Industrial Crops and Products 62 (2014) 293–298

Contents lists available at ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Short communication

Chemical composition of the essential oil of *Artemisia hedinii* Ostenf. et Pauls. from the Qinghai-Tibetan Plateau

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ARTICLE INFO

Article history:
Received 18 May 2014
Received in revised form 7 July 2014
Accepted 28 August 2014
Available online 18 September 2014

Keywords:
Artemisia hedinii
Essential oil
Chemical composition
Qinghai-Tibetan Plateau

ABSTRACT

The essential oil from the whole aerial part of *Artemisia hedinii*, which grows on the Qinghai-Tibetan Plateau, was analyzed by gas chromatography–mass spectrometry (GC–MS) to determine its chemical composition. GC–MS analysis revealed the presence of 65 compounds, representing 83.82% of the total relative content of the essential oil. The major components of the essential oil were determined to be 1,8-cineol (16.53%), camphor (15.20%), and dehydrosesquicineol (13.59%), whereas all of the other components were present in much lower amounts (0.03–2.57%).

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1. Introduction

Artemisia L. (*Compositae*) is one of the largest and most widely distributed plant genera in the world with more than 400 species. Species belonging to this particular genus are either herbs or small shrubs, and possess a broad range of special organoleptic characteristics. These plants have also been used for centuries in traditional folk medicine, with one of the most notable examples being the treatment of malaria. Plants belonging to this genus are mainly found in Asia, Europe and North America (Mucciarelli & Maffei, 2002), and approximately 186 species from this genus are widely spread distributed throughout China, including 82 endemic species. *Artemisia hedinii* Ostenf. et Pauls is an annual herb that grows on the Qinghai-Tibetan Plateau (QTP) at altitudes in the range of 1000–4000 m, over areas extended to Kashmir and Tajikistan (Shi et al., 2011). This particular herb has been used in traditional Tibetan medicine to treat a variety of different ailments, including inflammation and fever, as well as being used as detoxification and hemostatic agent (Salick et al., 2006). Despite its use in tradition Tibetan medicine, very little is known about the chemical composition of this species. To the best of our knowledge, the only study to have been reported in the literature pertaining to the chemical composition of *A. hedinii* was conducted by Tan et al. (1995), who identified eudesmane acid. Herein, we report for the first time the chemical composition of the essential oil from the aerial parts of *A. hedinii*, with the aim of identifying potential applications for *Artemisia* species from the QTP.

2. Materials and methods

2.1. Plant materials and method for the isolation of the essential oil

A. hedinii plant materials were collected from the central area of the QTP in the Qinghai province (Menyuan, longitude: 101°22′ E; latitude: 37°32′ N). The plant materials were collected during their flowering period in August, 2013, and were air-dried before being ground into a fine powder. Voucher specimens were deposited at the Baikal institute of Nature Management, Siberian Branch, Russian Academy of Sciences, Russia, and the Northwest Institute of Plateau Biology, Chinese Academy of Sciences, China. A 20 g portion of the powdered plant material was subjected to hydro-distillation for three hours in a Clevenger-type collector apparatus, and the

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http://dx.doi.org/10.1016/j.indcrop.2014.08.047
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resulting essential oil was isolated according to the procedure reported by Shang et al. (2012). It is important to mention that the essential oil used in the current study was only extracted from the whole aerial parts of the plant.

2.2. Analysis of the essential oil

The essential oil was analyzed by gas chromatography–mass spectrometry (GC–MS) to determine its chemical composition. GC–MS analysis was performed on an Agilent Technologies 6890 gas chromatograph (Agilent, Santa Clara, USA) coupled to a HP 5973 quadrupole mass selective detector (Hewlett-Packard, Palo Alto, USA). The GC system was equipped with a HP-5MS capillary column (30 m × 0.25 mm × 0.2 μm, Hewlett-Packard), and the MS system was operated in electron impact mode at 70 eV with the electron multiplier set at 2200 V. Helium (99.999% purity) was used as the carrier gas at a flow rate of 1 ml/min. The oven temperature was programmed to increase from 50 to 240 °C at a rate of 4 °C/min. The oven temperature was held at 240 °C for 5 min before being increased to 280 °C at a rate of 20 °C/min, and the oven was then held at this temperature for 5 min and the end of the run. The injector and detector temperatures were set to 280 and 250 °C, respectively. The column pressure was set to 52.8×10^3 Pa. The GC–MS systems were operated with a split ratio of 60:1. MS data were acquired in scan mode using whole range scanning at a speed of 2.5 s/time.

The chemical constituents in the essential oil were identified by comparing their GC–MS data with those held by the National Institute of Standards and Technology, as well as a comparison of their MS and calculated linear retention indices (RI) data with values from the literature (Tkachev, 2008). The RI of the different chemical constituents were obtained by the co-injection of a sample of the essential oil with a mixture of linear hydrocarbons C8–C20 (Sigma–Aldrich, St. Louis, USA) according to the method described by Tkachev (2008). The relative amount (%) of each individual component in the essential oil was expressed as its percent peak area relatively to the total peak area of all of the peaks in the GC spectrum of the oil.

Data pertaining to the chemical composition of the essential oil were subjected to multivariate statistical analysis using principal component analysis (PCA). The statistical analyses conducted in the current study were performed using version 6.0 of the Sirius software package (Kvalheim and Karstang, 1987). Compounds found in all or the majority of the samples were subjected to statistical analysis and their relative values (i.e., percentage of the sum) were logarithmically transformed. This process allowed for the derivation of an equation that could be used to define quantitative differences between the individual compounds.

3. Results and discussion

The chemical composition of the essential oil of *A. hedinii* is shown in Fig. 1 and Table 1
. GC–MS analysis of the essential oil revealed the presence of 65 compounds, representing 83.82% of the total relative content of the essential oil. The major components of the essential oil were determined to be 1,8-cineol (16.53%), camphor (15.20%), and dehydrosesquicineol (13.59%). All of the other components were present in much lower relative amounts based on peak area (i.e., 0.03–2.57%). 1,8-Cineol and camphor have been found in the essential oils of many other plants, and these compounds have been reported to exhibit several interesting biological properties, including antiseptic and anti-inflammatory activities (Atazhanova, 2008). Shang et al. (2012) reported that *Artemisia* species from the QTP contain considerable amounts of both of 1,8-cineol and

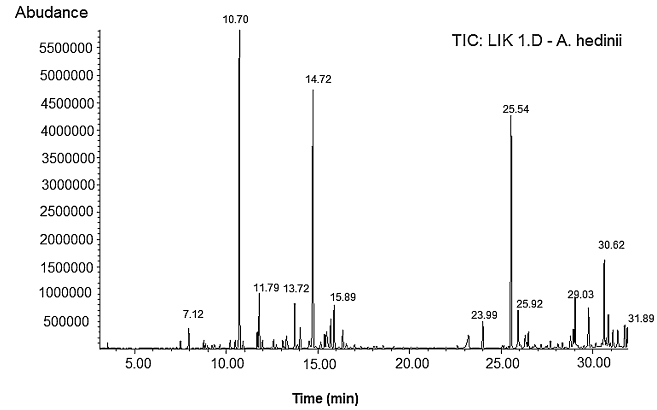

Fig. 1. Total ion scan from the essential oil of *Artemisia hedinii* Ostenf. et Pauls.

camphor, and similar combinations of camphor, cineole and dehydrosesquicineol were found in the essential oil of *Artemisia sieberi* Bess from Iran (Weyerstah et al., 1993). However, Ghasemi et al. (2007) did not report the presence of dehydrosesquicineol following their extraction of the essential oil of *A. sieberi* using supercritical CO_2.

Consideration of the literature data shows that the chemical composition of an essential oil can be dependent on several keys factors, including the location of the plant species (Zhigzhitzhapova et al., 2010) and method used to extract the oil (Ghasemi et al., 2007). Furthermore, the essential oils of a large number of different species of *Artemisia* have been shown to share a broad range of common chemical constituents (Suleimenov et al., 2010). Several plants from a subgenus of *Artemisia* (i.e., *A. hedinii*, *A. frigida*, *A. marshalliana*, and *A. gmelinii*) were collected from different regions of China and their essential oils were found to be very similar in terms of the large number of common chemical constituents. In contrast, plants belonging to a separate subgenus of *A. nanschanica* (i.e., subgenus *Dracunculus*) and *A. sieberi* (i.e., subgenus *Seriphidium*) have fewer chemical components in common with *A. hedinii*, even though the *A. nanschanica* was collected from the QTP (Table 1). PCA was applied

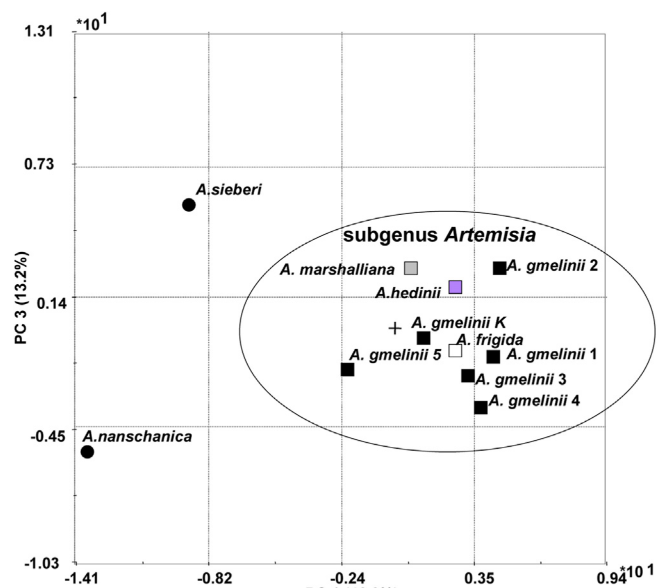

Fig. 2. PCA scores for the essential oils of plants belonging to the genus *Artemisia*, which contained 1,8-cineole and camphor as their major components. The graph shows *A. gmelinii:* K, Kazakhstan; 1, Russia, Irkutsky region, village Kultuk; 2, Mongolia, Bulganskiy aimak; 3, Russia, Olhon island; 4, Russia, Irkutsky region, Primosky range; 5, Russia, Buryatia, Selengisky district.

Table 1
Chemical compositions of the essential oils of *Artemisia* sp. from different regions of the world.

Compounds	Retention indices (RI)	Molecular formula	*Artemisia* sp., literature			
			A. hedinii our data	*A. frigida* Bodoev et al. (2000) [a]	*A. marshalliana* Suleimenov et al. (2010) [b]	*A. gmelinii* Suleimenov et al. (2010) [c]
			The habitation of the plants			
			China, QTP	Russia, Buryatia	Kazakhstan	Kazakhstan
			Peak area % (Percentage)			
Santolinatriene	905	$C_{10}H_{16}$	0.03		0.1	
Tricyclene	918	$C_{10}H_{16}$	0.03	0.05	0.1	0.1
3-Thujene	923	$C_{10}H_{16}$	0.04	0.01	0.3	0.1
α-Pinene	930	$C_{10}H_{16}$	0.34	0.25	4.1	0.1
Camphene	944	$C_{10}H_{16}$	0.92	0.65	1.3	1.8
Verbenene	950	$C_{10}H_{14}$	0.03			0.1
Benzaldehyde	956	C_7H_6O	0.03		0.1	
Sabinene	970	$C_{10}H_{16}$	0.38	0.01	0.8	0.2
β-Pinene	972	$C_{10}H_{16}$	0.21	0.15	1.7	0.1
Oct-1-en-3-ol	976	$C_8H_{16}O$	0.13	0.008	0.1	0.1
6- Methyl-5-hepten-2-on	984	$C_8H_{14}O$	0.15		0.1	
2,3-Dehydro-1,8-cineol	987	$C_{10}H_{16}O$	0.28	0.08	0.3	0.3
Yomogi alcohol	997	$C_{10}H_{18}O$	0.18		0.4	
α-Terpinene	1014	$C_{10}H_{16}$	0.41		0.2	1.0
para-Cymene	1021	$C_{10}H_{14}$	0.43	1.87	2.1	3.7
1,8-Cineol	1028	$C_{10}H_{18}O$	16.53	14.97	13.5	28.5
santolina alcohol	1034	$C_{10}H_{18}O$	0.38		0.2	
γ-Terpinene	1056	$C_{10}H_{16}$	0.85	1.25	0.9	1.4
Artemisia ketone	1059	$C_{10}H_{16}O$	2.68	0.07	4.4	
trans-Sabinene hydrate	1064	$C_{10}H_{18}O$	0.44	0.37	0.4	0.1
Artemisia alcohol	1081	$C_{10}H_{18}O$	0.47		1.1	
Terpinolene	1085	$C_{10}H_{16}$	0.19	0.30	0.2	0.2
cis-Sabinene hydrate	1095	$C_{10}H_{18}O$	0.45	0.45	0.3	0.1
Filifolone	1101	$C_{10}H_{14}O$	1.06			
α-Thujone		$C_{10}H_{16}O$			5.7	8.6
β-Thujone	1114	$C_{10}H_{16}O$	2.26		1.4	1.0
cis-*para*-Menth-2-en-1-ol	1117	$C_{10}H_{18}O$	0.30	0.75	0.2	2.5
Chrysanthenone	1122	$C_{10}H_{14}O$	1.14			0.1
trans-Pinocarveol	1136	$C_{10}H_{16}O$	0.67		0.4	
Camphor	1142	$C_{10}H_{16}O$	15.20	32.80	9.8	11.3
Isoborneol	1154	$C_{10}H_{18}O$	0.40			
Pinocarvone	1160	$C_{10}H_{14}O$	0.80	0.47		
Borneol	1163	$C_{10}H_{18}O$	1.57	15.27	3.3	9.3
Santolina alcohol acetate	1169	$C_{12}H_{20}O_2$	1.56			
Terpinen-4-ol	1174	$C_{10}H_{18}O$	2.34	6.65	2.6	3.3
α-Terpineol	1188	$C_{10}H_{18}O$	1.04	1.45	2.4	0.7
Myrtenol	1193	$C_{10}H_{16}O$	0.25	0.23	0.2	
Verbenone	1206	$C_{10}H_{16}O$	0.21			
trans-Carveol	1216	$C_{10}H_{16}O$	0.15	0.24	0.3	0.1
cis-Carveol	1228	$C_{10}H_{16}O$	0.12	0.16		
Cuminic aldehyde	1237	$C_{10}H_{12}O$	0.16			0.3
Carvone	1241	$C_{10}H_{14}O$	0.15	0.17		0.1
Isopiperitenone	1269	$C_{10}H_{14}O$	0.14			
Bornylacetate	1283	$C_{12}H_{20}O_2$	0.07	4.26	1.1	3.4
Chrysanthenone epoxide	1317	$C_{10}H_{14}O_2$	0.06			
Eugenol	1355	$C_{10}H_{12}O_2$	0.05		0.5	
α-Copaene	1374	$C_{15}H_{24}$	0.18		0.2	
Caryophyllene	1418	$C_{15}H_{24}$	1.61	0.08	0.8	0.1
Humulene	1452	$C_{15}H_{24}$	0.12		0.1	
β-*E*-farnesene	1455	$C_{15}H_{24}$	0.14		0.1	
Lavandulyl butanoate	1463	$C_{14}H_{24}O_2$	0.11			
Dehydro-sesquicineol	1468	$C_{14}H_{24}O$	13.59			
Germacrene D	1480	$C_{15}H_{24}$	2.37	0.13	2.9	0.3
(Z,E)-α-farnesene	1493	$C_{15}H_{24}$	0.93		0.1	
Bicyclogermacrene	1495	$C_{15}H_{24}$	0.29		1.0	
β-Bisabolene	1507	$C_{15}H_{24}$	0.13			0.3
Davana ether (isomer 1)	1511	$C_{15}H_{22}O_2$	0.18			
δ-Cadinene	1522	$C_{15}H_{24}$	0.23			0.9
Davana ether (isomer 2)	1530	$C_{15}H_{22}O_2$	0.11			
E-Nerolidol	1561	$C_{15}H_{26}O$	0.39		0.5	0.4
Spathulenol	1577	$C_{15}H_{24}O$	0.68	1.10	3.5	0.5
Caryophillene oxide	1582	$C_{15}H_{24}O$	0.98	0.65	1.2	1.1
cis-Davanone	1585	$C_{15}H_{24}O_2$	2.57			0.1
β-Eudesmol	1650	$C_{15}H_{26}O$	2.11		0.8	2.8
α-Cadinol	1654	$C_{15}H_{26}O$	0.27		1.0	
Epi-α-bisabolol	1682	$C_{15}H_{26}O$	1.55			

Table 1 (*Continued*)

Compounds	*Artemisia* sp., literature						
	A. gmelinii Zhigzhitzhapova et al. (2010) [d]					A.nanschanica, Shang et al. (2012) [e]	*A. sieberi*, Ghasemi et al. (2007) [f]
	The habitation of the plants						
	1 – Russia, Irkutsky region, village Kultuk	2 – Mongolia, Bulgansky aimak	3 – Russia, Olhon island	4 – Russia, Irkutsky region, Primosky range	5 – Russia, Buryatia, Selengisky district	China, QTP	Iran
	Peak area % (Percentage)						
Santolinatriene							
Tricyclene				0.2			
3-Thujene						11.60	
α-Pinene	0.4	0.7	0.1	0.4	0.4		2.51
Camphene	1.7	1.2	0.6		2.4		11.73
Verbenene							
Benzaldehyde							
Sabinene		0.3					0.69
β-Pinene	0.4	0.4	0.2	0.7	0.4		1.05
Oct-1-en-3-ol	0.6	0.6	0.3	0.6	0.5		0.69
6- Methyl-5-hepten-2-on							
2,3-Dehydro-1,8-cineol							
Yomogi alcohol							
α-Terpinene	0.8	0.8	0.7	1.5	1.1		0.26
para-Cymene	1.2	2.0	1.1	3.3	3.3		0.93
1,8-Cineol	21.5	25.4	20.3	36.5	40.3	9.43	9.91
santolina alcohol							
γ-Terpinene	1.4	1.5	1.4	2.6			
Artemisia ketone						7.40	
trans-Sabinene hydrate	0.8	0.7		0.4			
Artemisia alcohol						9.12	0.13
Terpinolene	0.3	0.3	0.3	0.6	0.4		
cis-Sabinene hydrate	1.2	1.1		0.7	0.8		
Filifolone							
α-Thujone						9.71	5.56
β-Thujone		0.5					
cis-para-Menth-2-en-1-ol	0.4	0.5	0.5	0.6			
Chrysanthenone							
trans-Pinocarveol							
Camphor	31.0	10.0	11.3	21.4	25.2	6.66	54.68
Isoborneol		1.0	0.8	0.7	0.5		
Pinocarvone	1.2	0.8	0.4	1.0	0.5		1.57
Borneol	17.6	4.5	6.5	9.6	8.0		1.30
Santolina alcohol acetate							
Terpinen-4-ol	4.7	5.2	5.6	7.7	4.5	2.16	
α-Terpineol	1.9	1.6	1.8	1.7	0.6		
Myrtenol		14.8					0.26
Verbenone							
trans-Carveol							
cis-Carveol							
Cuminic aldehyde							
Carvone							
Isopiperitenone							
Bornylacetate	2.5	0.6	0.8	1.8	0.9		
Chrysanthenone epoxide							
Eugenol							
α-Copaene			0.4				
Caryophyllene	1.4	1.3	0.7	0.6			
Humulene		0.4	0.3				
β-*E*-farnesene		0.3	0.2				
Lavandulyl butanoate							
Dehydro-sesquicineol							
Germacrene D	1.7	6.3	1.7	1.1			
(Z,E)-α-farnesene							
Bicyclogermacrene	1.1						
β-Bisabolene	0.9	1.1	0.6				
Davana ether (isomer 1)			0.3				
δ-Cadinene	0.5						
Davana ether (isomer 2)			0.5				
E-Nerolidol			0.6				
Spathulenol	2.3	1.1	3.5	0.6			

Table 1 (*Continued*)

Compounds	*Artemisia* sp., literature						
	A. gmelinii Zhigzhitzhapova et al. (2010) [d]					A.nanschanica, Shang et al. (2012) [e]	*A. sieberi*, Ghasemi et al. (2007) [f]
	The habitation of the plants						
	1 – Russia, Irkutsky region, village Kultuk	2 – Mongolia, Bulgansky aimak	3 – Russia, Olhon island	4 – Russia, Irkutsky region, Primosky range	5 – Russia, Buryatia, Selengisky district	China, QTP	Iran
	Peak area % (Percentage)						
Caryophillene oxide	2.6	0.6	2.9	1.3	0.4		
cis-Davanone		0.5	0.6				
β-Eudesmol							
α-Cadinol							
Epi-α-bisabolol							

Additional components which were identified in the oil:

[a] Hexanal (0.06%), α-terpinene (0.61%), phellandrene (0.06%), linalool (0.46%), nonanal (0.33%), α-campholenic aldehyde (0.25%), *trans*-piperitol (0.32%), *cis*-piperitol (0.58%), bornyl formate (0.33%), thymol (0.07%), carvacrol (0.06%), β-elemene (0.10%), bornylisobutyrate (0.15%), β-selinene (0.29%), hexahydrofarnesylacetone (0.21%).

[b] Hexanal (0.1%), *trans*-hexanal (0.1%), β-myrcene (0.6%), limonene (1.0%), *cis-β*-ocimene (0.6%), *trans-β*-ocimene (0.9%), linalool (0.7%), α-campholenic aldehyde (0.1%), *p*-menth-3-en-8-ol (0.1%), lavandulol (0.8%), *m*-cymen-8-ol (0.1%), *trans*-piperitol (0.1%), fragranol (0.5%), citronellol (0.2%), pulegone (0.7%), geraniol (0.2%), *cis*-chrysanthenyl acetate (0.1%), thymol (0.8%), carvacrol (0.2%), citronellyl acetate (0.5%), geranyl acetate (0.3%), β-elemene (0.4%), *cis*-jasmone (0.3%), methyleugenol (0.7%), β-copaene (0.1%), allo-aromadendrene (0.1%), γ-muurolene (0.3%), β-selinene (0.5%), α-muurolene (0.2%), γ-cadinene (0.4%), salvial-4(14)-en-1-ol (0.5%), humulen-6.7-epoxide (0.4%), γ-eudesmol (0.7%), α-bisabolol (1.8%), hexahydrofarnesylacetone (0.2%), phytol (0.4%).

[c] *cis*-Salvene (0.1%), β-phellandrene (0.3%), *p*-cymenene (0.1%), linalool (0.1%), *trans-p*-menth-2-en-1-ol (1.8%), camphene hydrate (0.1%), *cis*-chrysanthenol (1.4%), *m*-cymen-8-ol (0.2%), *cis*-piperitol (0.8%), *trans*-piperitol (0.9%), bornyl formate (0.2%), piperitone (0.2%), piperitone epoxide (0.3%), *cis*-chrysanthenyl acetate (0.1%), thymol (0.5%), ascaridole (0.2%), α-terpenyl acetate (0.1%), sabinyl propionate (0.1%), *cis*-jasmone (0.3%), β-selinene (0.3%), arteodouglasia oxide A (1.1%), humulen-6.7-epoxide (0.1%), γ-eudesmol (0.1%), caryphylla-4(12),8(13)-dien-5α-ol (0.1%), *epi*-α-cadinol (0.5%), α-muurolol (0.4%), chamazulene (0.6%).

[d] (1) β-Myrcene (0.6%), *trans*-sabinyl acetate (1.2%), myrthenylacetate (0.9%), α-zingiberene (3.0%).
(2) *cis*-Piperitol (0.3%), piperitone (0.4%), silphiperphol-5-ene (0.4%), α-guaiene (0.3%), *cis-treo*-davanofurane (58%), *ar*-curcumene (2.9%), β-selinene (1.0%), α-zingiberene (1.8%), α-presiphiperfolan-9-ol (4.8%), γ-elemene (7.4%), cadina-4,10(15)-dien-9β-ol (0.5%), dehydromethyleugenol (0.8%), copaborneol (0.9%), humulene-6,7 epoxide (0.8%), *trans*-1,4-cadinene (0.3%), menthen-1-ol (0.3%).
(3) α-Terpenyl acetate (0.5%).
(4) Verbenol (0.3%), β-phellandrene (0.3%), β-myrcene (0.4%), α-phellandrene (0.3%), linalool (0.4%), *cis*-sabinol (7.9%).

[e] Phellandrene (0.34%), linalool (10.94%), crithmene (0.45%), formosa camphor (0.76%), α-chamigrene (0.82%), cyclohexyl acetate (1.47%), hydrocinnamic acid (0.25%), penthamethyl benzene (0.82%), 1-methyl naphthalene (1.36%), 1-ethylidene-1H-indene (3.86%), 1,7-dimethyl naphthalene (2.64%), *trans*-4-methylene-2-hyenyl-methyl ester cyclopentanecarboxylic acid (0.25%), 1-(3-Methyl-1,3-butadienyl)-2,6-dimethyl-3-acetoxy-bicyclo[4.1.0]heptan-2-ol (0.23%), butylated hydroxytoluene (1.15%), 1-fluoro-1-(1-hexynyl)-2-phenyl-cyclopropane (0.33%), 1,2,3,4-tetrahydro-1,4,6-trimethyl-naphthalene (0.57%), 3-(2-methyl-propenyl)-1H-indene (0.16%), 4,4-dimethyl-3-(3-methylbut-3-enylidene)-2-methylenebicyclo[4.1.0]heptane (0.68%), 1,1,4a,7-tetramethyl-2,3,4,4a,5,6,7,8-octahydro-1H-benzo[7]annulen-7-ol (0.62%), guaiene (1.27%), widdrol (0.19%), 2,2′,5,5′-tetramethyl-1,1′-biphenyl (0.18%), 1,4a-dimethyl-7-(propan-2-ylidene)decahydronaphthalen-1-ol (0.22%), bisabolol (4.09%), 1-(2-hydroxy-2-methylpropyl)octahydro-1H-inden-2-ol (1.23%), 5,5a,6-trihydroxy-1,4-bis(hydroxymethyl)-1,7,9-trimethyl-1a,2,5,5a,6,9,10,10a-octahydro-1H-2,8a-methanocyclopenta[a]cyclopropa[e][10]annulen-11-one (0.30%), erysimosol (1.03%).

[f] β-Thujene (0.59%), lavender (0.15%), *cis*-arbesculone (0.32%), *trans*-arbesculone (0.13%), δ-thujone (0.56%), myrcenol (0.38%), *cis*-chrysanthenol (0.85%), *p*-cymen-8-ol (1.06%), *cis*-piperitol (0.56%), *trans*-piperitol (0.62%), piperitone (1.15%).

to examine the existence of any interrelationships between different species and the chemical constituents in their essential oils. The results of the PCA illustrated that plants belonging to the subgenus *Artemisia* formed a single cluster, whereas those belonging to *A. nanschanica* and *A. sieberi* were located in a different part of the graph (Fig. 2).

The chemical components in the essential oils of plants belonging to the genus *Artemisia* are determined by genetic and environmental factors. Determination of chemical constituents in the essential oil of *A. hedinii* could provide important information in terms of our overall understanding of plants belonging to the genus *Artemisia.* This better understanding could then help in the selection of specific *Artemisia* species for potential applications in the large-scale production of important chemicals. Future research in this area should focus on developing a detailed understanding of factors affecting the chemical constituents in the essential oil of *A. hedinii* such as the location and altitude at which the plants are grown.

Acknowledgements

This research was supported by the High-end Foreign Experts Recruitment Program (No. GDJ20146300006) of the State Administration of Foreign Experts Affairs, P.R. of China. We are thankful to Dr Gulzar Khan (Northwest Institute of Plateau Biology, Chinese Academy of Sciences, China) and Dylenova Elena (Buryat State University) for editorial assistance in the preparation of this manuscript.

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