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Composition of volatiles from *Sarcobatus vermiculatus* growing in southwestern Idaho

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Abstract
Sarcobatus vermiculatus is a succulent halophyte commonly found in the Great Basin deserts. The phytochemistry of this plant has not been thoroughly investigated, so the purpose of this work was to examine the volatiles produced by *S. vermiculatus*. The essential oils were obtained in paltry yields (0.012-0.027%) by hydrodistillation. Gas chromatographic analysis revealed the essential oils to be mainly composed of heptacosane (13.7-24.3%), 4-vinylguaiacol (11.6-13.7%), pentacosane (7.6-9.1%), tricosane (4.7-6.9%), and palmitic acid (3.9-5.3%). Terpenoids were relatively low in concentration (12.2-21.0%). Because of the low yields, *S. vermiculatus* cannot be considered a viable source of essential oil.

Keywords Greasewood, essential oil, gas chromatography, chiral, enantiomers

1. Introduction

Sarcobatus vermiculatus (Hook.) Torr. (Greasewood), Sarcobataceae, is a deciduous shrub, 1-2 m in height, with green succulent leaves (1.5-4 cm long) (Figure 1) [1]. The genus Sarcobatus is endemic to western North America, where it is largely found in the Great Basin and southwestern desert regions. Sarcobatus vermiculatus ranges from Alberta and Saskatchewan, Canada, south to northern Arizona and New Mexico, and from eastern Washington, Oregon, and California, east to the Dakotas, Nebraska, Kansas, and Texas (Figure 2) [2]. It is a common plant in alkaline habitats of the Great Basin. Sarcobatus was formerly placed in the Chenopodiaceae, but has been segregated into its own family, the Sarcobataceae, within the order Caryophyllales [3].

Fig 1: *Sarcobatus vermiculatus* from southwestern Idaho. Photograph by K. Swor

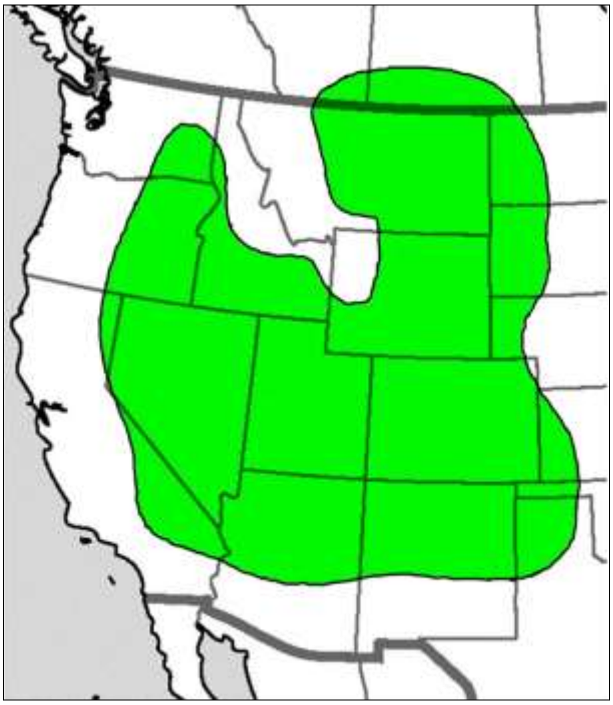

Fig 2: Range of *Sarcobatus vermiculatus* (greasewood). Adapted from Branson *et al*. [2].

Very little phytochemical work has been done on *S. vermiculatus*. Weber and co-workers analyzed the fatty acids in the seed oil of *S. vermiculatus* [4]. The seed oil was composed of 78.86% unsaturated fatty acids and 21.14% saturated, with linoleic acid (96.16%) dominating the unsaturated fraction, and palmitic acid (64.3%), myristic acid (13.15%), and stearic acid (5.82%) as major saturated fatty acids. As far as we are aware, there have been no investigations of the volatile phytochemicals of this plant. As part of our continuing exploration of the essential oils of Great Basin plants, this work presents the essential oil composition of *S. vermiculatus* growing in southwestern Idaho.

2. Materials and Methods

2.1 Plant Material

The aerial parts of three individual plants were collected on 28 June 2022 from Swan Falls, Snake River, Idaho. The plant was identified in the field by K. Swor, and verified by W.N. Setzer by comparison with samples from the New York Botanical Garden virtual herbarium (https://sweetgum.nybg.org/science/vh/specimen-list/?SummaryData=Sarcobatus%20vermiculatus, accessed on 29 June 2022). A voucher specimen (WNS-Sv-5662) has been deposited in the University of Alabama in Huntsville herbarium. The fresh aerial parts were stored at –20 °C until distilled. The aerial parts of each plant sample were hydrodistilled for 4 h using a Likens-Nickerson apparatus to give colorless residues (Table 1).

Table 1: Collection and hydrodistillation details of *Sarcobatus vermiculatus* from southwestern Idaho.

Plant sample	Coordinate and elevation	Mass aerial parts (g)	Mass essential oil (mg)
#1	43°14′47″N, 116°22′49″W, 704 m	127.46	15.3
#2	43°14′47″N, 116°22′48″W, 704 m	110.53	29.4
#3	43°14′47″N, 116°22′48″W, 704 m	151.05	24.3

2.2 Gas Chromatographic Analysis

The essential oils were analyzed by gas chromatography with flame ionization detection (GC-FID), gas chromatography – mass spectrometry (GC-MS) and chiral GC-MS as previously described [5]. Retention index values were determined using a homologous series of *n*-alkanes on a ZB-5ms column using the linear formula of van den Dool and Kratz [6]. The essential oil components were identified by comparison of the mass spectral fragmentation patterns and by comparison of retention index (RI) values available in the Adams [7], FFNSC 3 [8], NIST20 [9], and our own in-house database [10]. The identification of enantiomers was determined by comparison of retention times with authentic samples obtained from Sigma-Aldrich (Milwaukee, WI, USA).

3. Results and Discussion

Hydrodistillation of the aerial parts of *S. vermiculatus* gave poor yields (0.012-0.027%) of essential oils as colorless residues. The essential oils were subjected to gas chromatographic analysis (GC-MS, GC-FID, and chiral GC-MS). The chemical compositions of the *S. vermiculatus* samples are shown in Table 2; the enantiomeric distributions of chiral terpenoid constituents are listed in Table 3.

Table 2: Chemical compositions (%) of the essential oils of *Sarcobatus vermiculatus* from southwestern Idaho.

RI_{calc}	RI_{db}	Compound	#1	#2	#3
799	801	Hexanal	-	0.5	0.5
826	825	2-Furaldehyde	-	1.0	0.5
852	853	(3*Z*)-Hexenol	0.1	0.1	0.2
903	905	Heptanal	tr	0.3	0.2
945	942	4,4-Dimethylbut-2-enolide	0.1	0.1	0.2
949	950	Camphene	-	0.2	0.4
960	959	Benzaldehyde	0.1	0.6	0.7
971	971	Sabinene	-	0.5	-
971	971	Artemiseole	-	-	0.8
977	978	β-Pinene	-	0.4	-
989	989	2-Pentylfuran	-	0.6	0.5
994	996	Yomogi alcohol	0.3	-	0.4
1024	1025	*p*-Cymene	0.1	0.2	0.3
1028	1030	Limonene	tr	0.2	0.1
1030	1031	β-Phellandrene	0.1	0.3	0.4
1031	1032	1,8-Cineole	0.3	1.0	4.5
1033	1033	Benzyl alcohol	0.3	-	0.1
1056	1056	Artemisia ketone	0.7	1.2	0.2
1070	1070	Dihydromyrcenol	0.2	0.4	0.2
1078	1079	Artemisia alcohol	0.2	-	0.2
1084	1086	Terpinolene	-	0.3	0.3
1099	1101	Linalool	0.3	0.3	0.3
1102	1102	6-Methylhepta-3,5-dien-2-one	0.2	0.2	0.1
1104	1107	Nonanal	0.4	0.8	1.1
1106	1105	α-Thujone	0.7	2.6	1.2
1111	1111	Phenethyl alcohol	0.4	0.2	0.2
1118	1118	β-Thujone	0.1	0.2	0.1
1146	1145	Camphor	0.3	0.3	2.3
1148	1144	*trans*-Tagetone	0.4	-	-
1149	1153	1-Phenyl-2-propyn-1-ol	-	0.1	0.4
1163	1162	β-Artemisyl acetate	0.7	0.1	0.3
1168	1169	Thujol	-	0.5	0.3
1179	1180	Terpinen-4-ol	0.3	0.3	0.4
1205	1206	Decanal	0.1	0.1	0.2
1211	1210	*exo*-2-Hydroxycineole	0.3	0.1	-
1214	1217	Coumaran	0.8	0.5	0.7
1225	1226	Benzothiazole	0.3	0.3	0.2
1306	1309	4-Vinylguaiacol	13.7	11.6	12.8
1352	1356	Eugenol	0.5	1.6	0.3
1380	1380	(*E*)-β-Damascenone	2.2	1.5	4.5
1394	1394	Vanillin	2.1	0.8	1.5
1420	1424	(*E*)-β-Caryophyllene	0.5	0.7	0.3
1441	1434	4-Propylresorcinol	0.3	0.4	0.1
1449	1447	Geranyl acetone	0.4	0.4	0.2
1479	1481	(*E*)-β-Ionone	0.3	0.4	0.3
1482	1483	Germacrene D	0.7	0.6	0.4
1484	1483	Davana ether 1	0.3	0.3	0.2
1489	1483	2-Methyl-6-propyldodecane	0.4	0.3	0.1
1499	1496	Capillene	0.4	0.4	0.2
1503	1502	Davana ether 2	1.0	1.0	0.5
1505	1504	Davana ether 3	0.3	0.3	0.2
1520	1519	*trans*-Calamenene	-	1.3	0.1
1522	1521	Davana ether 4	0.8	0.4	0.4
1525	1524	Dihydroactinidiolide	0.3	0.3	0.4
1549	1546	α-Elemol	0.2	-	-
1559	a	4-Ethenyl-2,6-dimethoxyphenol	0.4	-	-
1562	1562	(*E*)-Nerolidol	0.7	1.5	0.5
1579	1577	Davanone	0.2	-	-
1581	1587	Caryophyllene oxide	0.2	0.3	0.2
1643	1642	(*Z*)-Methyl jasmonate	0.4	1.3	0.5
1655	1656	β-Eudesmol	1.2	0.8	1.0
1802	1805	2-Ethylhexyl salicylate	0.4	0.5	0.4
1842	1841	Phytone	1.4	2.5	1.7
1874	-	Unidentified [b]	-	1.2	0.2
1960	1958	Palmitic acid	4.9	3.9	5.3
1995	1994	1-Eicosene	0.3	0.3	0.1

2000	2000	Eicosane	0.2	0.3	0.1
2095	2099	1-Heneicosene	0.2	0.4	0.1
2100	2100	Heneicosane	0.5	1.1	0.4
2111	2109	Phytol	1.0	0.9	4.2
2132	2128	Linoleic acid	1.1	0.9	3.0
2195	2198	1-Docosene	1.0	1.5	0.7
2200	2200	Docosane	0.7	1.2	0.4
2226	2234	3,5-Dimethoxystilbene	-	-	0.4
2295	2298	1-Tricosene	0.3	0.5	-
2300	2300	Tricosane	5.3	6.9	4.7
2306	2306	2-Heneicosanone	0.7	0.7	0.4
2396	2397	1-Tetracosene	0.9	0.8	0.4
2400	2400	Tetracosane	1.1	1.3	0.6
2496	2496	1-Pentacosene	0.5	0.4	0.3
2500	2500	Pentacosane	9.1	7.6	7.6
2510	2513	2-Tricosanone	3.5	4.0	2.0
2596	2596	1-Hexacosene	-	-	0.2
2600	2600	Hexacosane	0.8	0.7	0.4
2633	2632	Tetracosanal	0.6	1.0	1.0
2663	-	Unidentified [c]	0.5	1.6	0.9
2700	2700	Heptacosane	24.3	14.0	13.7
2713	d	2-Pentacosanone	1.6	1.4	1.1
2800	2800	Octacosane	1.0	0.5	0.4
2807	2810	Squalene	-	-	0.5
2888	2893	Hexacosanal	-	-	0.4
		Monoterpene hydrocarbons	0.2	2.0	1.5
		Oxygenated monoterpenoids	4.8	7.1	11.1
		Sesquiterpene hydrocarbons	1.2	2.5	0.9
		Oxygenated sesquiterpenoids	5.0	4.6	2.9
		Diterpenoids	1.0	0.9	4.2
		Triterpenoids	0.0	0.0	0.5
		Benzenoid aromatics	19.6	16.9	17.9
		Fatty acid derivatives	59.3	52.3	45.9
		Others	5.6	7.6	8.4
		Total identified	96.8	93.9	93.3

RI_{calc} = Retention index calculated with respect to a homologous series of n-alkanes using the linear formula of van den Dool and Kratz [6]. RI_{db} = Retention index from the databases (Adams [7], FFNSC 3 [8], NIST20 [9], Satyal [10]). tr = trace (< 0.05%). [a] The MS comparison (NIST20) gave 88% match, but an RI value was not available for comparison.

[b] MS(EI): 234(14%), 220(17%), 219(100%), 191(11%), 163(21%), 145(30%), 109(17%), 105(13%), 93(15%), 91(16%), 55(19%), 41(15%).

[c] MS(EI): 337(4%), 281(2%), 267(2%), 253(2%), 239(2%), 225(4%), 211(3%), 197(4%), 183(5%), 169(6%), 155(7%), 141(10%), 127(13%), 113(16%), 99(25%), 85(54%), 71(71%), 57(100%), 43(60%). The MS looks like a normal alkane, but the RI is not correct.

[d] The RI for 2-pentacosanone was not available, but by homology with 2-tricosanone, it should be around 2713.

The yields of essential oil were very low, so *S. vermiculatus* is not a viable source of essential oil. The essential oils were dominated by fatty-acid derived compounds (45.9-59.3%), including heptacosane (13.7-24.3%), pentacosane (7.6-9.1%), tricosane (4.7-6.9%), and palmitic acid (3.9-5.3%). The concentrations of terpenoid components were relatively low with monoterpenoids ranging from 5.0% to 12.5% and sesquiterpenoids 3.9-7.1%.

Benzenoid aromatics were relatively abundant (16.9-19.6%), and the phenolic compound, 4-vinylguaiacol, was particularly plentiful (11.6-13.7%). 4-Vinylguaiacol is a decomposition product of ferulic acid and is responsible for an off-flavor of orange juice [11] and beer [12] and is produced via thermal [13] or enzymatic [14, 15] decarboxylation of ferulic acid. The compound has shown notable antibacterial and antifungal activity [16] as well as cytotoxic activity against human colorectal cancer cells [17].

Although detected in relatively small concentrations, benzothiazole (0.2-0.3%) was unexpected. The compound has been reported in cranberry (*Vaccinium macrocarpon* Aiton) fruit [18] and guava (*Psidium guajava* L.) fruit [19]. Benzothiazole has shown insecticidal activity against the red flour beetle (*Tribolium castaneum* (Herbst)) [20].

Although terpenoid components were in relatively low concentrations in *S. vermiculatus* essential oils, it was possible to carry out chiral GC-MS (Table 3). The (–)-enantiomers were only detected for camphene, camphor, (*E*)-β-caryophyllene, and germacrene D. The (+)-enantiomers were the exclusive stereoisomers for β-pinene, α-thujone, and (*E*)-nerolidol. Both enantiomers of camphene are widespread in essential oils [21]. (–)-camphor is less common than (+)-camphor, but it is the major enantiomer in *Tanacetum parthenium* Sch. Bip. [21] as well as *Coriandrum sativum* L. herb [22] and *Sassafras albidum* (Nutt.) Nees wood [23] essential oils. (–)-(*E*)-β-caryophyllene is the common enantiomer found in higher plants while the (+)-enantiomer is found in liverworts [21]. Both (–)- and (+)-germacrene D co-occur in different ratios in many essential oils [24]. However, (–)-germacrene D was the predominant enantiomer in *Gynoxys miniphylla* Cuatrec. [25] and *Pinus ponderosa* Douglas ex C. Lawson [26] essential oils, while the (+)-enantiomer dominated in *S. albidum* [23] and *Agastache foeniculum* (Pursch) Kuntze [27] essential oils. (*S*,*E*)-(+)-Nerolidol is the more common enantiomer [21].

Table 3: Enantiomeric distribution of chiral terpenoid components of *Sarcobatus vermiculatus*.

Compound	#1		#2		#3	
	RT (min)	EE	RT (min)	EE	RT (min)	EE
(–)-Camphene	nd		nd		17.99	100
(+)-β-Pinene	nd		20.43	100	nd	
(–)-β-Phellandrene	nd		26.46	100	nd	
(+)-α-Thujone	nd		45.16	100	45.12	100
(–)-Camphor	nd		nd		50.16	100
(–)-(*E*)-β-Caryophyllene	69.39	100	69.39	100	nd	
(–)-Germacrene D	nd		73.73	100	nd	
(+)-(*E*)-Nerolidol	83.60	100	83.61	100	nd	

RT = Retention time. nd = Not detected. EE = Enantiomeric excess.

4. Conclusions

This is the first report of the volatile phytochemistry of *Sarcobatus vermiculatus*. The essential oil yields were paltry, so this plant cannot be considered as a viable source of essential oils. Furthermore, terpenoid components were found in low concentrations, but fatty-acid derived compounds and benzenoid aromatics were relatively abundant.

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