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Chemical Compositions and Biological Activities of *Scutellaria* Genus Essential Oils (Lamiaceae)

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Abstract

Context: Essential oils are secondary metabolites with versatile organic structures that, due to their compounds, have useful medicinal properties. There are about 250 species of the genus of *Scutellaria* perennial flowering plants from the Lamiaceae family. Its application for the treatment of allergy, inflammatory, hyperlipidemia, arteriosclerosis, hypertension, and hepatitis has a long history.
Evidence Acquisition: Various studies on the chemical compounds of the *Scutellaria* genus have identified several compounds, especially essentials oils. The current review is based on the evidence found in Chemical Abstract, Science Direct, Scopus, PubMed, Web of Knowledge, and Google Scholar databases.
Results: Many studies on the chemical components of essential oils from the *Scutellaria* genus have identified several compounds. We summarized the chemical compositions and biological activities of *Scutellaria* essential oils. Hexadecanoic acid, germacrene D, β-caryophyllene, linalool, β-farnesene, and eugenol are the main compounds in essential oils of this genus. Despite many reports about essential oils of *Scutellaria* species (more than 38), a large number of species have not been studied yet. Therefore, several studies should be conducted on the chemical compounds and biological activities of unstudied *Scutellaria* essential oils.
Conclusions: This review has summarized reports on the chemistry and biological activities of *Scutellaria* essential oils, such as antioxidant, antimicrobial, antifeedant, phytotoxic, and acaricidal toxicities, based on the recent literature.

Keywords: Scutellaria, Lamiaceae, Essential Oils, Chemical Composition, Biological Activities

1. Context

The *Scutellaria* genus that can be found in East Asia, the United States, and Europe include perennial flowering plants in the Lamiaceae (mint) family, which contains 350 species (1, 2). There are about 300 species of this genus in Asia (3-6). In Iran, the *Scutellaria* genus is represented by 27 species, which 12 of them are endemic (7). *Scutellaria* genus has been used for the treatment of hyperlipidemia, allergy, inflammatory, arteriosclerosis, hepatitis, and hypertension for hundreds of years (8). It's about 2000 years that Asian medicine, especially Chinese medicine, is using *Scutellaria* for the treatment of fevers, colds, diphtheria, and high blood pressure (9). The genus of *Scutellaria* has several therapeutic properties such as antitumor, hepatoprotective, antioxidant, anti-inflammatory, anticonvulsant, antibacterial, and antiviruses activities (8). Also, *Scutellaria* species are useful in treating nervous system problems, including anxiety, insomnia, and hysteria (2). More than 295 compounds have been isolated from this genus (10, 11), such as flavonoids (12), phenylethanoid glycosides, and terpenes (Iridoid glycosides, monoterpenes, diterpenes, and triterpenoids) (13). Flavonoids (almost flavones) are common bioactive compounds of the *Scutellaria* genus (14).

Essential oils are secondary metabolites with versatile organic structures that have useful medicinal properties (15). They can be extracted from plants using classical and advanced techniques (16). There are various methods to extract essential oils, such as hydrodistillation, steam distillation, microwave, organic solvent extraction, supercritical CO_2, and ultrasonic and high-pressure solvent extraction (17, 18). Various factors affect the compositions of the essential oils, including geographical and climatic conditions, harvesting time, physiological age, plant storages, extraction methods, kind of drying. Besides, it should be noted that various parts of the plant contain different compositions (19-22). The major essential oil compounds are terpenoids, which are classified as monoterpens, sesquiterpenes, diterpenes, triterpenes, and tetraterpenes (23, 24). Essential oils can defend the plant against predators, parasites, environmental stress, and diseases. Meanwhile, during the insects' reproductive process, they attract insects (25).

2. Evidence Acquisition

The recent literature about the essential oils of different species of *Scutellaria* was reviewed (26-32). Although some review studies are conducted on the *Scutellaria* genus (8, 13) but evidence about the *Scutellaria* essential oils is not sufficient. Therefore this review was focused on the chemical compounds and biological activities of the *Scutellaria* genus essential oils.

3. Results

3.1. Chemical Compositions of Scutellaria Genus Essential Oils

Many studies have shown variations in the chemical compounds of *Scutellaria* genus essential oils. Several factors affect the variations in the essential oil compositions, including harvesting time, soil PH, drying conditions, geographic location, kind of subspecies, part of the plant, and extraction method (19-22).

The oils extracted from different *Scutellaria* species have similar compounds (Table 1). The compositions of essential oils are classified in Figures 1 to 4; the sesquiterpenes are the most common compound of the *Scutellaria* essential oils. Hexadecanoic acid, Germacrene D, β-caryophyllene, Linalool, β-Farnesene, and Eugenol are the main compounds of the essential oils of this genus. The structures of these compounds are shown in Figure 5. Several hydrocarbons and oxygenated terpenoid compounds have been identified from *Scutellaria* species (Figures 2 to 5). Hexadecanoic acid is a saturated fatty acid in plants, animals, and microorganisms (33). Germacrene D is a precursor of various sesquiterpenes such as cadinenes and selinenes (34, 35). Germacrene D has insecticidal activity against mosquitoes (36), aphids (37), and ticks (38). β-caryophyllene is a natural sesquiterpene with dietary phytocannabinoid that has therapeutic potential for anxiety, neuropathic pain, ulcerative colitis, endometriosis, and renal protection (39-42). Linalool is a monoterpene compound that is found in many plants; it is effective against several bacteria and fungi and possesses anti-inflammatory, antinociceptive, and antihyperalgesic activities (43). β-Farnesene is a strong pheromone in most aphid species (44).

Despite the many reports about essential oils of *Scutellaria* species (more than 38), a large number of species have not been studied yet. Therefore, more studies on the chemical composition of unstudied *Scutellaria* essential oils are

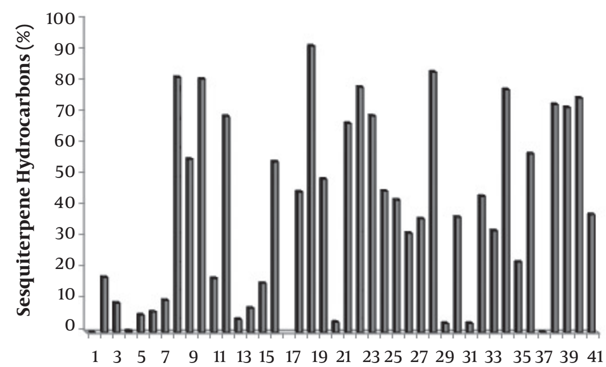

Figure 1. Relative abundance of sesquiterpene hydrocarbons in the essential oils of *Scutellaria* species. 1: *S. Albida* (27); 2: *S. albida subsp albida* (47); 3: *S. albida subsp colchica* (47); 4: *S. albida subsp condensata* (47); 5: *S. albida subsp velenovskyi* (47); 6: *S. barbata* (69); 7: *S. barbata* (50); 8: *S. baicalensis* (Chinese Medicinal Plants) (52); 9: *S. baicalensis* (UC Berkeley Botanical Gardens) (52); 10: *S. baicalensis* (Horizon Herbs) (52); 11: *S. brevibracteata* (48); 12: *S. californica* (60); 13: *S. cypria var. elatior* (59); 14: *S. cypria var. Cypria* (59); 15: *S. diffusa* (49); 16: *S. galericulata* (63); 17: *S. grossa Wall ex Benth* (67); 18: *S. hastifolia* (48); 19: *S. havanensis Jacq* (65); 20: *S. heterophylla* (49); 21: *S. immaculate* (58); 22: *S. orientalis L. subsp. Virens* (61); 23: *S. lateriflora* (64); 24: *S. litwinowii* (53); 25: *S. laeteviolacea* (55); 26: *S. luteo-caerulea* (64); 27: *S. orientalis ssp. alpina* (48); 28: *S. orientalis subsp. Virens* (57); 29: *S. pinnatifida ssp. alpina* (56); 30: *S. pinnatifida ssp. alpina* (68); 31: *S. parvula* (63); 32: *S. rupestris* (28); 33: *S. ramosissima* (58); 34: *S. rubicunda* (26); 35: *S. repens* (67); 36: *S. sieberi* (28); 37: *S. strigillosa* (54); 38: *S. schachristanica* (58); 39: *S. sibthorpii* (59); 40: *S. salviifolia* (49); 41: *S. volubilis* (51); 42: *S. Wightiana Beth* (13).

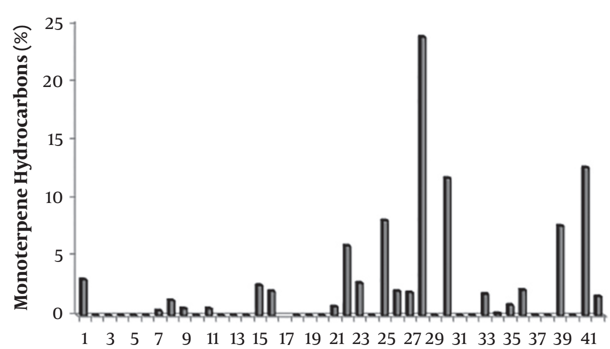

Figure 2. Relative abundance of monoterpene hydrocarbons in the essential oils of *Scutellaria* species. 1: *S. Albida* (27); 2: *S. albida subsp albida* (47); 3: *S. albida subsp colchica* (47); 4: *S. albida subsp condensata* (47); 5: *S. albida subsp velenovskyi* (47); 6: *S. barbata* (69); 7: *S. barbata* (50); 8: *S. baicalensis* (Chinese Medicinal Plants) (52); 9: *S. baicalensis* (UC Berkeley Botanical Gardens) (52); 10: *S. baicalensis* (Horizon Herbs) (52); 11: *S. brevibracteata* (48); 12: *S. californica* (60); 13: *S. cypria var. elatior* (59); 14: *S. cypria var. Cypria* (59); 15: *S. diffusa* (49); 16: *S. galericulata* (63); 17: *S. grossa Wall ex Benth* (67); 18: *S. hastifolia* (48); 19: *S. havanensis Jacq* (65); 20: *S. heterophylla* (49); 21: *S. immaculate* (58); 22: *S. orientalis L. subsp. Virens* (61); 23: *S. lateriflora* (64); 24: *S. litwinowii* (53); 25: *S. laeteviolacea* (55); 26: *S. luteo-caerulea* (64); 27: *S. orientalis ssp. alpina* (48); 28: *S. orientalis subsp. Virens* (57); 29: *S. pinnatifida ssp. alpina* (56); 30: *S. pinnatifida ssp. alpina* (68); 31: *S. parvula* (63); 32: *S. rupestris* (28); 33: *S. ramosissima* (58); 34: *S. rubicunda* (26); 35: *S. repens* (67); 36: *S. sieberi* (28); 37: *S. strigillosa* (54); 38: *S. schachristanica* (58); 39: *S. sibthorpii* (59); 40: *S. salviifolia* (49); 41: *S. volubilis* (51); 42: *S. Wightiana Beth* (13).

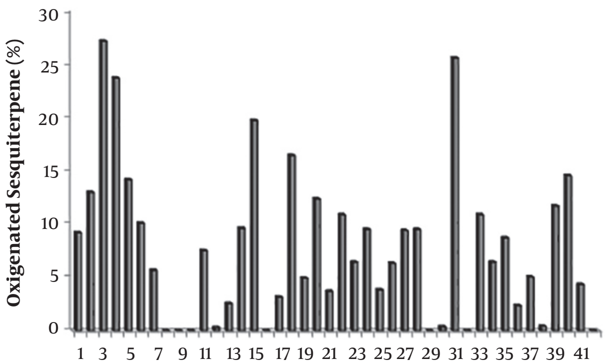

Figure 3. Relative abundance of oxygenated sesquiterpenes in the essential oils of *Scutellaria* species. 1: *S. Albida* (27); 2: *S. albida subsp albida* (47); 3: *S. albida subsp colchica* (47); 4: *S. albida subsp condensata* (47); 5: *S. albida subsp velenovskyi* (47); 6: *S. barbata* (69); 7: *S. barbata* (50); 8: *S. baicalensis* (Chinese Medicinal Plants) (52); 9: *S. baicalensis* (UC Berkeley Botanical Gardens) (52); 10: *S. baicalensis* (Horizon Herbs) (52); 11: *S. brevibracteata* (48); 12: *S. californica* (60); 13: *S. cypria var. elatior* (59); 14: *S. cypria var. Cypria* (59); 15: *S. diffusa* (49); 16: *S. galericulata* (63); 17: *S. grossa Wall ex Benth* (67); 18: *S. hastifolia* (48); 19: *S. havanensis Jacq* (65); 20: *S. heterophylla* (49); 21: *S. immaculate* (58); 22: *S. orientalis L. subsp. Virens* (61); 23: *S. lateriflora* (64); 24: *S. litwinowii* (53); 25: *S. laeteviolacea* (55); 26: *S. luteo-caerulea* (64); 27: *S. orientalis ssp. alpina* (48); 28: *S. orientalis subsp. Virens* (57); 29: *S. pinnatifida ssp. alpina* (56); 30: *S. pinnatifida ssp. alpina* (68); 31: *S. parvula* (63); 32: *S. rupestris* (28); 33: *S. ramosissima* (58); 34: *S. rubicunda* (26); 35: *S. repens* (67); 36: *S. sieberi* (28); 37: *S. strigillosa* (54); 38: *S. schachristanica* (58); 39: *S. sibthorpii* (59); 40: *S. salviifolia* (49); 41: *S. volubilis* (51); 42: *S. Wightiana Beth* (13).

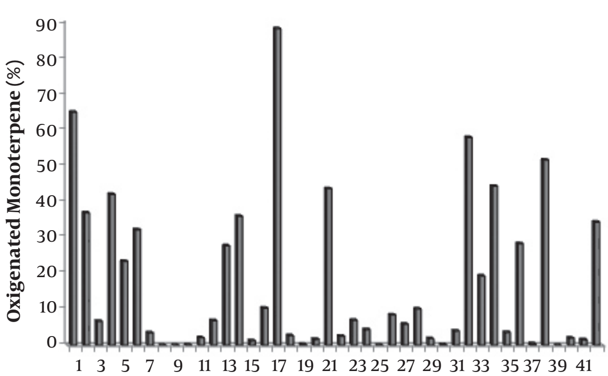

Figure 4. Relative abundance of oxygenated monoterpenes in the essential oils of *Scutellaria* species. 1: *S. Albida* (27); 2: *S. albida subsp albida* (47); 3: *S. albida subsp colchica* (47); 4: *S. albida subsp condensata* (47); 5: *S. albida subsp velenovskyi* (47); 6: *S. barbata* (69); 7: *S. barbata* (50); 8: *S. baicalensis* (Chinese Medicinal Plants) (52); 9: *S. baicalensis* (UC Berkeley Botanical Gardens) (52); 10: *S. baicalensis* (Horizon Herbs) (52); 11: *S. brevibracteata* (48); 12: *S. californica* (60); 13: *S. cypria var. elatior* (59); 14: *S. cypria var. Cypria* (59); 15: *S. diffusa* (49); 16: *S. galericulata* (63); 17: *S. grossa Wall ex Benth* (67); 18: *S. hastifolia* (48); 19: *S. havanensis Jacq* (65); 20: *S. heterophylla* (49); 21: *S. immaculate* (58); 22: *S. orientalis L. subsp. Virens* (61); 23: *S. lateriflora* (64); 24: *S. litwinowii* (53); 25: *S. laeteviolacea* (55); 26: *S. luteo-caerulea* (64); 27: *S. orientalis ssp. alpina* (48); 28: *S. orientalis subsp. Virens* (57); 29: *S. pinnatifida ssp. alpina* (56); 30: *S. pinnatifida ssp. alpina* (68); 31: *S. parvula* (63); 32: *S. rupestris* (28); 33: *S. ramosissima* (58); 34: *S. rubicunda* (26); 35: *S. repens* (67); 36: *S. sieberi* (28); 37: *S. strigillosa* (54); 38: *S. schachristanica* (58); 39: *S. sibthorpii* (59); 40: *S. salviifolia* (49); 41: *S. volubilis* (51); 42: *S. Wightiana Beth* (13).

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3.2. Biological Activities of Scutellaria Essential Oils

3.2.1. Antioxidant Activity

Compared to the results on the antioxidant activity of *Scutellaria* extracts (70-72), the essential oils of *Scutellaria* species only have moderate antioxidant activity (57). Zokirjonovna et al. (2016) evaluated the antioxidant activity of essential oils of three Uzbek *Scutellaria* species (i.e., *S. immaculata, S. ramosissima, and S. schachristanica*). The *Scutellaria* essential oils of these species exhibited moderate antioxidant activity due to the presence of eugenol, thymol, and carvacrol, but it was weaker than ascorbic acid (57).

3.2.2. Antimicrobial Activity

There are reports on the biological activities of *Scutellaria* genus essential oils, and most of the studies have investigated the antimicrobial activity of essential oils from this genus. The antimicrobial activity of these oils could be due to the components such as linalool, eugenol, and other long-chain alcohols (73). Moreover, other compounds such as thymol and alpha-terpineol could also contribute to the antimicrobial activity of the essential oil (74, 75). Yu et al. (2004) investigated the antibacterial activities of *S. barbata* essential oils against 17 microorganisms (*Enterococcus faecalis, Staphylococcus aureus, Serratia marcescens, Escherichia coli, Stenotrophomonas maltophila, Pseudomonas aeruginosa, Staphylococcus heamolyticus, Staphylococcus epidermidis, Candida tropicalis, Staphylococcus simulans, Citrobacter freundii, Salmonella paratyphi-A, Shigella flexneri, Klebsiella pneumoniae, Salmonella typhi, Serratia liquefaciens*, and *Candida albicans*) using the disc diffusion and broth microdilution methods. According to their results, the essential oil demonstrated a strong bactericidal effect; *S. epidermidis* was the most sensitive microorganism (29 mm inhibition zone and 0.77 mg/mL MBC), and *C. albicans* was the most resistant to the extract (7 - 9 mm and 24.50 mg/mL MBC) (69). Based on the results reported by Zhu et al. (2016), the essential oils from *S. strigillosa* had higher antimicrobial effects on gram-positive bacteria than gram-negative bacteria and fungus (53). Another study by Pant et al. (2012) demonstrated that the essential oils of *S. grossa* had significant antibacterial activity against *B. subtilis, E. faecalis, K. pneumonia*, and *S. enterica* (65). Skaltsa (2005) reported a moderate activity against *S. aureus* and *B. cereus* for the essential oils of *S. rupestris* and *S. sieberi* that were collected from Greece (28). In a study by Skaltsa et al. (2000), it was revealed that the essential oil of *S. albida subsp albida* was moderately active against *E. coli, S. aureus, B. subtilis, P. aeruginosa*, and *S. cerevisiae*, which can

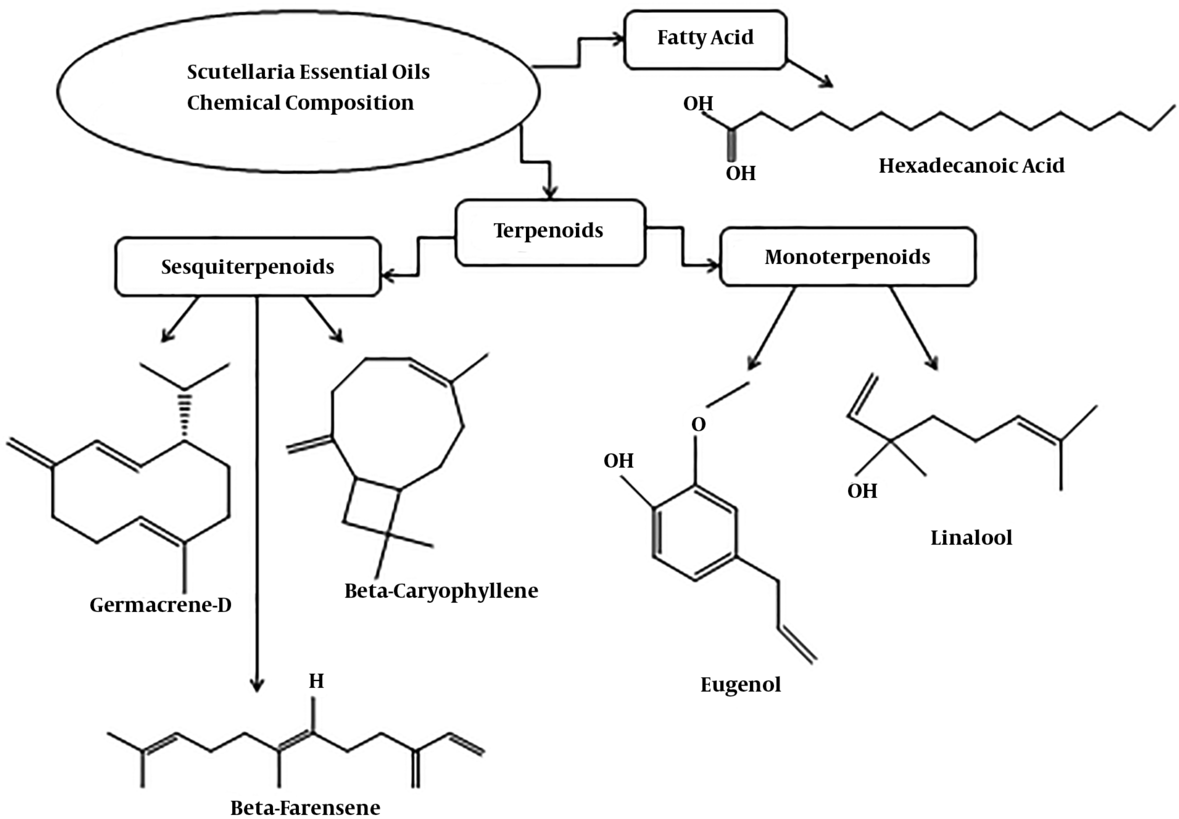

Figure 5. Chemical structures of the most frequent compounds from the essential oils of the *Scutellaria* genus

be attributed to high levels of linalool and nerolidol content (27). Dereboylu et al. (2012) investigated the antimicrobial activities of the volatile compounds of *S. sibthorpii, S. cypria var. cypria*, and *S. cypria var. elatior* against 7 bacteria and one fungis (*S. aureus, B. subtilis, S. typhimurium, E. faecalis, E. coli, P. aeruginosa, K. pneumonia*, and *C. albicans*) and reported that S. aureus was the most sensitive microorganism (58). The antibacterial activity of *S. repens* essential oil was tested on *S. aureus, E. faecalis, A. tumefac iens, E. chrysanthemi, X. phaseoli, E. coli, S. enterica, K. pneumoniae*, and *P. multocida* (67), and according to the results, the essential oil showed a high level of antibacterial activity. The maximum zone of inhibition was 23 mm for *E. coli*, 18 mm for *E. faecalis*, 15 mm for *K. pneumonia*, and 12 mm for *B. subtilis* (67). The antimicrobial activities of *Scutellaria* essential oils are summarized in Table 2.

3.2.3. Antifeedant Activity

In the study performed by Formisano et al. (2013), the essential oils of three *Scutellaria* species (*S. brevibracteata, S. hastifolia* and *S. orientalis ssp. alpina*) are studied against the feeding and egg-laying behavior of *Spodoptera littoralis*. The results of the insect assays showed that the essential oil of *S. hastifolia* was the only oil that could deter *Spodoptera littoralis* larvae from feeding on treated discs, whereas both *S. brevibracteata* and *S. hastifolia* could deter female moths from laying eggs on papers treated with their extracts (47). In another study, Rosselli et al. (2007) reported that essential oil of *S. rubicunda subsp. linnaeana* has antifeedant activity against *Spodoptera littoralis* (26). In their study, the essential oil of plant stimulated a dose-dependent positive feeding response from larvae of *S. littoralis* (feeding index (FI) 50% = 925 ppm; FI at 100 ppm = 44.85). A study on *S. rubicunda subsp. linnaeana* revealed that aerial parts of the plant that contains scutecyprol B, scutalbin C, and scutecyprol B had antifeedant activity against larvae of five

Table 2. Antibacterial and Antifungal Activities of *Scutellaria* Species

Microorganism	*Scutellaria* Species								
	S. barbata	***S. strigillosa***	***S. grossa***	***S. rupestris* ssp. *adenotricha***	***S. sieberi***	***S. albida* ssp. *albida***	***S. cypria* var. *cypria***	***S. sibthorpis***	***S. repens***
S. aureus	√	√	-[a]	√	√	√	√	√	√
E. coli	√	√	-	-	-	√	√	√	√
P. aeruginosa	√	√	-	-	-	√	√	-	-
S. epidermidis	√	-	-	-	-	-	-	-	-
S. heamolyticus	√	-	-	-	-	-	-	-	-
S. simulans	√	-	-	-	-	-	-	-	-
E. faecalis	√	-	√	-	-	-	√	-	√
C. freundii	√	-	-	-	-	-	-	-	-
K. pneumoniae	√	-	√	-	-	-	√	√	√
S. flexneri	√	-	-	-	-	-	-	-	-
S. paratyphi	-	-	-	-	-	-	-	-	-
S. liquefaciens	√	-	-	-	-	-	-	-	-
S. marcescens	√	-	-	-	-	-	-	-	-
S. maltophilia	√	-	-	-	-	-	-	-	-
C. albicans	√	√	-	-	-	-	-	-	-
C. tropicalis	√	-	-	-	-	-	-	-	-
B. subtilis	-	√	√	-	-	-	√	√	√
S. cerevisiae	-	√	-	-	-	√	-	-	-
S.enterica	-	-	√	-	-	-	-	-	√
B. cereus	-	-	-	√	√	√	-	-	-
M. flavus	-	-	-	-	-	-	-	-	-
P. mirabilis	-	-	-	-	-	-	-	-	-
S. thyphimirium	-	-	-	-	-	-	√	√	-
X. phaseoli	-	-	-	-	-	-	-	-	√
E.chrysanthemi	-	-	-	-	-	-	-	-	√
A.tumefaciens	-	-	-	-	-	-	-	-	√
P. multocida	-	-	-	-	-	-	-	-	√

[a]Microorganism was not tested or essential oil had little activity or it was inactive

species of Lepidoptera (FI at 100 ppm = 100) (1).

3.2.4. Phytotoxic Effect

The phytotoxic effect of *S. strigillosa* essential oil was evaluated by conducting bioassays against amaranth and bluegrass (amaranthus is a cosmopolitan genus of annual or short-lived perennial plants, and bluegrass refers to several species of grasses of the genus Poa). 3 μL/mL of essential oil could completely inhibit amaranthus seedling growth and caused a significant inhibitory effect on bluegrass (53).

3.2.5. Acaricidal Toxicities Activity

The acaricidal activity of *S. barbata* essential oil was higher than the activity observed in the positive controls (benzyl benzoate), which was evaluated via fumigant and contact toxicity bioassays against *Dermatophagoides farinae*, *D. pteronyssinus*, and *Tyrophagus putrescentiae* (45).

4. Conclusions

Scutellaria is a genus in the Lamiaceae family and for thousands of years, has been used as a medicine (76, 77). In recent years, many studies are performed on the essential oils of different species of *Scutellaria* (8, 13, 26-32). However, many species of the *Scutellaria* genus are not investigated, and therefore many studies can be performed on the components and biological activities of uninvestigated *Scutellaria* essential oils.

In the current review, chemical compositions of essential oils and biological activities (antioxidant, antimicrobial, antifeedant, phytotoxic, and acaricidal activities) of the *Scutellaria* genus are summarized. Hexadecanoic acid, germacrene D, β-caryophyllene, linalool, β-farnesene, and eugenol were the main compounds. (several compounds of these oils have medicinal properties). This review can serve as a reference for natural products and ethnopharmacology fields.

Footnotes

Authors' Contribution: This work was performed by the collaboration of all authors. Ameneh Mohammadi contributed to the study design, data collection, assessment of documents, data analysis, writing the first draft, and managing the research. Jamal Kasaian was a supervisor of the research project and contributed with original data, critical editing, and reviewing the manuscript. Peiman Alesheikh was the second supervisor of the research project and cooperated in the clinical process, assessment of neonates, critical editing, and reviewing the manuscript. All authors read and approved the final manuscript.

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Table 1. Major Essential Oil Components (> 10%) of *Scutellaria* Species

Compound	*Scutellaria* species	Origin	Amount (%)	Ref.
Hexadecanoic acid	*S. barbata*	Korea	58.52	(45)
	S. albida subsp albida	Turkey	15.6	(46)
	S. albida subsp colchica	Turkey	12.9	(46)
	S. albida subsp velenovskyi	Turkey	17.3	(46)
	S. brevibracteata	Lebanon	12.6	(47)
	S. diffusa	Turkey	29.9	(48)
	S. heterophylla	Turkey	16.0	(48)
	S. barbata	China	28.6	(49)
Hydroxynaphthalene	*S. barbata*	Korea	12.22	(45)
Germacrene D	*S. volubilis*	Ecuador	20.4	(50)
	S. baicalensis	United States	12.4	(51)
		United States	27.5	(51)
		United States	13.0	(51)
	S. litwinowii	Iran	16.9	(52)
	S. strigillosa	China	37.78	(53)
	S. salviifolia	Turkey	40.0	(46)
	S. laeteviolacea	Japan	21.67	(54)
	S. orientalis subsp alpina	Iran	39.7	(55)
	S. orientalis subsp Virens	Iran	16.5	(56)
	S. ramosissima	Uzbekistan	23.96	(57)
	S. sibthorpii	Turkey	42.01	(58)
	S. heterophylla	Turkey	21	(46)
	S. pinnatifida subsp alpina	Iran	39.7	(55)
β-**Caryophyllene**	*S. volubilis*	Ecuador	17.5	(50)
	S. baicalensis	US	22.3	(51)
	S. baicalensis	US	23.1	(51)
	S. baicalensis	US	41.5	(51)
	S. californica	US	56.6	(51)
	S. albida subsp albida	Turkey	14.2	(48)
	S. albida subsp velenovskyi	Turkey	20	(48)
	S. sieberi	Greece	14.2	(28)
	S. salviifolia	Turkey	11	(46)
	S. orientalis subsp alpina	Iran	15	(55)
	S. orientalis subsp Virens	Iran	13.4	(56)
	S. orientalis subsp Virens	Turkey	22.08	(59)
	S. ramosissima	Uzbekistan	11.09	(57)
	S. sibthorpii	Turkey	22.58	(58)
	S. brevibracteata	Lebanon	14.4	(47)
	S. hastifolia	Lithuania	12.9	(47)

	S. hastifolia	Lithuania	12.9	(60)
	S. galericulata	Canada	29.4	(61)
	S. heterophylla	Turkey	13.0	(46)
	S. pinnatifida subsp. alpina	Iran	15.0	(55)
	S. rubicunda	Italy	28.7	(26)
	S. luteo-caerulea	Iran	24.8	(62)
	S. parvula	Canada	29.4	(61)
	S. havanensis Jacq.	Cuba	75.6	(63)
α-Humulene	*S. volubilis*	Ecuador	14.7	(50)
	S. havanensis Jacq.	Cuba	11.6	(63)
Linalool	*S. albida subsp albida*	Turkey	20.4	(46)
	S. albida subsp condensata	Turkey	28.5	(46)
	S. albida subsp albida	Greece	52.6	(27)
	S. sieberi	Greece	22.7	(28)
	S. rupestris	Greece	38.8	(28)
	S. schachristanica	Uzbekistan	26.98	(57)
	S. cypria var. elatior	Turkey	10.92	(58)
	S. rubicunda	Italy	27.8	(26)
Nerolidol	*S. albida subsp condensata*	Turkey	16.8	(46)
Tetradecanoic acid	*S. albida subsp velenovskyi*	Turkey	10.2	(46)
Cadinene	*S. lateriflora*	Iran	27.0	(64)
	S. orientalis subsp virens	Turkey	19.92	(59)
Calamenene	*S. lateriflora*	Iran	15.2	(64)
β-Farnesene	*S. litwinowii*	Iran	20.3	(52)
	S. galericulata	Canada	17.0	(61)
	S. parvula	Canada	17.0	(61)
	S.Wightiana benth	India	22.07	(13)
Bicyclo-germacrene	*S. salviifolia*	Turkey	14.0	(46)
Hexahydro farnesyl acetone	*S. orientalis subsp. alpina*	Lebanon	11.7	(47)
1-octen-3-ol	*S. laeteviolacea*	Japan	27.72	(54)
	S. grossa Wall ex Benth	India	32.0	(65)
Terpinolene	*S. orientalis subsp Virens*	Iran	15.6	(56)
Acetophenone	*S. immaculata*	Uzbekistan	30.39	(57)
	S. schachristanica	Uzbekistan	34.74	(57)
Eugenol	*S. immaculata*	Uzbekistan	20.61	(57)
	S. schachristanica	Uzbekistan	20.67	(57)
	S. cypria var cypria	Turkey	23.05	(58)
Thymol	*S. immaculata*	Uzbekistan	10.04	(57)
Palmitic acid	*S. cypria var cypria*	Turkey	27.0	(57)
	S. cypria var elatior	Turkey	46.76	(57)
Phytol	*S. brevibracteata*	Lebanon	10.7	(47)
4-vinylguaiacol	*S. brevibracteata*	Lebanon	10.2	(47)

βisabolol	*S. galericulata*	Canada	20.6	(61)
	S. parvula	Canada	20.6	(61)
Bergamotene	*S. galericulata*	Canada	13.4	(61)
	S. parvula	Canada	13.4	(61)
Methyl chavicol	*S. pinnatifida A. Hamilt Subsp pinnatifida*	Iran	81.9	(66)
Aromadendrene	*S. repens*	India	30.7	(67)
β -Funebrene	*S. repens*	India	15.0	(67)
1, 4- Benzenediol-2, 5-dimethyl	*S.Wightiana benth*	India	21.53	(13)
Pipertone oxide	*S.Wightiana benth*	India	16.23	(13)
α-Humulene	*S. havanensis Jacq*	Cuba	11.6	(63)
Limonene	*S. angustifolia*	Laos	30.3	(68)
Fenchone	*S. angustifolia*	Laos	26.7	(68)
Alpha-pinene	*S. angustifolia*	Laos	11.9	(68)