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CHEMICAL COMPOSITION AND ANTIMICROBIAL ACTIVITY OF *Scutellaria araxensis* ESSENTIAL OIL FROM IRAN

Z. Gharari,[1] K. Bagheri,[1] H. Danafar,[2] and A. Sharafi[2*]

The skullcaps, *Scutellaria*, belonging to the Lamiaceae family, are widely distributed in the world, excluding South Africa. There are approximately 350–400 known species belonging to this genus [1]. The Iranian flora comprises 20 species and two hybrids from this genus, in which 10 species and two hybrids are endemic [2]. The essential oil of *S. araxensis* Grossh and its antibacterial activity is reported in this study. *S. araxensis* is a perennial herb and an endemic plant that grows widely around the Aras River at 800 meters above sea level in Tabriz, Iran. In traditional Iranian medicine, all parts of this plant are popularly used in the preparation of various traditional medicines to treat constipation, wounds, and stress [3]. The therapeutic effects of herbaceous plants coming under the genus *Scutellaria* is related to the presence of flavonoids, mainly baicalin, baicalein, wogonin, and wogonoside, and terpenoids like diterpenes and iridoid glycosides [4, 5]. Flavones such as aglycones baicalein, wogonin and chrysin are the major bioactive compounds extracted from the root and shoot of *S. araxensis* [6]. The extract of the most famous plant from this genus, *Scutellaria baicalensis* Georgi, has substantial antibacterial [7], antiviral [8], and neuroprotective activities [9]. To the best of our knowledge, there is no study on the essential oil composition and antibacterial effect of the essential oil of this plant.

Essential Oil Components. The aerial parts of *S. araxensis* were collected from Tabriz Province in Iran in its flowering stage (July, 2018). The plant was identified by Dr. Alireza Yazdinejad (Department of Pharmacognosy, School of Pharmacy, Zanjan), and a voucher specimen was deposited in the herbarium of the School of Pharmacy, Zanjan University of Medical Sciences, Zanjan, Iran (No. 1316). Hydrodistillation of dried aerial parts of *S. araxensis* yielded 0.56% (v/w) of a yellowish essential oil. Sixty-seven components were characterized in the essential oil of *S. araxensis*, which represents 87.4% of the total oil components detected. The compounds were identified based on their mass spectra compared with those in the GC/MS library (Wiley 7n D. 04.00 and NIST) and by calculation of their retention indices (RI) relative to *n*-alkanes (C6–C24) [10]. Essential oil and antibacterial activity of this plant have not been evaluated previously, but several studies were conducted for other species and subspecies [11–13]. In this study, the essential oil analysis of *S. araxensis* revealed that *cis*-anethole (28.5%) is present in the highest amount. However, the amount of this compound has been reported poorly in other species of *Scutellaria* [14].

The principal components were oxygenated monoterpenes (40%) and ketones (21.2%), with acetophenone (20%) as the main constituent. *cis*-Anethole (28.5%) and *p*-menthan-3-one (7.5%) were the main oxygenated monoterpenes. The oxygenated sesquiterpene (1.3%), sesquiterpene hydrocarbons (2.5%), and monoterpene hydrocarbons (0.9%) were present in low amounts. Alcohols, acids, aldehydes, and acetates were the other main compounds, comprising 2.2%, 0.6%, 0.5%, and 0.1% of the oil, respectively. The bioactive constituents with their abundance in percent (%) and retention index (RI) are presented in Table 1.

1) Department of Plant Production and Genetics, Faculty of Agriculture, University of Zanjan, Zanjan, Iran; 2) Zanjan Pharmaceutical Biotechnology Research Center, School of Pharmacy, Zanjan University of Medical Sciences, Zanjan, Iran, fax: 024 33473639, e-mail: sharafi.a@gmail.com. Published in *Khimiya Prirodnykh Soedinenii*, No. 4, July–August, 2020, pp. 640–642. Original article submitted April 26, 2019.

TABLE 1. Compounds Identified in the Essential Oil of *S. araxensis* Using GC-MS

Compound	RI	%	Compound	RI	%
Hexane	601	Tr.	α-Copaene	1390	0.1
Heptane	699	0.3	Tetradecane	1401	1.6
2-Hexenal	855	Tr.	*cis*-Thujopsene	1425	0.1
3-Hexen-1-ol	857	0.1	Benzene, 1,3-bis(1,1-dimethylethyl)	1431	0.8
1-Octen-3-ol	977	0.8	β-Bourbonene	1434	0.1
p-Menth-3-ene	990	0.2	Aromadendrene	1443	0.3
Decane	1000	1.6	*trans*-β-Farnesene	1458	0.1
Benzene acetaldehyde	1020	0.1	*trans*-Caryophyllene	1472	0.3
1,8-Cineol	1035	Tr.	α-Amorphene	1476	0.2
Acetophenone	1070	20	β-Selinene	1484	0.1
Linalool	1093	0.9	Pentadecane	1501	1.9
Undecane	1103	1.1	Germacrene-D	1502	0.6
1,2-Trimethylene(5-exo,6-exo-(2)h(2))-8,9,10-trinorborn-2(3′)-ene	1132	0.1	δ-Cadinene	1534	0.4
			Phenol, 2,4-bis (1,1-dimethylethyl)	1540	0.9
Menthone	1139	0.5	β-Cubebene	1545	0.1
cis-Verbenol	1156	0.7	Isoaromadendrene epoxide	1584	0.1
Menthol	1161	0.1	Hexadecane	1600	1.5
neo-Menthol	1183	0.6	1-Benzoylcyclohexanol	1636	1.1
α-Terpineol	1197	0.1	*t*-Cadinol	1640	0.2
Dodecane	1198	2	α-Cadinol	1653	0.3
Naphthalene	1200	0.3	2-Hydroxy-4,6-cyclooactadien-1-one	1686	0.2
2-(3′,3′-Dimethyl-1′-butyn-1′-yl)-1-cyclohexene carbaldehyde	1203	0.2	Vulgarol B	1694	0.1
			diepi-α-Cedrene epoxide	1700	0.4
Levoverbenone	1205	0.3	Heptadecane	1703	0.4
2,2,6,7-Tetramethyl-10-oxatricyclo[4.3.0.1(1,7)]decan-5-ol	1213	0.3	Alloaromadendrene oxide	1705	0.2
			Octadecane	1803	0.5
(2,2,6-Trimethylbicyclo[4.1.0]hept-1-yl)-methanol	1217	0.1	*p*-Menthan-3-one	1855	7.5
			Nonadecane	1897	1.9
Pulegone	1232	0.2	Palmitic acid	1969	0.6
Carvone	1245	0.3	Eicosane	2000	1.5
p-Anisaldehyde	1251	0.2	Heneicosane	2096	1.0
cis-Anethole	1256	28.5	Phytol	2119	1.0
Azulene	1297	0.4	Docosane	2201	0.5
trans-Anethole	1307	0.2	Pentacosane	2506	0.3
α-Longipinene	1346	0.1	Octacosane	2797	0.1
Methyl 4,8-dimethylnonanoate	1369	0.1			

RI: the Kovats retention indices determined on HP-5 capillary column, using the homologous series of *n*-alkanes (C6–C24). Tr.: trace, less than 0.05%.

Antimicrobial Activities. The effects of the essential oil on the growth of five bacteria, Gram-positive bacteria *Staphylococcus aureus* (ATCC 29737) and Gram-negative bacteria *Escherichia coli* (ATCC 10536), *Klebsiella pneumoniae* (ATCC 10031), *Salmonella paratyphi* (ATCC 5702), and *Proteus vulgaris* (PTCC 1182), were measured *in vitro* by the agar disc diffusion method and reported as inhibition zone in diameter (mm) and minimum inhibitory concentration (MIC). Serial dilutions of the essential oil sample were prepared in a concentration range from 25 to 500 μg/mL in sterile test tubes containing nutrient broth (Table 2). Kanamycin and gentamicin were used as positive control, and a disc containing DMSO was used as negative control against bacterial strains, which had not effect on the bacterial growth. The *S. araxensis* essential oil showed strong activity against *S. aureus* and *S. paratyphi* and moderate activity against *P. vulgaris*, *K. pneumonia*, and *E. coli*, which could be explained by its high content of *cis*-anethole (28.5%) and acetophenone (20%), as they have been previously proved to possess antibacterial activity [15, 16]. *p*-Menthan-3-one, the other major monoterpene of *S. araxensis* (7.5%) is a major derivative of peppermint oil. It is basically a mixture of L-menthone and *iso*-menthone isomers and has a variety of medicinal properties such as antioxidant, anti-inflammatory, and antibacterial activities [17, 18].

TABLE 2. Antimicrobial Activity of *S. araxensis* Essential Oil

Microorganism	Essential oil of *S. araxensis*		Kanamycin (5 μg/disc)		Gentamicin (10 μg/disc)	
	IZ [a]	MIC [b]	IZ	MIC	IZ	MIC
S. aureus	22+++	500	12	250	19	500
E. coli	11+	500	7	500	17	500
K. pneumoniae	13+	250	9	250	23	250
S. paratyphi	18++	500	8	500	18	500
P. vulgaris	14+	250	10	250	21	500

[a] IZ: inhibition zone, diameter of the inhibition zone (mm) around the impregnated discs including diameter of the disc (6 mm): no inhibition (–), +moderate activity (10–15 mm), ++strong activity (15–20 mm), +++very strong activity (20 < mm);
[b] MIC: minimal inhibition concentrations, μg/mL.

The maximum antibacterial activity of *S. araxensis* essential oil was observed against *S. aureus*, followed by *S. paratyphi*, *P. vulgaris*, *K. pneumoniae*, and *E. coli*.

In the essential oils obtained from the aerial parts of *S. araxensis*, oxygenated monoterpenes such as *cis*-anethole are present in high amounts. Also the results obtained from antibacterial test clearly elucidate the significant inhibitory effect of *S. araxensis* essential oil against *S. aureus*. This antibacterial activity might be related to *cis*-anethole and *p*-menthan-3-one in the essential oil, which exert toxic effects and provide evidence to support the use of this plant in traditional medicine. Moreover, *cis*-anethole can be regarded as the most odor-active component in *S. araxensis* perfume.

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