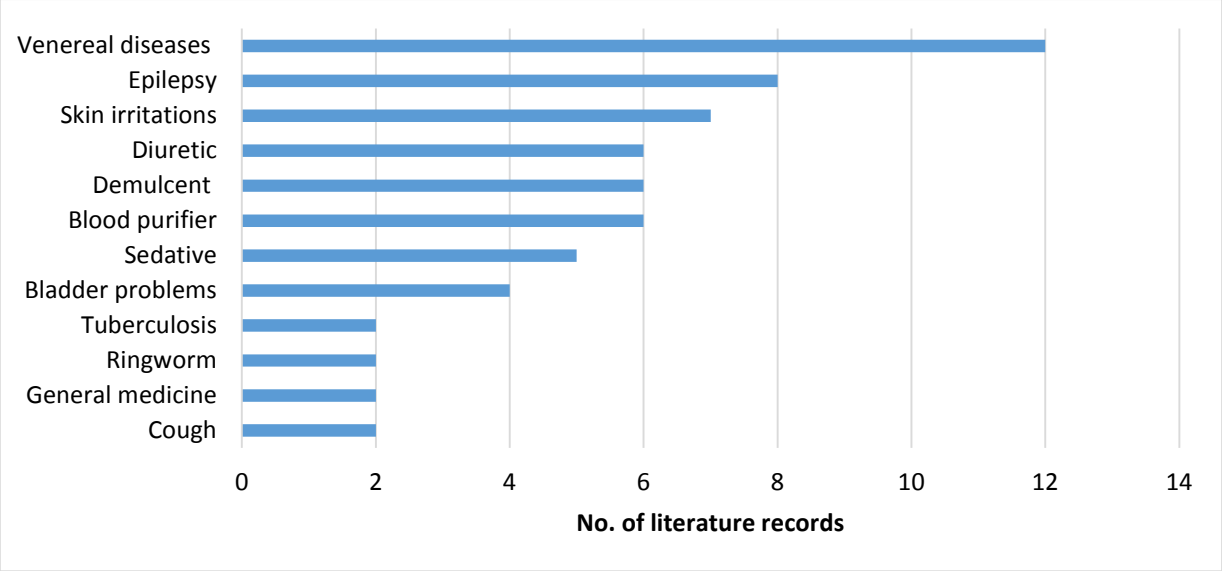
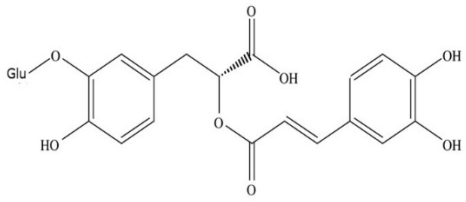


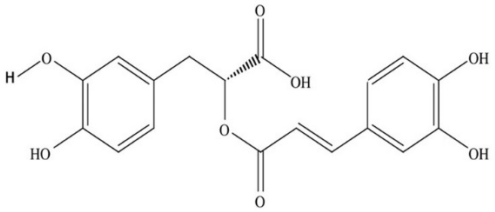
Figure 1. Medicinal applications of Arctopus echinatus **derived from literature records**

Table 2: Phytochemical composition of *Arctopus echinatus*

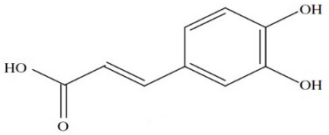
Phytochemical composition	Value	Plant part	Reference
α-Aminoadipic acid (mg/g dry weight)	3.1	Roots	Olivier[55]
β-Aminoisobutyric acid (mg/g dry weight)	2.9 – 3.1	Roots	Olivier[55]
γ-Aminobutyric acid (mg/g dry weight)	0.6 – 6.0	Roots	Olivier[55]
(R)-3'-O-β-D-glucopyranosylrosmarinic acid	-	Roots	Olivier et al.[5]
Alanine (mg/g dry weight)	14.1	Roots	Olivier[55]
Allo-isoleucine (mg/g dry weight)	4.7 – 5.0	Roots	Olivier[55]
Asparagine (mg/g dry weight)	347.7	Roots	Olivier[55]
Aspartic acid (mg/g dry weight)	2.2 – 19.0	Roots	Olivier[55]
Caffeic acid	-	Roots	Olivier et al.[5]
Dehydro-manoxyloxide isomer (%)	1.0 - 5.0	Roots	Olivier[55]
Ent-trachyloban-19-oic acid	-	Roots	Olivier and Van Wyk[54]
Glucoside	-	Roots	Watt and Breyer-Brandwijk[34]
Glutamic acid (mg/g dry weight)	4.5 – 6.6	Roots	Olivier[55]
Glutamine (mg/g dry weight)	7.6	Roots	Olivier[55]
Histidine (mg/g dry weight)	10.8 – 11.9	Roots	Olivier[55]
Isoleucine (mg/g dry weight)	1.5 – 1.6	Roots	Olivier[55]
Kauranol (%)	1.0 - 5.0	Roots	Olivier[55]
Kauren-19-oic acid	-	Roots	Olivier and Van Wyk[54]
Kaurenoic acid (%)	6.0 - 20.0	Roots	Olivier[55]
Lysine (mg/g dry weight)	10.2 – 11.0	Roots	Olivier[55]
Manool (%)	>20.0	Roots	Olivier[55]
Methyl-16β-hydroxy-ent-kaur-11-en-19-oate	-	Roots	Olivier and Van Wyk[54]
Methyl hydroxy-kaurenoate isomer (%)	1.0 - 5.0	Roots	Olivier[55]
Methyl hydroxy-dehydro-kaurenoate isomer (%)	1.0 - 5.0	Roots	Olivier[55]
Ornithine (mg/g dry weight)	4.7 – 4.8	Roots	Olivier[55]
Phenylalanine (mg/g dry weight)	8.2 – 8.5	Roots	Olivier[55]
Proline (mg/g dry weight)	11.3 – 240.4	Roots	Olivier[55]
Resin	-	Roots	Watt and Breyer-Brandwijk[34]
Rosmarinic acid	-	Roots	Olivier et al.[5]
Serine (mg/g dry weight)	3.5	Roots	Olivier[55]
Sucrose	-	Roots	Watt and Breyer-Brandwijk[34]
Trachylobanoic acid isomer (%)	6.0 - 20.0	Roots	Olivier[55]
Tryptophan (mg/g dry weight)	12.5 – 13.4	Roots	Olivier[55]
Tyrosine (mg/g dry weight)	5.5 – 6.8	Roots	Olivier[55]
Valine (mg/g dry weight)	1.5 – 2.4	Roots	Olivier[55]



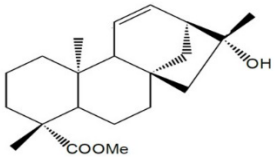
(R)-3'-O-β-D-glucopyranosylrosmarinic acid



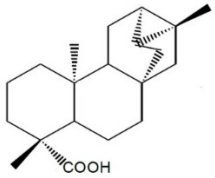
Rosmarinic acid



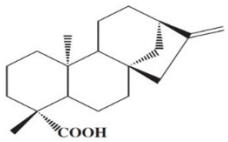
Caffeic acid



Methyl-16β-hydroxy-ent-kaur-11-en-19-oate



Ent-trachyloban-19-oic acid



Kauren-19-oic acid

Figure 2: Chemical structures of major compounds identified from Arctopus echinatus

Phytochemistry of *Arctopus echinatus*

Watt and Breyer-Brandwijk[34] identified glucoside, resin and sucrose from the roots of *A. echinatus* (Table 2). Olivier et al.[5] identified three phenolic acid compounds (R)-3'-O-β-D-glucopyranosylrosmarinic acid, caffeic acid and rosmarinic acid from the roots of *A. echinatus* (Table 2, Figure 2). Olivier and Van Wyk[54] identified three diterpene compounds ent-trachyloban-19-oic acid, kauren-19-oic acid and methyl-16β-hydroxy-ent-kaur-11-en-19-oate from roots of *A. echinatus* (Table 2, Figure 2).

Biological activities of *Arctopus echinatus*

The following biological activities have been reported from the root extracts of *A. echinatus*: antibacterial,[27] antifungal[27] and $GABA_A$ benzodiazepine receptor-binding[41] activities. Van Wyk et al.[22] argued that the biological activities of the species are probably due to kaurenoic acids. The same authors argued that rosmarinic acid and its glycosides are known to have antioxidant, astringent, anti-inflammatory, antimutagenic, antibacterial and antiviral activities.

Antibacterial activities

Magee et al.[27] evaluated antibacterial activities of methanol: water (80: 20) extracts of the roots of *A. echinatus* against *Staphylococcus aureus, Staphylococcus epidermidis, Escherichia coli, Proteus vulgaris, Enterobacter aerogenes, Pseudomonas aeruginosa* and *Klebsiella pneumoniae* using the microplate method with ciprofloxacin as a positive control. The extract exhibited activities against the majority of tested pathogens with the exception of *Proteus vulgaris* and *Pseudomonas aeruginosa* exhibiting the minimum inhibitory concentrations (MIC) values ranging from 0.05 mg/mL to 4.0 mg/mL.[27]

Antifungal activities

Magee et al.[27] evaluated antifungal activities of methanol: water (80: 20) extracts of the roots of *A. echinatus* against *Candida albicans* and *Cryptococcus neoformans* using the microplate method with amphotericin B as a positive control. The extract exhibited activities against *Candida albicans* with the MIC values ranging from 4.0 mg/mL to 6.0 mg/mL.[27]

$GABA_A$ benzodiazepine receptor-binding activities

Stafford et al.[41] evaluated the $GABA_A$ benzodiazepine receptor-binding activities of ethanolic whole plant extracts of *A. echinatus* by assessing the binding of ^{3}H-Ro 15-1788 (flumazenil) to the benzodiazepine site. The extract showed good dose-dependent activities. These findings support the traditional use of *A. echinatus* as a sedative and anti-convulsant.[41]

CONCLUSION

The present review summarizes the ethnomedicinal uses, phytochemistry and biological activities of the root extract of *A. echinatus*. The historical traditional usage of *A. echinatus* as herbal medicine in the Eastern Cape and Western Cape provinces in South Africa calls for detailed phytochemical and pharmacological studies aimed at correlating its documented ethnomedicinal uses with the phytochemical and pharmacological properties of the species. There is need for clinical and toxicological evaluations of both crude extracts and phytochemical compounds associated with *A. echinatus*.

Conflict of interest

The author declares that he has no conflict of interest.

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