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CHEMICAL COMPOSITION OF THE ESSENTIAL OILS OF THREE *Rhodiola* SPECIES FROM TIBET

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The genus *Rhodiola* (Crassulaceae), consisting of about 90 species, is widely distributed in the high cold region of the Northern Hemisphere. In China, there are over 70 species, mainly growing in the Qinghai-Tibet Platean [1]. A number of *Rhodiola* species have been used as traditional medicines in the treatment of long-term illnesses and weaknesses due to infection for more than 1000 years in China and other countries such as Russia, Mongolia, and India [2, 3]. Recent pharmacological studies found that some *Rhodiola* species such as *R. crenulata* contain many active ingredients, *e.g.*, salidroside, with strong properties such as anti-anoxia, anti-fatigue, anti-toxic, anti-radiation, anti-tumor, anti-aging, and active-oxygen scavenging as well as learning and memory enhancers [4–6].

There are some reports on the phytochemical analysis of *Rhodiola* species, especially the chemical composition of rhizomes of *Rhodiola*. The main useful components include salidroside and tyrosol, which are rich in the rhizomes [7–9]. According to a survey of the available literature, however, only few species have been studied for their essential oils [3, 10–14].

Herein we report the chemical constituents of the essential oils from rhizomes of *R. sacra* (Prain ex Hamet) S. H. Fu, *R. calliantha* (H. Ohba) H. Ohba, and *R. himalensis* (D. Don) S. H. Fu, collected from Tibet in August of 2004: *R. sacra* at Mt. Gambo Utse (alt. 4100–4300 m), *R. calliantha* at Mt. Tuojia (alt. 4100–4200 m), and *R. himalensis* at Mt. Mila (alt. 4100–4300 m). The roots of samples were cut into small segments, dried, and stored at room temperature prior to analysis.

Each sample was weighed (100 or 200 g), then steam distilled with a Clevenger-type apparatus for 3 h. The oil was collected, dried over anhydrous sodium sulfate, and stored at 4°C until analyzed. The GC-MS analysis was performed on a combined GC-MS instrument (Finnigan Voyager, San Jose, CA, USA) using a HP-5 fused silica capillary column (30 m length, 0.25 mm diameter, 0.25 μm film thickness). A 1 μL aliquot of oil was injected into the column using a 10:1 split injection, which temperature was set at 250°. The GC program was initiated by a column temperature set at 60° for 2 min, increased to 250° at a rate of 10°/min, and held for 10 min. Helium was used as the carrier gas (1.0 mL/min). The mass spectrometer was operated in the 70 eV EI mode with scanning from 41 to 450 amu at 0.5 s, and the mass source was set at 200°. The identifications of the volatile costituents were based on GC retention indices (relative to *n*-alkanes, from C8 to C20) and computer matching of their mass spectral fragmentation patterns with those stored in the spectrometer database using the National Institute of Standards and Technology Mass Spectral database (NIST-MS, 1998).

The hydrodistillation of the three *Rhodiola* species gave light yellowish oils with a yield of 0.05±0.01% (w/w). As shown in Table 1, 38 components were identified in the oil of *R. sacra*, which represented 98.70% of the total composition of the oil. Hexadecanoic acid (41.34%), 9,12-octadecadienoic acid (18.21%), and *n*-tricosane (4.97%) were major constituents in the essential oil of *R. sacra*. In the essential oil of *R. calliantha*, 26 components were identified, which represented 99.39% of the total composition. 9,12-Octadecadienoic acid (41.32%), hexadecanoic acid (35.73%), and 9-hexadecenoic acid (3.38%) were major constituents in the essential oil of *R. calliantha*. For *R. himalensis*, 28 components were identified, which represented 92.44% of the total composition. Geraniol (23.23%), hexadecanoic acid (18.90%), and 9,12-octadecadienoic acid (9.51%) were major constituents in the essential oil of this species.

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TABLE 1. Chemical Constituents of the Essential Oils of Three *Rhodiola* Species from Tibet

Compound	RI	GC area, %			Compound	RI	GC area, %		
		R. sacra	*R. calliantha*	*R. himalensis*			*R. sacra*	*R. calliantha*	*R. himalensis*
Myrcene	990	-	-	0.43	*n*-Octadecane	1800	0.87	0.75	-
Limonene	1032	-	-	0.19	Pentadecylic acid	1859	0.83	0.83	1.10
trans-Ocimene	1038	-	-	0.18	*n*-Nonadecane	1900	0.45	0.41	1.41
cis-Ocimene	1048	-	-	0.26	9-Hexadecenoic acid	1943	2.77	3.38	3.51
1-Octanol	1070	-	-	2.43	Hexadecanoic acid	1965	41.34	35.73	18.90
trans-Linalool oxide	1081	0.70	-	-	*n*-Heneicosane	2100	1.04	0.77	3.40
cis-Linalool oxide	1095	0.33	-	-	9,12-Octadecadienoic acid	2136	18.21	41.32	9.51
α-Linalool	1104	0.18	-	0.45	Octadecanoic acid	2162	1.70	1.86	1.14
Benzene ethanol	1114	-	-	2.88	*n*-Docosane	2200	0.39	0.69	-
Pinen-3-ol	1152	0.76	-	-	5-Eicosene	2286	0.27	0.18	1.85
Octanoic acid	1168	-	-	0.18	*n*-Tricosane	2300	4.97	2.35	2.12
3-Pinenone	1175	0.35	-	-	*n*-Tetracosane	2400	0.37	0.12	-
3-Pinanone	1186	0.71	-	-	Eicosanal		1.58	1.41	1.20
α-Terpineol	1199	0.75	-	0.17	*n*-Pentacosane		1.38	0.85	0.74
Myrtenol	1206	2.20	-	8.15	Tricosanal		0.29	0.17	-
trans-Carveol	1220	0.46	-	-	Docosanol acetate		1.56	1.04	2.04
cis-Carveol	1236	0.30	-	-	Tetracosanal		3.00	1.23	-
Geraniol	1261	0.13	-	23.23	*n*-Heptacosane		1.53	0.55	-
cis-Myrtanol	1273	0.46	-	-	Pentacosenol acetate		0.79	0.50	0.67
n-Pentadecane	1500	1.97	0.87	0.70	Hexacosanal		0.45	0.15	-
n-Cetane	1600	1.91	1.04	1.24	*n*-Nonacosane		0.61	0.23	-
n-Heptadecane	1700	1.64	0.94	1.00	Hexacosanol acetate		0.50	0.48	-
Myristic acid	1758	0.94	1.54	3.27					

RI: retention indices calculated against *n*-alkanes.

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