Unlocking the Therapeutic Potential of the Genus *Senecio* (Asteraceae): Essential Oil Composition and Pharmacological Insights

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Received: October 18, 2023
Accepted: January 25, 2025

Senecio is the largest and most complex genus in the family of the Asteraceae with more than 1,500 species distributed widely throughout the world. A comprehensive search of the electronic databases (1986–2023) using the keywords of '*Senecio*' and 'essential oil' revealed that an essential oils composition breakdown is available for 57 species, with α-pinene, α-farnesene, germacrene D, p-cymene, myrcene, α-terpinene, and caryophyllene oxide being the most identified components. The pharmacological activities have been summarized of different species including antimicrobial, antioxidant, repellent, antifungal, acaricidal, anti-inflammatory, cytotoxicity, phytotoxic, anticholinesterase, allelopathic, nematicidal, antimalarial, antileishmanial, α-glucosidase, anticorrosive, analgesic, and toxicity. This review is expected to lay the foundation for further studies of this genus and provides guidance for selecting accessions of species with the best chemical profiles.

Keywords: Asteraceae, *Senecio*, essential oil, composition, α-pinene, antimicrobial.

1. INTRODUCTION

Plants have been used as medicines since ancient times and were effectively recognised as bactericides, fungicides, virucides, antiparasitics, and pesticides. In several cases, their properties are mainly attributed to their essential oils (EOs). EOs from aromatic plants are considered a vital source of medicine that contains unique bioactive compounds. They are widely used in the pharmaceutical, agricultural, cosmetic, and food industries due to their pharmacological properties [1-3]. Investigations into the potential uses of plant EOs are again exciting the interest of scientists in further research. *Senecio*, the largest and most widespread genus of the family Asteraceae, includes more than 1,500 species. Among them, 270 species are reported in Argentina, 22 species are found in Morocco, and 6 occur in Egypt. The genus is also widespread in the temperate regions of Europe, North America, Asia, and South Africa . *Senecio* is derived from the Latin word *senex*, which literally means 'old man', referring to the white egrets that alight on the achenes during plant fructification. Several species of *Senecio* have been documented in the literature to date, some of which are distributed worldwide (*Senecio vulgaris*), while others can only be found in restricted areas (e.g., *Senecio rosinae*, reported only on the island of Corsica) . Other species of the genus *Senecio* have been used in traditional medicine for the treatment of asthma, coughs, bronchitis, eczema, and for healing wounds . Several phytochemical studies have investigated EOs of *Senecio* and discovered significant chemical variability.
To appreciate the potential of the genus *Senecio,* a review is therefore required of their traditional uses, chemical compositions, and the pharmacological activities of its EOs.

2. SEARCH STRATEGY

The protocol for performing this study was developed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) : (a) the first step was to exclude duplicate articles, (b) titles and abstracts were then read and the inclusion and exclusion criteria were applied, (c) all articles resulting from this stage were read in full, and the inclusion and exclusion criteria were applied again. Figure 1 shows the flow diagram of the identification and selection of articles. Following this step, we selected the articles for this study. This systematic review was conducted through searches using Scopus, PubMed, Science Direct, SciFinder, and Google Scholar. The keywords used were '*Senecio*', 'essential oil', and 'biological activity' to find articles over the period from the beginning of the database until October 2023. The inclusion of articles was based on the following criteria: (1) type of publication - original research articles, (2) only articles in English, (3) articles must present the chemical composition of *Senecio* essential oils, (4) articles must discuss the bioactivity of the essential oils. The following were the exclusion criteria : (1) articles that did not present the search terms in the title and abstract; (2) review articles, (3) full-text articles not found, (4) articles without one of the keywords and (5) articles that did not present the composition of the EOs.

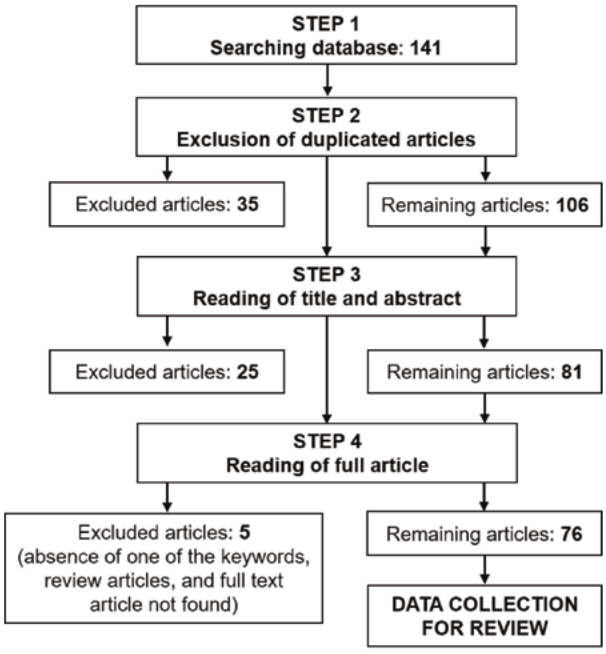

Figure 1 - PRISMA flow diagram of included studies

3. TRADITIONAL USES

The traditional uses of various *Senecio* species highlight their ethnomedicinal importance in different cultures [9-23]. The leaves of *S. ambavilla* are used for treating wounds, boils, and skin diseases. An infusion of its leaves is also traditionally used for managing rheumatism, gout, and gastrointestinal complaints . Similarly, *S. anteuphorbium* is applied as a sedative for abdominal or back pain and is also employed to treat rheumatism, wounds, and injuries [10], while its poultices offer sedative relief for abdominal and dorsal issues [11]. In traditional Chinese medicine, *S. cannabifolius* is valued for the treatment of viral influenza, icteric hepatitis, and stomach ailments [12]. *S. cineraria* has been recognized for its role in alleviating eye problems , while *S. filaginoides* is used to address rheumatic pains and toothaches [13]. *S. flammeus* is another species popular in Chinese folk medicine, primarily for treating inflammation and ulcers [14]. *S. glaucus* is known for managing respiratory and hepatic conditions, including coughs, fever, colds, bronchitis, and asthma, as well as for treating eczema and wounds [15]. The water extract of *S. graciliflorus* leaves is traditionally used for treating skin rashes and eruptions [16]. *S. graveolens* has distinctive medicinal properties: it is reputed to counteract mountain sickness and act as an emmenagogue, a digestive aid, and a cough suppressant [17]. Similarly, *S. nudicaulis* is employed for its ability to treat colic, fever, and various skin diseases, including conjunctivitis [18,19]. *S. nutans* has a wide range of uses, such as lowering blood pressure, alleviating altitude sickness, and relieving cold-related discomfort, bronchitis, whooping cough, asthma, stomach aches, and fever [20]. *S. pogonias* is applied in the treatment of hepatic disorders, fever, coughs, and colds [17], while *S. serpens* serves both medicinal and ornamental purposes in regions like Portugal, Morocco, and Egypt [21]. Lastly, *S. ventanensis* is known for its role in treating wounds and as an anti-emetic, anti-inflammatory, and vasodilatory agent [22]. *S. vulgaris*, with its broad spectrum of uses, acts as a diaphoretic, antiscorbutic, purgative, diuretic, and an anthelmintic [23]. It is also used to expel kidneys gravel. These diverse applications underline the vast medicinal potential of the *Senecio* genus in traditional practices.

4. CHEMICAL COMPOSITION

The analysis of EOs from *Senecio* species involves various techniques designed to extract, identify, and characterize the volatile compounds present. One of the most widely used methods of extraction is steam distillation. This technique is effective in obtaining oils in a relatively pure form and is commonly used for aromatic species. However, it can cause the degradation of heat-sensitive compounds and often requires a large amount of plant material. Another method is solvent extraction, which is often

employed when steam distillation is not effective or when higher yields are needed. Hydrodistillation, a variant of steam distillation, involves directly boiling plant material in water. This method is effective for both dried and fresh plant samples and is simpler than steam distillation. However, it can lead to the loss of volatile compounds if not carefully controlled and requires larger quantities of plant material.

Various techniques are used to analyze their chemical composition. Gas chromatography (GC), often coupled with mass spectrometry (GC-MS), is one of the most commonly used methods for identifying and quantifying volatile compounds in EOs. It offers high sensitivity and resolution, allowing for the detailed identification of terpenes, aldehydes, ketones, and other compounds. However, it requires sophisticated equipment and expertise, and preparing samples can be time-consuming. For analyzing non-volatile or thermally unstable compounds, high-performance liquid chromatography (HPLC) is sometimes used. In addition to chromatographic techniques, Fourier Transform Infrared (FTIR) spectroscopy is employed to study the functional groups present in EOs. FTIR provides rapid, non-destructive analysis of chemical compositions and is especially useful for confirming the presence of functional groups like alcohols, aldehydes, or esters. However, it provides less detailed structural information compared to techniques like GC-MS.

Numerous investigations have explored the chemical composition of EOs of the *Senecio* genus. Table I shows the details of the isolated EOs, including the main components [24-83]. In this context, it appears that monoterpenes and sesquiterpenes (hydrocarbons and oxygenated) constitute the main components of the *Senecio* EOs. EOs of *S. glaucus* [36], *S. pogonias*, *S. oreophyton* [43], *S. giganteus* [47], *S. graciliflorus* [52], *S. mustersii*, *S. subpanduratus* [38], and *S. farfarifolis* [73] were found to contain α-pinene at high concentrations. Meanwhile, EOs of *S. nutans* [31], *S. polyanthemoides* [68], *S. subulatus* [33], and S. *squalidus* [74] were characterized by an abundance of *p*-cymene. In another study, α-farnesene was notable for its richness in the EOs of *S. cannabifolius* [26] and *S. flammeus* [51], while β-farnesene was found in the EOs of *S. racemosus* and *S. trapezuntinus* [67]. In addition, germacrene D was also present as a major component in EOs of *S. rufinervis* [61-62], *S. crassiflorus* [71], and *S. argunensis* [83]. Several *Senecio* EOs presented an entirely different chemical profile compared to other species of the *Senecio* genus. 9,10-Dehydrofukinone, 1-nonene, 1-undecanol, 1-tridecene, and 1,10β-epoxy-6-oxofuranoeremophilane were found to be the main components of the EOs of *S. viridis* [29], *S. filaginoides* [37], *S. belgaumensis* [59], *S. coincyi* [65], and *S. royleanus* [66], respectively. There was significant intra- and interspecies variation in the chemical compositions of EO extracted from *Senecio* species, which appears to be influenced by the environmental factors of plant cultivation. Indeed, it has been reported that the chemical profiles of EO could vary with season, plant age, soil composition, collection time, and geographic origin. This variability might also be correlated to the genetic characteristics of the plant and/or to the source of the EOs [84-85].

5. PHARMACOLOGICAL ACTIVITIES

Senecio species have been used for centuries as a folk remedy because of their diverse pharmacological activities. The genus is a rich source of bioactive components, which are implicated in the reported pharmacological activities of the genus *Senecio*. EOs also have several promising pharmacological activities, briefly described here.

5.1. ANTIMICROBIAL ACTIVITY

Different microbes, bacteria, fungi and yeast are associated with the antimicrobial activity of EOs derived from several species of *Senecio.* Details of the activity are summarized in Table II [86-90]. The EOs from various *Senecio* species exhibit notable antimicrobial activity, particularly against significant bacterial and fungal pathogens. *S. graveolens* demonstrates strong activity with MIC values of 8.73 mg/mL for *Micrococcus luteus*, 10.91 mg/mL for *Staphylococcus aureus*, and an impressive 0.02 mg/mL for *Candida albicans* [86]. Similarly, *S. nemorensis* shows potent inhibition against *Bacillus cereus* (20 mm), *Staphylococcus aureus* (17 mm), and *Enterococcus faecalis* (18 mm), making it highly effective against Gram-positive bacteria [87]. Other significant examples include *S. pandurifolius*, which displays remarkable activity against *Mycobacterium smegmatis* within a large inhibition zone of 30 mm [60], and *S. nutans*, which effectively inhibits *Vibrio cholerae* within a 22 mm inhibition zone and a low MIC of 0.4 mg/mL [30]. *S. belgaumensis* also stands out for its strong antimicrobial effects against *S. faecalis*, *Aspergillus fumigatus*, and *A. niger*, with MIC values ranging from 0.015 to 0.104 mg/mL [88]. These findings highlight the significant antimicrobial potential of certain *Senecio* species, especially against major pathogens like *S. aureus*, *V. cholerae*, and *C. albicans*. This underscores their potential in developing natural antimicrobial agents and merits further exploration.

5.2. ANTIOXIDANT ACTIVITY

The antioxidant activity of *S. anteuphorbuim* EO was determined by the ability of the EO to inhibit

the bleaching of β-carotene by peroxide generation along linoleic acid oxidation. The EO presented a percentage rate of 49.42% at 4 mg/mL [79]. Furthermore, *S. massaicus* EO exhibited antioxidant in reducing power and ABTS assays with A0.50 value 93.0 µg/mL and IC50 value of 88.7 µg/mL respectively, compared to the CUPRAC test A0.50 value of 116.5 µg/mL. For the DPPH method, the EO did not display radical activity where the inhibition rate did not exceed 37% in the high concentration tested (200 µg/mL) [80]. Furthermore, the *S. glaucus* EO showed a strong antioxidant effect with EC50 values for DPPH radical scavenging of 1.6 and 1.9 µL/mL for capetula and shoot EOs, respectively [34]. In another study, *S. nudicaulis* EO was found to exhibit significant activity by scavenging DPPH, ABTS and nitric oxide radicals with IC50 values of 10.61, 11.85, and 11.29 µg/mL, respectively [45]. Similarly, *S. graciliflorus* flower EO exhibited a strong antioxidant potential, displaying IC50 values of 21.6 and 26.0 µg/mL in DPPH and hydroxyl radical assays, respectively [52].

The DPPH assay was chosen to evaluate the antioxidant potential of EOs from the genus *Senecio* because it is simple, reliable, and well-suited to this purpose. It directly measures the ability of antioxidants to neutralize free radicals, which is highly relevant when studying the radical-scavenging activity of EOs. The assay is quick and does not require complex equipment, making it practical for testing complex mixtures like EOs. Unlike other assays, such as TEAC and FRAP, the DPPH assay works well with both hydrophilic and lipophilic antioxidants, making it more suitable for EOs that are rich in hydrophobic compounds. TEAC involves additional steps to generate radicals, which can introduce variability, while FRAP measures the reducing power rather than directly assessing free radical scavenging. Other assays like ORAC and CUPRAC are more complex and time-consuming. Overall, the DPPH assay provides a straightforward and accurate way to evaluate the antioxidant properties of *Senecio* EOs, ensuring reliable results while avoiding the limitations of other methods.

5.3. REPELLENT EFFECT

The *S. scandens* EO decreased its repellent effect against *L. serricorne* from 78.63 to 0.13 nL/cm^2 and the effect of EO on *L. bostrychophila* fell from 63.17 to 12.63 nL/cm^2, The percentage of repellency value of EO against *L. bostrychophila* was similar to DEET (N,N-diethyl-meta-toluamide), which indicated that EO had great potential insecticidal activity for *L. bostrychophila* [26]. In another study, *S. glaucus* EO repelled *Tetranychus urticae* adults after 24, 48, and 72 h of exposure. After 72 h, a low repellent effect was observed in adults with *T. urticae* at the highest concentration tested, with a repellency index of 24% [36]. Furthermore, *S. pogonias* and *S. oreophyton* EOs showed good repellent properties against *Triatoma infestans* with repellency percentage values of 76% and 36% at 24 h, respectively [43].

5.4. ANTIFUNGAL ACTIVITY

The *S. nutans* and *S. viridis* EOs displayed moderate activity against *Fusarium graminearum* and *F. verticillioides* (MIC value of 1.2 mg/mL) and there was a weak effect against *Aspergillus carbonarius* and *A. niger* (MIC values of >1.2 mg/mL) [29]. The antifungal activity of *S. glaucus* EO was tested against the phase method (VF) and the poisoned food method (PF). The EO recorded an inhibition of 83% at 16 µL/mL using the PF method, while the VF method recorded 86% inhibition of mycelial growth of *B. cinerea* at 0.8 µL/ml air [91]. In another work, the EO of *S. amplexicaulis* exhibited significant activity against five phytopathogenic fungi, *Sclerotium rolfsii*, *Macrophomina phaseolina*, *Rhizoctonia solani*, *Pythium debaryanum* and *Fusarium oxysporum,* with EC50 values of 164.9, 157.0, 199.2, 187.4, and 159.0 µg/mL, respectively [49].

The EOs contain bioactive compounds like terpenoids and phenolic acids, which are effective against both Gram-positive and Gram-negative bacteria. These compounds work by disrupting bacterial membranes, interfering with enzymes, and preventing biofilm formation. *Senecio* EOs are particularly effective against Gram-positive bacteria such as *Staphylococcus aureus* and *Bacillus subtilis*, which have simpler cell membranes that are easily disrupted. They also active against Gram-negative bacteria like *Escherichia coli* and *Pseudomonas aeruginosa*. Although Gram-negative bacteria have an extra outer membrane for protection, the oils can penetrate and damage their cell structure.

5.5. ACARICIDAL ACTIVITY

The efficacy of *S. cannabifolius* EO against females and larvae of *Rhipicephalus microplus* was assessed by the adult immersion test (AIT) and the larval immersion test (LIT). LIT revealed that EO achieved 100% mortality at a concentration of 1.6% wt/vol, whereas biochemical assays indicated that the EO can significantly reduce the overall detoxification enzyme activities in engorged females and larvae at a high concentration (≥0.4% wt/vol) [27]. Furthermore, *S. glaucus* EO recorded significant mortality in adults 24, 48, and 72 h after treatment. The mortality rate ranged from 32 to 100%, and the probit analysis indicated an LD50 of 5843 ppm [91].

5.6. ANTI-INFLAMMATORY ACTIVITY

The EOs of the capetula and shoots of *S. glaucus* exerted the highest anti-inflammatory effect after 3

and 4 hours of carrageenan injection with percentage inhibition of 43.3% and 44.3%, respectively [34]. Furthermore, *S. flammeus* EO significantly reduced carrageenan-induced paw oedema by 17.42%, 52.90% and 66.45%, 4 h after carrageenan injection, respectively, and significantly reduced myeloperoxidase activity. The EO (10, 30, and 90 mg/kg) also produced a significant dose-dependent response in reducing TPA-induced ear oedema by 20.27%, 33.06%, and 53.90%, respectively. Furthermore, EO produced significant dose-response anti-inflammatory activity against cotton pellet-induced granuloma that peaked at the highest dose of 90 mg/kg (49.08% wet weight and 47.29% dry weight) [51].

5.7. CYTOTOXICITY STUDIES

S. glaucus capetula EO was found to be the most potent against human breast cancer cells (MCF-7) with an IC50 value of 1.5%, followed by shoot EO against the same cell line with an IC50 value of 2.1% [34]. In addition, as regards the inhibitory activity against hepatocellular carcinoma cells (HePG2), EO exhibited a promising activity with an IC50 value of 5.63 µg/mL [39]. In another study, the flower and root EO of *S. graciliflorus* showed strong activity against lung cell lines (A-549) with IC50 values of 19.1 and 21.3 µg/mL, respectively [52]. *S. rowleyanus* EO showed significant activity against brain tumour cell line (U251) and liver carcinoma cell line (MCF-8) with IC50 values of 5.0 and 2.6 µg/mL, respectively [70], while *S. leucanthemifolius* EO displayed significant activity against the human cervix uteri cancerous cell line (HeLa) with an IC50 value of 1.15 µL/mL [50].

5.8. PHYTOTOXIC ACTIVITY

The *S. amplexicaulis* EO inhibited the germination of *Triticum aestivum* (65.0%) and *Phalaris minor* (58.3%) at 500 µg/mL compared to the control. At a higher concentration (500 µg/mL), EO inhibited the shoot and root lengths of both test crops [49]. Another study on the EO of *S. erucifolius* reported the length of roots of *Medicago sativa*, *Urtica cannabina* and *Amaranthus retroflexus* increased by 21.00, 10.46, and 2.53%, respectively, after treatment with EO at the lowest concentration of 0.125 mg/mL and decreased by 9.36, 23.00, and 19.53% after treatment at the highest concentration of 4 mg/mL [82].

5.9. ANTICHOLINESTERASE ACTIVITY

The *S. massaicus* EO exhibited strong inhibitory activity against butyrylcholinesterase (BChE: IC50 value 13.85 µg/mL) and acetylcholinesterase (AChE: IC50 value 10.34 µg/mL) [80]. Furthermore, *S. ventanensis* EO was found to exert a weak activity in the AChE assay with a percentage inhibition of 8.9% (conc. 2.5%), compared to the positive control serine with 99.0% [48].

5.10. ALLELOPATHIC EFFECT

The allelopathic effect of *S. anteuphorbium* EO was evaluated by studying the inhibition of the germination and growth of *Lactuca sativa* seeds. At a high concentration of EO (0.28 mg/mL), the growth of the shoots and roots was reduced by 87.60% and 78.88%, respectively. The EO recorded an IC50 value of 0.12 mg/mL for shoot growth and 0.15 µg/mL for root growth, respectively [24].

5.11. NEMATICIDAL ACTIVITY

The nematicidal activity of *S. glaucus* EO was tested using two bioassays aimed at the mortality of second-stage juveniles (J2) and the inhibition of *Meloidogyne javanica* eggs. The effect exerted by the EO was nematostatic with a percentage inhibition of 95%, immobility of J2 and 92% inhibition of egg hatch at 16,000 ppm [91].

5.12. ANTIMALARIAL ACTIVITY

The *S. acaulis* EO showed moderate activity against chloroquine-sensitive *Plasmodium falciparum* (D6) and chloroquine-resistant *Plasmodium falciparum* (W2) with IC50 values of 8020.3 and 5785.4 µg/mL, respectively [42].

5.13. ANTILEISHMANIAL ACTIVITY

The *S. acaulis* EO exerted a weak activity against *Leishmania donovani* with IC50 and IC90 values of 24.3 and 34.3 µg/mL, respectively [42].

5.14. α-GLUCOSIDASE ACTIVITY

The *S. scandens* EO displayed strong inhibitory activity on α-glucosidase with an IC50 value of 0.1304 mg/mL, compared to the positive control acarbose of 23.4 mg/mL [92].

5.15. ANTICORROSIVE ACTIVITY

The *S. inaequidens* EO showed promising activity against mild steel in 1M HCl. The EO was found to inhibit 90.56% at 2g/L [55].

5.16. ANALGESIC ACTIVITY

The *S. rufinervis* EO produced a significant and dose-dependent inhibition of acetic acid-induced writhing (85% at 75 mg). The effect was more significant than the standard drug pentazocine (72.3% at dose 75 mg/kg) [62].

5.17. TOXICITY STUDIES

The *S. argunensis* EO exhibited acute lethal toxicity (25%) against *Artemia salina* larvae at a concentration of 1 mg/mL [83]. Additionally, the EO of *S. scandens* showed strong contact toxicity with *Tribolium castaneum*, *Lasioderma serricorne* and *Liposcelis bostrychophila* with LD50 values of 18.01, 20.11, and 72.14 µg/cm^2, respectively [26].

Table I - Major chemical components identified from *Senecio* essential oils

Species	Locality	Part	Yield (%)	Identification (No. %)	Major components
S. anteuphorbium	Morocco	Aerial parts	0.30	46, 85.62	Bicyclogermacrene (22.75%), spathulenol (25.26%), epi-β-eudesmol (6.8%), and selina-4,11-diene (5.08%) [24]
		Aerial parts	0.15	21, 99.60	γ-Selinene (27.2%), cyperene (21.7%), γ-cadinene (11.4%), and α-cyperone (8.1%) [25]
S. scandens	China	Aerial parts	0.84	20, 88.03	Humulene epoxide II (18.05%), 1,4,7-cycloundecatriene-1,5,9,9-tetramethyl-Z,Z,Z- (17.69%), caryophyllene oxide (16.24%), linalool (7.16%), and caryophyllene (4.52%) [26]
S. cannabifolius	China	Aerial parts	0.83	68, 99.2	Eucalyptol (13%), camphor (10.6%), germacrene D (6.0%), and caryophyllene oxide (6.1%) [27[
		Leaves	0.503	26, NM	α-Farnesene (13.37%), n-hexadecanoic acid (8.62%), 2,6-dimethyl-6-(4-methyl-3-pentenyl)-bicyclohept-2-ene (6.93%), and caryophyllene (5.32%) [26]
		Stems	0.036	36, NM	n-Hexadecanoic acid (24.12%), caryophyllene oxide (11.16%), 1-methyl-2-pentyl-cyclopropane (9.55%), and caryophyllene (5.78%) [26]
S. pedunculatus	India	Leaves	0.05	20, 93.44	Caryophyllene oxide (23.5%), δ-cadinene (10.4%), humulene epoxide II (9.4%), and myrcene (8.2%) [28]
S. nutans	Argentina	Aerial parts	1.42	25, 89.50	Sabinene (27.6%), α-phellandrene (15.7%), o-cymene (9.6%), and β-pinene (6.1%) [29]
	Chile	Leaves	0.37	19, 100	Methyl cinnamate (44.9%), p-cymenol (27.2%), terpinen-4-ol (6.8%), AND α-terpineol (4.1%) [30]
	Peru	Leaves	0.15	60, 93.70	p-Cymene (51.7%), α-phellandrene (21.8%), and (Z)-methyl cinnamate (3.7%) [31]
	Italy	Aerial parts	0.16	21, 94.30	α-Phellandrene (15.5%), α-terpinene (15.1%), sabinene (13.3%), δ-3-carene (8.8%), and p-cymene (8.8%) [32]
S. viridis	Argentina	Aerial parts	0.14	12, 97.50	9,10-Dehydrofukinone (92.7%) [29]
			0.10	14, 94.80	α-Thujene (31.7%), β-phellandrene (15.7%), α-pinene (9.0%), camphene (8.9%), and sabinene (7.0%) [33]
S. glaucus	Egypt	Capetula (flower)	0.50	33, 97.10	m-Mentha-1(7),8-diene (31.4%), cis-m-mentha-2,8-diene (22.9%), and dehydrofukinone (17.2%) [34]
		Shoots	0.25	33, 96.00	m-Mentha-1(7),8-diene (25.6%), dehydrofukinone (19.9%), and *cis*-m-mentha-2,8-diene (8.2%) [34]
		Aerial parts	0.25	80, 90.00	Myrcene (24.0%), dehydrofukinone I (21.0%), and p-cymene (9.9%) [35]
	Morocco	whole plants	0.20	84, 94.30	α-Pinene (26.2%), myrcene (11.4%), and p-cymene (9.9%) [36]
S. filaginoides	USA	Aerial parts	0.34	56, 96.1-97.6%	1-Nonene (2.0-4.7%), α-pinene (28.3-40.5%), sabinene (1.5-1.9%), β-pinene (4.7-5.4%), and δ-3-carene (1.8-5.7%) [37]
	Argentina	Aerial parts	NM	7, 60.90	β-Terpinene (28.0%), α-pinene (20.0%), and α-terpinene (4.4%) [38]
S. vulgaris	Egypt	Whole plants	NM	14, 98.53	Butylated hydroxytoluene (63.87%), 4,4'-ethylenebis(2,6-di-tert-butylphenol) (8.29% [39]
	France	Aerial parts	0.13-0.16	54, 95.20	α-Humulene (57.3%), (E)-β-caryophyllene (5.6%), terpinolene (5.3%), ar-curcumene (4.3%), and geranyl linalool (3.4%) [40]
S. serpens	Egypt	Aerial parts	0.09	38, 99.9	α-Myrcene (26.0%), α-pinene (22.81%), β-pinene (16.44%), germacrene D (8.94%), and 1-nonene (8.88%) [41]

Table I - continue

S. acaulis	Egypt	Aerial parts	0.11	22, 81.08	Limonene (13.32%), β-pinene (11.54%), sabinene (10.79%), and cryptone (10.13%) [42]
S. pogonias	Argentina	Aerial parts	0.40	19, 97.60	α-Pinene (48.0%), α-phellandrene (22.0%), p-cymene (7.1%), and β-pinene (5.9%) [43]
S. oreophyton	Argentina	Aerial parts	1.00	18, 97.30	α-Pinene (40.0%), p-mentha-1(7), 8-diene (31.0%), and β-phellandrene (5.3%) [43]
S. nudicaulis	India	Aerial parts	0.1-0.6	8, 96.30	α-Humulene (30.2%), germacrene D (26.3%), β-caryophyllene (22.3%), and linoleic acid (9.7%) [44]
			NM	30, 95.30	Caryophyllene oxide (24.99%), humulene epoxide II (21.25%), α-humulene (18.75%), β-caryophyllene (9.67%) [45]
S. giganteus	Algeria	Aerial parts	0.02	40, 92.38	Hexadecanoic acid (17.80%), isophytol (12.43%), 3-methyl pentanol (7.28%), phytol (6, 66%), and the spathulenol (4.47%) [46]
			0.80	18, 82.80	α-Pinene (19.4%), 6,10,14-trimethyl-2-pentadecanone (19.1%), pentacosane (16.9%), and tricosane (11.9 %) [47]
S. ventanensis	Argentina	Aerial parts	0.015	23, 98.50	α-Terpinene (12.2%), limonene (11.9%), α-humulene (10.5%), sabinene (9.1%), terpinolene (8.8%), and p-cymene (8.1%) [48]
S. amplexicaulis	India	Roots	0.66	18, 94.70	α-Phellandrene (48.57%), o-cymene (16.80%) and β-ocimene (7.61%) [49]
S. leucanthemifolius	Morocco	Whole plant	NM	NM	α-Hydroxy-p-cymen (27.3%), carvacrol (12.2%), nerol (10.9%), carveol (9.2%), and *cis*-α-bisabolene (7.0%) [50]
S. flammeus	China	Aerial parts	0.38	48, 98.41	α-Farnesene (11.26%), caryophyllene (8.69%), n-hexadecanoic acid (7.23%), and α-pinene (6.36%) [51]
S. graciliflorus	India	Flower	0.08	17, 99.90	α-Pinene (33.97%), cis-ocimene (26.83%), β-pinene (11.9%), and 1,2,3-trimethylcyclohexane(6.37%) [52]
		Leaf	0.07	20, 95.50	*cis*-Ocimene (24.14%), α-Pinene (18.36%), 1,2,3-trimethylcyclohexane(14.11%), and β-pinene (6.41%) [52]
		Stem	0.04	19, 98.93	*cis*-Ocimene (24.97%), α-pinene (24.66%), 1,2,3-trimethylcyclohexane(11.15%), and β-pinene (9.05%) [52]
		Root	0.04	17, 95.96	α-Pinene (36.36%), 1,2,3-trimethylcyclohexane (13.32%), *cis*-ocimene (11.15%), and β-pinene (10.84%) [52]
S. bombayensis	India	Flower	0.20	46, 98.20	Linalool (26.3%), β-cedrene (14.5%), E-β-farnesene (10.8%), 2,5-dimethoxy-p-cymene (7.0%), (E)-β-ocimene (5.9%), terpinen-4-ol (5.1%), and Z-β-ocimene (4.7%) [53]
S. selloi	Brazil	Aerial parts	0.0035	20, 71.3	α-Zingiberene (54.0%) and α-isolimonene (16.0%) [54]
S. inaequidens	France	Aerial parts	NM	60, 98.8	Myrcene (21.4%), (Z)-β-ocimene (17.6%), α-pinene (12.5%), limonene (8.1%), and cacalohastine (6.8%) [55]
S. vernalis	Turkey	Aerial parts	0.40	39, 91.50	β-Phellandrene (12.6%), 1,8-cineole (9.2%), caryophyllene oxide (7.3%), β-selinene (6.3%), and limonene (6.2%) [56]
		Flower	0.16	69, 93.40	β-Pinene (13.0%), (E)-caryophyllene (28.6%), δ-3-carene (10.4%), germacrene D (8.6%), α-phellandrene (8.3%), (Z)-β-ocimene (4.7%), and α-humulene (4.5%) [57]
	Iran	Aerial parts	0.16	10, 98.90	Spathulenol (37.1%), 1,8-cineol (19.0%), m-cymene (16.6%), and isobicyclo-germacrenal (15.2%) [58]

Table I - continue

S. belgaumensis	India	Flower	0.20	48, 91.50	1-Undecanol (19.5%), β-caryophyllene (18.9%), caryophyllene oxide (10.4%), and γ-terpinene (9.2%) [59]
S. pandurifolius	Turkey	Flower	0.24	45, 90.10	α-Cuprenene (30.7%), borneol (11.9%), β-eudesmol (9.3%), 1-undecene (7.4%), (E)-caryophyllene (6.0%), nonadecane (4.4%), and hexadecane(4.0 %) [60]
		Leaves	0.15	60, 88.00	α-Zingiberene (16.1%), borneol (13.4%), 1-undecene (8.3%), (E)-γ-bisabolene (6.4%), β-eudesmol (5.3%), and bicyclogermacrene (4.5%) [60]
		Stems	0.19	42, 89.00	γ-Curcumene (14.9%), undecane (12.0%), α-zingiberene (9.0%), (E,E)-α-farnesene (8.8%), (E)-caryophyllene (7.2%), and 6-methoxy-2-(1-buten-3-yl)-naphthalene (6.5%) [60]
S. rufinervis	India	Leaves	0.50	11, 70.17	Germacrene D (40.19%), β-pinene (12.33%), and p-cymene (4.15%) [61]
		Roots	0.40	15, 72.14	Germacrene D (24.95%), α-cubebene (8.14%), and α-longipinene (6.46%) [61]
		Leaves	0.50	11, 78.18	Germacrene D (40.19%), β-pinene (12.23%), β-caryophyllene (6.21%), and β-longipinene (4.15%) [62]
		Leaves	0.60	92.50	Germacrene D (33.7%), δ-cadinene (5.5%), γ-cadinene (5.5%), germacrene D-4-ol (5.4%), α-cadinol (4.9%), and β-longipinene (4.0%) [63]
		Roots	0.50	89.10	Germacrene D (32.9%), germacrene A (19.5%), δ-elemene (7.6%), α-cubebene (4.9%), and β-eudesmol (3.0%) [63]
S. atacamensis	Chile	Leaves	1.04	19, 75.69	α-Terpinene (36.05%), α-phellandrene (27.79%), and p-cymene (11.85%) [64]
		Stems	0.92	24, 68.49	α-Phellandrene (25.37%), p-cymene (22.55%), and α-terpinene (20.57%) [64]
S. coincyi	Spain	Leaves	0.01	38, 60.00	1-Tridecene (28.1%), β-bisabolene (6.1%), and 1-pentadecene (6.0%) [65]
S. royleanus	India	Aerial parts	0.24	43, 96.50	1,10β-Epoxy-6-oxofuranoeremophilane (69.2%) and 1β-10-epoxyfuranoeremophilane (3.3%) [66]
		Flowers	0.18	44, 97.10	1,10β-Epoxy-6-oxofuranoeremophilane (39.4%), (E)-β-ocimene (17.0%), 1β-10-epoxyfuranoer-emophilane (8.2%), and α-pinene (7.6%) [66]
		Leaves	0.30	44, 95.50	1,10β-Epoxy-6-oxofuranoeremophilane (50.3%) and 1β-10-epoxyfuranoeremophilane (25.2%) [66]
		Stems	0.14	41, 95.00	1,10β-Epoxy-6-oxofuranoeremophilane (54.9%), γ-muurolene (9.8%), and (E)-β-ocimene (7.9%) [66]
S. othonnae	Turkey	Flowers	0.12	56, 83.10	Caryophyllene oxide (18.6%), (E)-caryophyllene (13.7%), α-cadinol (7.4%), and 1-undecene (6.8%) [67]
S. racemosus	Turkey	Flowers	0.08	38, 97.70	(E)-β-Farnesene (21.6%), (E)-caryophyllene (20.0%), γ-amorphene (19.1%), and 1-undecene (11.4%) [67]
S. nemorensis	Turkey	Flowers	0.12	37, 86.80	γ-Curcumene (42.8%), (E)-β-Farnesene (25.2%), and β-curcumene (6.2%) [67]
S. mustersii	Argentina	Aerial parts	0.81	24, 95.20	α-Pinene (53.3%) and β-pinene (21.2%) [38]
S. subpanduratus	Argentina	Aerial parts	0.71	21, 92.90	α-Pinene (22.1%), β-pinene (11.9%), sabinene (23.8%), terpinen-4-ol (10.2%) and p-cymene (8.7%) [38]

Table I - continue

S. polyanthemoides	South Africa	Flower	0.10	13, 97.00	p-Cymene (24.7%), limonene (18.3%), and myrcene (15.7%) [68]
		Leaves	0.23	8, 94.10	β-Selinene (32.7%), caryophyllene oxide (13.4%), α-pinene (11.8%), and 1,8-cineole (11.4%) [68]
		Stems	0.17	8, 99.60	α-Pinene (21.4%), p-cymene (18.7%), limonene (18.1%), β-pinene (12.4%), and 1,8-cineole (9.3%) [68]
S. platyphyllus	Turkey	Flowers	0.12	48, 94.40	(E)-Caryophyllene (28.6%), germacrene D (23.4%), and (*E*)-β-farnesene (6.8%) [57]
S. adenotrichius	Chile	Aerial parts	0.36	11, 91.30	Dehydrofukinone (70.9%), (E)-β-ocimene (5.8%), and α-terpinene (4.5%) [69]
S. zoellneri	Chile	Aerial parts	0.41	21, 97.00	δ-3-Carene (19.5%), β-phellandrene (18.0%), β-pinene (16.4%), and α-pinene (10.8%) [69]
S. rowleyanus	Egypt	Aerial parts	0.10	25, 99.95	Spathulenol (22.9%), myrcene (12.80%), germacrene B (12.4%), viridiflorol (10.99%), and *trans*-caryophyllene (8.42%) [70]
S. subulatus var. *salsus*	Argentina	Aerial parts	0.10	18, 95.50	p-Cymene (33.3%), β-pinene (31.2%), γ-terpinene (15.6%), and α-thujene (5.0%) [33]
S. subulatus var. *erectus*	Argentina	Aerial parts	0.10	13, 97.50	γ-Terpinene (53.6%), p-cymene (18.3%), β-pinene (17.3%), and α-thujene (5.2%) [33]
S. argophylloides	Argentina	Aerial parts	0.20	13, 99.80	Camphene (52.7%), sabinene (12.3%), and β-phellandrene (10.7%) [33]
S. trapezuntinus	Turkey	Flowers	0.15	34, 91.70	(E)-β-Farnesene (26.3%), β-selinene (11.8%), eremophilane (9.2%), 14-hydroxy-9-epi-(E)-caryophyllene (7.8%), γ-gurjunene (7.7%), and (E)-caryophyllene (7.1%) [67]
		Leaves	0.12	26, 86.20	(E)-β-farnesene (16.9%), β-selinene (11.6%), 14-hydroxy-9-epi-(E)-caryophyllene (10.5%), eremophilane (9.3%), (E)-caryophyllene (8.7%), and δ-amorphene (7.3%) [67]
		Stems	0.10	12, 73.50	(E)-β-farnesene (31.2%), eremophilane (9.9%), γ-gurjunene (8.1%), and (E)-caryophyllene (5.4%) [67]
S. crassiflorus	Brazil	Leaves	0.023	15, 98.90	α-Cadinol (56.0%), t-muurolol (25.0%), and germacrene D (6.1%) [71]
		Aerial parts	0.023	14, 98.80	Germacrene D (59.0%) and germacrene B (22.0%) [71]
		Stems	0.033	17, 97.70	Germacrene D (48.0%), germacrene B (24.0%), α-cadinol (5.7%) [71]
S. leucostachys	Iran	Leaves	0.80	31, 98.60	Sabinene (20.7%), α-phellandrene (19.7%), germacrene D (10.8%), and β-caryophyllene (8.2%) [72]
S. farfarifolius	Turkey	Aerial parts	0.29	77, 95.00	α-Pinene (48.3%), 1,8-cineole (10.3%), germacrene D (3.4%), and sabinene (3.4%) [73]
S. squalidus	Serbia	Aerial parts	0.025	58, 94.10	p-Cymene (29.3%), α-phellandrene (24.7%), and α-pinene (8.0%) [74]
S. graveolens	Argentina	Leaves	0.57	14, NM	α-Terpinene (60.0%), p-cymene (14.0%), terpinen-4-ol (5.5%), and α-phellandrene (4.0%) [75]
S. chysanthemides	India	Aerial parts	0.02	19, 95.59	β-Thujone (84.17%) and α-terpineol(2.53%) [76]
S. aegyptius	Egypt	Flowers	0.30	19, NM	1,10-Epoxyfuranoeremophilane (55.3%), 1-nonane (17.0%), and myrcene (8.9%) [77]
		Leaves	0.40	17, NM	1,10-Epoxyfuranoeremophilane (66.3%),1-nonane (22.0%), and myrcene (3.4%) [77]
		Stems	0.10	18, NM	1,10-Epoxyfuranoeremophilane (46.4%),1-nonane (19.0%), and myrcene (10.6%) [77]
		Roots	0.05	6, NM	1,10-Epoxyfuranoeremophilane (69.0%), drima-7,9-(11)-diene (19.0%), and β-elemene (4.2%) [77]

Table I- continue

S. ambavilla	India	Aerial parts	0.02	62, 97.00	*allo*-Aromadendrene (40%), α-pinene (14%), α-himachalene (6.2%), and β-himachalene (5.8%) [78]
S. anteuphorbuim	Morocco	Aerial parts	0.40	41, 78.94	Selina-4,11-diene (8.07%), β-gurjunene (7.68%), γ-cadinene (6.86%), and γ-muurolene (5.65%) [79]
S. massaicus	Algeria	Aerial parts	0.18	22, 97.41	m-Cymene (30.58%), n-hexadecanoic acid (14.88%), and docosane-11-decyl (10.43%) [80]
S. pterophorus	South Africa	Leaves	NM	38, 98.00	Limonene (10.3-32.3%), myrcene (14.4-19.7%), sabinene (13.0-18.0%), α-phellandrene (3.4-16.9%), and p-cymene (15.6-16.7%) [81]
S. erucifolius	China	Aerial parts	0.18	37, 85.70	Dibutyl phthalate (16.2%), isoledene (7.7%), β-*cis*-ocimene (5.5%), butylcyclopentane (4.9%), and germacrene D (4.8%) [82]
S. argunensis	Russia	Aerial parts	0.10	17, 99.80	Germacrene D (46.5%), caryophyllene oxide (9.9%), *trans*-caryophyllene (7.6%), and β-thujene (7.5%) [83]

NM – not mentioned

Table II - Antimicrobial activities of *Senecio* essential oils

Essential oils	Description
S. graveolens	Bacterial effects on *M. luteus*, *S. aureus*, and *C. albicans* with MIC values of 8.73, 10.91, and 0.02 mg/mL, respectively [86]
S. othonnae	Potent activity (zone of growth inhibition) against *B. cereus* (15 mm), *S. aureus* (10 mm), *E. faecalis* (15 mm), and *C. tropicalis* (9 mm) [87]
S. nemorensis	Potent activity (zone of growth inhibition) against *B. cereus* (20 mm), *S. aureus* (17 mm), *E. faecalis* (18 mm), and *C. tropicalis* (15 mm) [87]
S. atacamensis	Moderate inhibition against *K. pneumoniae* with an inhibition zone of 18 mm [64]
S. rufinervis	Exhibited significant activity against *B. subtilis* with an inhibition zone of 11 mm [61]
S. pandurifolius	Strong activity against *M. smegmatis* with an inhibition zone of 30 mm [60]
S. belgaumensis	Effective against *S. faecalis*, *A. fumigatus*, and *A. niger* with MIC values of 0.015, 0.045, and 0.104 mg/mL, respectively [88]
S. selloi	Weak activity against *Bacillus subtilis* with MIC and MBC value of 4400 µg/mL [54]
S. leucanthemifolius	Considerable activity (zone of growth inhibition) against two *E. coli* genetically modified strains MG (12 mm) and TG1 (12 mm), *Rhizobium* RP8 (12 mm) and *B. subtilis* (16 mm) [89]
S. giganteus	Moderate activity against *E. coli* and *Shigella sp*. with a diameter of inhibition of 12-14 mm. Besides, the EO was found inactive against *S. aureus*, *K. pneumonia*, and *P. aeruginosa* with an inhibition diameter of 7.5-11 mm [46]
S. nutans	Exhibited an important activity with a diameter of inhibition zone growth of 22 mm and the MIC value of 0.4 mg/mL against pathogenic bacteria *V. cholera* [30]
S. nudicaulis	Inhibited by *Aeromonas hydrophilla* (MIC value 25 µL/mL), followed by *P. aeruginosa*, *E. coli*, and *S. candidus* (each MIC value of 30 µL/mL) [90]
S. acaulis	Exhibited activity against *Cryptococcus neoformans* and *Staphylococcus aureus* with IC50 values of 36.02 and 197.98 µg/mL, respectively [42]
S. anteuphorbium	Demonstrated moderate activities with MIC values in the range of 0.51-1.02 mg/mL for yeasts and between 2.3-4.6 mg/mL for bacteria [25]
S. glaucus	Exhibited the activity against *B. subtilis* and *C. tropicalis* with MIC value of 3.1 µL/mL [34]
S. pedunculatus	Effectiveness against *Bacillus subtilis* (MIC value 11.65 µL/mL) and *A. flavus* (MIC value 8.75 µL/mL) [28]
S. aegyptius	Significant level of activity against *C. albicans* (16-20 mm), *S. aureus* (8-10 mm), *A. flavus* (6-8 mm), *B. subtilis* (7-9 mm), and *E. coli* (7-8 mm) [77]
S. crassiflorus	Active against *B. cereus* with MIC value of 1025 µg/mL [71]
S. pogonias	Best activity against *E. coli* (MIC value 2000 µg/mL), whereas *S. oreophyton* EO was active against *S. coagulase negative 968* (MIC value 1000 µg/mL) [43]
S. anteuphorbuim	Exhibited activity against *S. aureus* and *E. coli* with MIC values of 40.8 and 6.72 mg/mL, respectively [79]

6. CONCLUSION AND FUTURE OUTLOOK

In the present review, the medicinal uses, the composition of EO and the pharmacological properties of different species of *Senecio* have been underlined. The genus *Senecio* belongs to the Senecioneae tribe of the family Asteraceae, which is distributed in Europe, western and Central Asia, and northern Africa. It has been widely used in popular medicine in several countries due to its interesting pharmacological properties. As of December 2022, 55 *Senecio* species had been studied for their composition of EOs of various parts and evaluated for pharmacological potential. Among these, the most studied is *S. nutans* from four countries. In terms of the EO, *Senecio* EOs contain a variety of major components, in particular monoterpenes. According to the reports published in this regard, α-pinene has been identified as the main component of a large number of EOs. However, the frequency of other groups of natural components like sesquiterpenes (hydrocarbons and oxygenated) was considerably lower than that of monoterpenes. In addition, the obtained EOs have been tested and evaluated for their biological - mainly antimicrobial and antioxidant - activities. However, most scientific studies have focused on testing EOs through in vitro studies, while biological media available in vivo and biochemical investigations relating to the mechanism of action of the tested EOs are lacking. Several in vitro evaluations might be developed in vivo in order to evaluate their abilities to address numerous diseases. Since the probable toxicological impacts of the *Senecio* species have not so far been evaluated, these characteristics should be taken into consideration in future reports.

Disclosure statement

The authors declare no conflict of interest in this article.

Acknowledgement

This research was supported by the Geran Penyelidikan Universiti (Kecemerlangan@UPSI) under grant number 2025-0012-103-01, funded by Universiti Pendidikan Sultan Idris.

REFERENCES

[1] N.N.A.N.M.A. Azman, W.M.N.H.W. Salleh, N.A. Ghani. Essential oils composition and bioactivities of most prevalent species of genus *Piper* in Malaysia: a scope review. Riv. Ital. delle Sostanze Grasse, 100(2), 109-116 (2023).

[2] A.A.H. Yahaya, W.M.N.H.W. Salleh. *Magnolia* genus - a systematic review on the composition and biological properties of its essential oils. Riv. Ital. delle Sostanze Grasse, 99(3), 249-261 (2022).

[3] W.M.N.H.W. Salleh, H. Kassim, A. Tawang. Volatile components and biological activities of Pulicaria essential oils. A review. Riv. Ital. delle Sostanze Grasse, 98(1), 49-58 (2021).

[4] D. Romo-Asunción, M.A. Ávila-Calderón, M.A. Ramos-López, J.E. Barranco-Florido, S. Rodríguez-Navarro, S. Romero-Gomez, E.J. Aldeco-Pérez, J.R. Pacheco-Aguilar, M.A. Rico-Rodríguez. Juvenomimetic and insecticidal activities of Senecio salignus (Asteraceae) and *Salvia microphylla* (Lamiaceae) on *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Fla Entomol. 99(3), 345-351 (2016).

[5] D. Jeanmonod, A. Schlussel, J. Gamisans. Asteraceae-II. In Compléments au Prodrome de la Flore Corse. Genève: Conservatoire et Jardin botanique, 2004.

[6] Y. Yang, L. Zhao, Y.F. Wang, M.L. Chang, C.H. Huo, Y.C. Gu, Q.W. Shi, H. Kiyota. Chemical and pharmacological research on plants from the genus *Senecio*. Chem. Biodivers. 8, 13-72 (2011).

[7] D. Moher, A. Liberati, J. Tetzlaff, G.A. Douglas. PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann. Intern. Med. 151, 264-269 (2009).

[8] S. Darshan, C.S. Satish, D.S. Manisha. Chemical and potential biological perspectives of genus *Senecio* (Asteraceae). Eur. J. Pharm. Med. Res. 4(11), 200-222 (2017).

[9] R. Lavergne. Tisaneurs et Plantes m'dicinales indigenes de Me de La Rdunion. Editions Orphie, F-93190 Livry-Gargan, 1990.

[10] D. Cicuzza, D.S. Staheli, R. Nyffeler, U. Eggli. Morphology and anatomy support a reclassification of the African succulent taxa of *Senecio* S.L. (Asteraceae: Senecioneae). Haseltonia, 23, 11-26 (2017).

[11] B. Saadi, F. Msanda, H. Boubaker. Contributions of folk medicine knowledge in South-western Morocco: the case of rural communities of Imouzzer Ida Outanane region. Int. J. Med. Pl. Res. 2(1), 135-145 (2013).

[12] B. Wu, W.H. Lin, H.Y. Gao, L. Zheng, L.J. Wu, C.S. Kim. Four new antibacterial constituents from *Senecio cannabifolius*. Pharm. Biol. 44(6), 440-444 (2006).

[13] S.B. Gonzalez, S. Molares. Plantas medicinales utilizadas en comunidades rurales del Chubut, Patagonia Argentina. B. Latinoam. Caribe. Pl. 3, 58-62 (2004).

[14] P. Joffe. Creative Gardening with Indigenous Plants: A South African Guide. Briza Publication, Pretoria, South Africa, 2001.

[15] G.B. Hammond, I.D. Fernández, L.F. Villegas, A.J. Vaisberg. A survey of traditional medicinal plants from the Callejon de Huaylas, Depart-

ment of Ancash, Peru. J. Ethnopharmacol. 61, 17-30 (1998).
[16] M.K. Koul. Medicinal Plants of Kashmir and Ladakh, Temperate and Cold Arid. Himalaya Indus Publishing Company, Tagore Garden, New Delhi, 1997.
[17] A.L. Cabrera. Fitogeografí´a de la Repu´ blica Argentina. Bol. Soc. Argent. Bot. 14, 1-42 (1971).
[18] A. Nazir, A.K. Pala, N.P. Negi, Todaria. Traditional uses of medicinal plants of Pauri Garhwal, Uttrakhand. Nat. Sci. 8, 57-61 (2010).
[19] P. Kumari, G.C. Joshi, L.M. Tewari. Diversity and status of ethnomedicinal plants of Almora district in Uttarakhand, India. Int. J. Biodivers. Conserv. 3, 298-326 (2011).
[20] F. Carod-Artal, C. Vázquez-Cabrera. An anthropological study about headache and migraine in native cultures from Central and South America. Headache 47, 834-841 (2007).
[21] A.M. Barata, F. Rocha, V. Lopes, E. Bettencourt, A.C. Figueiredo. Medicinal and aromatic plants-Portugal. Medicinal and aromatic plants of The World, Encyclopedia of Life Support Systems (EOLSS). Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, 2011.
[22] B. Nordenstam. *Senecio* - systematic review. In: Heywood VH, Harbone JB, Turner BL, (Eds.). The Biology and Chemistry of the Compositae. Academic Press, London, England, 1977.
[23] T.G. Tutin, D. Lcve, A. Hansen. In Flora Europaea, Cambridge University Press, Cambridge, 1976.
[24] S. Ouhaddou, A. Aghraz, W.B. Bakrim, S. Sissi, M. Larhsini, M. Markouk, K. Bekkouche, S. Arrigo, N. Cicero, R. Costa, R. Vadalà. Analysis of volatiles in *Senecio anteuphorbium* essential oil with a focus on its allelopathic effect by means of gas chromatography. Separations 9(2), 36 (2022).
[25] N. Elhidar, A. Nafis, A. Kasrati, A. Goehler, J.A. Bohnert, A. Abbad, L. Hassani, N.E. Mezrioui. Chemical composition, antimicrobial activities and synergistic effects of essential oil from *Senecio anteuphorbium*, a Moroccan endemic plant. Ind Crops Prod. 130:310-315 (2019).
[26] F. He, J.Y. Liu, L.J. Chen, Z.Q. Cheng, M.Q .Cheng, S.S. Du, Y.L. Sang, Y.J. Hao. Contact toxicity and repellence of essential oil from *Senecio scandens* and its major components against threestored product insects. Nat. Prod. Res. 36(17), 4452-4456 (2022).
[27] P. Yang, M. Jia, L. Zhu. Acaricidal activity of the essential oil from *Senecio cannabifolius* and its constituents eucalyptol and camphor onengorged females and larvae of Rhipicephalus microplus (Acari: Ixodidae). Exp. Appl. Acarol. 83(3),411-426 (2021).
[28] N. Bhatt, .N Joshi, K. Ghai. Chemical composition and in-vitro antimicrobial activity of leaf essential oils of *Senecio pedunculatus* Edgew. and *Nepeta coerulescens* Maxim. J. Biol. Active Prod. Nat. 11(1), 1-10 (2021).
[29] C.E. Galvez, C.M. Jimenez, A.D.L.A. Gomez, E.F. Lizarraga, D.A. Sampietro. Chemical composition and antifungal activity of essential oils from *Senecio nutans*, *Senecio viridis*, *Tagetes terniflora* and *Aloysia gratissima* against toxigenic *Aspergillus* and *Fusarium* species. Nat. Prod. Res. 34(10), 1442-1445 (2020).
[30] A. Paredes, Y. Leyton, C. Riquelme, G. Morales. A plant from the altiplano of Northern Chile *Senecio nutans*, inhibits the *Vibrio cholerae* pathogen. SpringerPlus 5(1), 1788 (2016).
[31] A.J. Belaunde, J.G. Sandoval, L.D. Martino, F. Senatore, V.D. Feo. Chemical composition and antibacterial activity of *Senecio nutans* essential oil. J. Essent. Oil Bearing Pl. 10(4), 332-338 (2007).
[32] V. De Feo, E.U. Soria, R.U. Soria, F. Senatore. Chemical composition of essential oils of *Senecio nutans* Sch.Bip. (Asteraceae). Flav. Fragr. J. 18(3), 234-236 (2003).
[33] J.S. Dambolena, M.P. Zunino, E. Banchio, E.I. Lucini, F.N. Biurrun, A. Rotman, O. Ahumada, J.A. Zygadlo. Essential oil composition of three species of *Senecio* from Argentina. J. Essent. Oil Bearing Pl. 11(6), 623-627 (2008).
[34] T. Ramadan, A. Zaher, A. Amro, R. Sultan. Chemical composition and biological activity of *Capetula* and shoots essential oils of *Senecio glaucus* L. J. Essent. Oil Bearing Pl. 23(1), 168-183 (2020).
[35] H.L. De Pooter, L.F. De Buyck, N.M. Schamp, E. Aboutabl, A. De Bruyn, S.Z. Husain. The volatile fraction of Senecio glaucus subsp. coronopifolius. Flav. Fragr. J. 1(4-5), 159-163 (1986).
[36] K. Basaid, B. Chebli, R. Bouharroud, J.N. Furze, A.L. de Oliveira, E.H. Mayad. Chemical characterization of essential oils of *Senecio glaucus* ssp. *coronopifolius* (Maire) Alexander and *Ridolfi asegetum* (L.) Moris growing in Morocco. J. Essent. Oil Bearing Pl. 23(5), 918-930 (2020).
[37] C.M. van Baren, S.B. González, A.L. Bandoni, P. Di Leo Lira, M.A. Bucio, A. Hernández-Barragán, P. Joseph-Nathan. GC-FID-MS and X-ray diffraction for the detailed evaluation of the volatiles from *Senecio filaginoides*. Nat. Prod. Commun. 15(10), 1-7 (2020).
[38] L, Arancibia, C, Naspi, G, Pucci, M, Arce. Aromatic plants from Patagonia: Chemical composition and antimicrobial activity of the essential oil of *Senecio mustersii* and *S. subpanduratus*. Bol. Latinoam. Caribe Pl. Med. Arom. 9(2), 123-126 (2010).

[39] M.M. Hamed, M.A. Abd El-Mobdy, M.T. Kamel, H.I. Mohamed, A.E. Bayoumi. Phytochemical and biological activities of two Asteraceae plants *Senecio vulgaris* and *Pluchea dioscoridis* L. Pharmacologyonline 2, 101-121 (2019).
[40] S. Andreani, J. Paolini, J. Costa, A. Muselli. Essential-oil composition and chemical variability of *Senecio vulgaris* L. from Corsica. Chem. Biodivers. 12(5), 752-766 (2015).
[41] I.A. Saleh, A.N.G. El Gendy, M.A. Afifi, H.R. El-Seedi. Microwave extraction of essential oils from *Senecio serpens* G.D. Rowly and comparison with conventional hydro-distillation method. J. Essent Oil Bearing Pl. 22(4), 955-961 (2019).
[42] R.M.S. Ashour, A. El Sayed, M. Elyamany, D. Abou-Hussein. Chemical profile and biological activities of the aerial parts of *Senecio acaulis* (L.f.) Sch.Bip. Pharmacogn. Res. 10(2), 130-136 (2018).
[43] S. Lopez, B. Lima, M.B. Agüero, M.L. Lopez, M. Hadad, J. Zygadlo, D. Caballero, R. Stariolo, E. Suero, G.E. Feresin, A. Tapia. Chemical composition, antibacterial and repellent activities of *Azorella trifurcata*, *Senecio pogonias*, and *Senecio oreophyton* essential oils. Arabian J. Chem. 11(2), 181-187 (2018).
[44] V. Kumar, C.S. Mathela. Chemical constituents of essential oils of Himalayan *Nepeta cilliaris* Benth. and *Senecio nudicaulis* Buch-Ham. Ex D.Don. J. Essent. Oil Res. 30(3), 207-213 (2018).
[45] P. Sharma, G.C. Shah. Composition and antioxidant activity of *Senecio nudicaulis* Wall. ex DC. (Asteraceae): A medicinal plant growingwild in Himachal Pradesh, India. Nat. Prod. Res. 29(9), 883-886 (2015).
[46] M. Kenoufi, T. Lograda, P. Chalard, G. Figueredo, M. Ramdani. Chemical composition, antimicrobial activity and chromosome number of *Senecio giganteus* Desf. from Algeria. Int. J. Pharmacogn. Phytochem. Res. 8(11), 1772-1777 (2016).
[47] S. Chibani, W. Gherboudj, A. Kabouche, R. Touzani, A. Aburjai, Z. Kabouche. GC-MS analysis of *Senecio giganteus* Desf. from Algeria. J. Essent. Oil Bearing Pl. 16(1), 123-125 (2013).
[48] N.P. Alza, A.P. Murray. Chemical constituents and acetylcholinesterase inhibition of *Senecio ventanensis* Cabrera (Asteraceae). Rec. Nat. Prod. 10(4), 513-518 (2016).
[49] R. Singh, V. Ahluwalia, P. Singh, N. Kumar, O. Prakash Sati, N. Sati. Antifungal and phytotoxic activity of essential oil from root of *Senecio amplexicaulis* Kunth. (Asteraceae) growingwild in high altitude-Himalayan region. Nat. Prod. Res. 30(16), 1875-1879 (2016).
[50] T. Ouchbani, S. Ouchbani, R. Bouhfid, N. Merghoub, A.R. Guessous, M.E.L. Mzibri, E.M. Essassi. Chemical composition and antiproliferative activity of *Senecio leucanthemifolius* Poiret essential oil. J. Essent. Oil Bearing Pl. 14(6), 815-819 (2011).
[51] K.J. Xiao, W.X. Wang, J.L. Dai, L. Zhu. Anti-inflammatory activity and chemical composition of the essential oils from *Senecio flammeus*. Excli J. 13, 782-791 (2014).
[52] S.H. Lone, A. Bhat, H.M. Bhat, R. Majeed, R. Anand, A. Hamid, M.A. Khuroo. Essential oil composition of *Senecio graciliflorus* DC: Comparative analysis of different parts and evaluation of antioxidant and cytotoxic activities. Phytomedicine 21(6), 919-925 (2014).
[53] R.K. Joshi. Chemical constituents of essential oil of *Senecio bombayensis* flower. Maejo Int. J. Sci. Technol. 8(2), 161-164 (2014).
[54] G.N.S. Silva, T.B. Spader, S.H. Alves, C.A. Mallmann, B.M. Heinzmann. Composition and evaluation of the antimicrobial activity of the essential oil of *Senecio selloi* Spreng DC. Rev. Bras. Pl. Med. 15(4), 503-507 (2013).
[55] S. Andreani, M. Znini, Paolini, L. Majidi, B. Hammouti, J. Costa, A. Muselli. Application of senecio inaequidens essential oil and its fractions as eco-friendly inhibitors of mild steel corrosionin 1M HCL solution. Int. J. Electrochem. Sci. 8(10), 11896-11915 (2013).
[56] E. Bagci, O. Kilic. Chemical composition of essential oil of *Senecio vernalis* Wwaldst. et kit. (Asteraceae) from Turkey. J. Essent. Oil Bearing Pl. 15(3), 399-404 (2012).
[57] A. Usta, O. Ucuncu, T.B. Cansu, S. Terzioglu, N. Yayli. Chemical composition of the essential oils from flowers of *Senecio vernalis* and *Senecio platyphyllus* van *platyphyllus*. Asian J. Chem. 21(8), 6369-6374 (2009).
[58] D. Nori-Shargh, S. Raftari, F. Deyhimi. Analysis of the essential oil of *Senecio vernalis* Waldst. & Kit. from Iran. Flav. Fragr. J. 23, 357-359 (2008).
[59] R.K. Joshi. GC/MS analysis of the essential oil of *Senecio belgaumensis* flowers. Nat. Prod. Commun. 6(8), 1145-1146 (2011).
[60] N. Kahriman, G. Tosun, S. Terzioglu, S.A. Karaoglu, N. Yayli. Chemical composition and antimicrobial activity of the essential oils from the flower, leaf, and stem of *Senecio pandurifolius*. Rec. Nat. Prod. 5(2), 82-91 (2011).
[61] D. Mishra, S. Joshi, S.P. Sah, A. Dev, G. Bisht. Chemical composition and antimicrobial activity of the essential oils of *Senecio rufinervis* DC. (Asteraceae). Ind. J. Nat. Prod. Resour. 2(1), 44-47 (2011).
[62] D. Mishra, G. Bisht, P.M. Mazumdar, S.P. Sah. Chemical composition and analgesic activity of *Senecio rufinervis* essential oil. Pharm. Biol.

48(11), 1297-1301 (2010).
[63] B.C. Thakuri, R.C. Padalia, C.S. Chanotiya, A. Tiwari, C.S. Mathela, H. Kharkwal. Sesquiterpene rich oils from leaves and roots of *Senecio rufinervis* DC. J. Essent. Oil Res. 20(5), 435-436 (2008).
[64] J. Benites, F. Bravo, M. Rojas, R. Fuentes, C. Moiteiro, F. Venancio. Composition and antimicrobial screening of the essential oil from the leaves and stems of *Senecio atacamensis* Phil. from Chile. J. Chilean Chem. Soc. 56(2), 712-714 (2011).
[65] C. Arrabal, F. Martínez García, M. Paz Arraiza, S. Guerrero García. Chemical composition of essential oil of *Senecio coincyi*, an endemic species of the Central Iberian Peninsula. Nat. Prod. Commun. 6(1), 123-126 (2011).
[66] C.M.S. Bisht, A.B. Melkani, V. Dev, P.S. Beauchamp. 1,10β-epoxy-6-oxofuranoeremophilane and other terpenoids from the essential oil of *Senecio royleanus* DC. J. Essent. Oil Res. 23(1), 102-104 (2011).
[67] O. Ucuncu, N. Yayli, A. Yasar, S. Terzioglu, N. Yayli. Chemical composition of the essential oils from flower, leaf, and stem of *Senecio trapezuntinus* Boiss. grown inTurkey. Nat. Prod. Commun. 3(6), 925-928 (2008).
[68] L.A. Oladipupo, O.O. Adebola. Chemical composition of the essential oils of the flowers, leaves and stems of two *Senecio polyanthemoides* Sch.Bip. samples from South Africa. Molecules 14(6), 2077-2086 (2009).
[69] H.M. Niemeyer. Composition of essential oils from five aromatic species of Asteraceae. J. Essent. Oil Res. 21(4), 350-353 (2009).
[70] S.S. El Hawary, A.E. Galal, M.F. Yousif, F.N. Kirollos. GC-MS and bioactivity of the essential oil of *Senecio rowleyanus* Jacobs. Pharmacogn. Mag. 4(16), 273-277 (2008).
[71] A.L. Murari, F.H. De Carvalho, B.M. Heinzmann, T.M. Michelot, R. Horner, C.A. Mallmann. Composition and antibacterial activity of the essential oils of *Senecio crassiflorus* var. *crassiflorus*. Quim. Nova 31(5), 1081-1084 (2008).
[72] M. Mirza, Z.B. Nik. Chemical composition of the essential oil of *Senecio leucostachys* Baker. J. Essent. Oil Bearing Pl. 11(2), 179-183 (2008).
[73] K.H.C. Baser, B. Demirci. The essential oil of *Senecio farfarifolius* Boiss. et Kotschy growing in Turkey. J. Essent. Oil Res. 16, 558-559 (2004).
[74] J.C. Chalchat, Z.A. Maksimovic, S.D. Petrovic, M.S. Gorunovic. Essential oil of *Senecio squalidus* L., Asteraceae. J. Essent. Oil Res. 16(3), 227-228 (2004).
[75] C. Perez, A.M. Agnese, J.L. Cabrera. The essential oil of *Senecio graveolens* (Compositae): Chemical composition and antimicrobial activity tests. J. Ethnopharmacol. 66(1), 91-96 (1999).
[76] N. Mengi, S.N. Garg, S.K. Agarwal, C.S. Mathela. The occurrence of β-thujone and a new p-menthane derivative in *Senecio chrysanthemoides* leaf oil. J. Essent. Oil Res. 7(5), 511-514 (1995).
[77] A. El-Shazly, G. Doral, M. Wink. Chemical composition and biological activity of the essential oils of *Senecio aegyptius* var. *discoideus* Boiss. Z. Naturforsch. J. Biosci. 57(5-6), 434-439 (2002).
[78] R.R. Vera, S.J. Laurent, D.J. Fraisse. Chemical composition of the essential oil of *Senecio ambavilla* (Bory) Pers. from Réunion Island. J. Essent. Oil Res. 6(1), 21-25 (1994).
[79] I.N. Irahal, L.F. Azzahra, F. Hmimid, A. Errami, I. Guenaou, I. Diawara, M. Kettani-Halabi, S. Fahde, L. Ouafik, N. Bourhim. Identification of the chemical composition of six essential oils with mass spectroscopy and evaluation of their antibacterial and antioxidant potential. Flav. Fragr. J. 36(4), 465-476 (2021).
[80] S. Kebbi, L. Noman, I. Demirtas, C. Bensouici, S. Adem, S. Benayache, F. Benayache, R. Seghiri, M. Gok. In vitro antioxidant and anticholinesterase activities of *Senecio massaicus* essential oil and its molecular dockingstudies as a potential inhibitor of Covid-19 and Alzheimer's diseases. J. Biol. Active Prod. Nat. 11(4), 380-394 (2021).
[81] O.A. Lawal, A.O. Oyedeji. Volatile constituents of *Senecio pterophorus* (African daisy) DC. from South Africa. Nat. Prod. Commun. 5(11), 1811-1814 (2010).
[82] C.P. Zhang, Z.O. Toshmatov, S.X. Zhou, W.J. Li, C. Zhang, H. Shao. Chemical composition and phytotoxic activity of essential oil from *Senecio erucifolius*. Chem. Nat. Compd. 57(3), 580-582 (2021).
[83] E.M. Suleimen, Z.B. Iskakova, Z.A. Ibataev, P.G. Gorovoi, R.V. Dudkin, S.A. Ross. Constituent composition and cytotoxic activity of essential oil from *Senecio argunensis*. Chem. Nat. Compd. 52(6), 1125-1126 (2016).
[84] M.M. Ahmad, S.U. Rehman, Z. Iqbal, F.M. Anjum, J.I. Sultan. Genetic variability to essential oil composition in four *Citrus* fruit species. Pak. J. Bot. 38(2), 319-324 (2006).
[85] L. Alcaraz-mel, S. Real-cosio, V. Such, E. Svajdlenka. Differences in essential oil production and leaf structure in phenotypes of damiana (*Turnera diffusa* Willd.). J. Plant Biol. 50, 378-382 (2007).
[86] C. Perez, A.M. Agnese, J.L. Cabrera. The essential oil of Senecio graveolens (Compositae): Chemical composition and antimicrobial activity tests. J. Ethnopharmacol. 66(1), 91-96 (1999).
[87] O. Ucuncu, N. Kahriman, S. Terzioglu, S.A. Karaoglu, N. Yayli. Composition and antimicrobial

activity of the essential oils from flowers of *Senecio othonnae, S. racemosus*, and *S. nemorensis*. Nat. Prod. Commun. 5(5), 831-834 (2010).
[88] R.K. Joshi. In vitro antimicrobial activity of the essential oil of the endemic plant *Senecio belgaumensis*. J. Biol. Active Prod. Nat. 2(6), 382-386 (2012).
[89] F.E.J. Idrissi, T. Ouchbani, S. Ouchbani, A.E. Hourch, A.F. Maltouf, E.M. Essassi. Comparative chemical composition and antimicrobial activity of essential oil and organic extracts of *Senecio leucanthemifolius* Poiret. J. Essent. Oil Bearing Pl. 18(1), 29-35 (2015).
[90] V. Kumar, C.S. Mathela, G. Tewari, A. Panwar, V. Pandey. In vitro antimicrobial activity of essential oils and their acetylenic constituents. Ind. J. Nat. Prod. Resour. 8(1), 63-68 (2017).
[91] K. Basaid, E.H. Mayad, R. Bouharroud, J.N. Furze, H. Benjlil, A.L. De Oliveira, B. Chebli. Biopesticidal value of *Senecio glaucus* subsp. *coronopifolius* essential oil against pathogenic fungi, nematodes,and mites. Mat Today: Proceedings 27, 3082-3090 (2020).
[92] M. Lin, L. Qirong, L. Dandan, L. Shan, W. Xiaomei, Z. Yuanyuan. Alpha-glucosidase inhibitory activities of essential oils extracted from three Chinese herbal medicines. Chem. Eng. Transact. 64, 61-66 (2018).