Nat. Volatiles & Essent. Oils, 2016; 3(4): 13-23

NVEO
Natural Volatiles & Essential Oils

RESEARCH ARTICLE

Chemical Composition of *Heracleum platytaenium* Boiss. (Apiaceae) essential oil from Turkey

Ceyda Sibel Kılıç[1*], Betül Demirci[2], Maksut Coşkun[1], Kemal Hüsnü Can Başer[3]

[1] Department of Pharmaceutical Botany, Faculty of Pharmacy, Ankara University, 06100 Ankara, TURKEY
[2] Department of Pharmacognosy, Faculty of Pharmacy, Anadolu University, 26470 Eskisehir, TURKEY
[3] Department of Pharmacognosy, Faculty of Pharmacy, Near East University, Nicosia, N. Cyprus, Mersin 10, TURKEY

*Corresponding author. Email: erdurak@pharmacy.ankara.edu.tr

Abstract

Heracleum platytaenium Boiss. is a monocarpic and strongly aromatic plant that is endemic for Turkey. Many studies on activities, constituents and composition of the essential oil of different parts of this species and other *Heracleum* species have been conducted. However, as far as we are concerned, the essential oil composition of the roots has not been investigated. In this study, we investigated the essential oil composition of the roots of *H. platytaenium* and identified *p*-cymene (33.9%), terpinolene (14.3%), γ-terpinene (7.1%), elemicine (3.1%) and myristicine (2.9%) as the major constituents.

Key words: *Heracleum platytaenium,* Apiaceae, essential oil, GC, GC-MS

Introduction

Heracleum L. belongs to the family Apiaceae and is represented by 23 taxa in Turkey and 7 of these species are endemics (Guner, 2012). The genus has a widespread distribution throughout Europe, therefore some of the species are considered to be invasive (Bahadori et al., 2016). Some species of the genus are being used in traditional medicine in our country and also throughout the world. *Heracleum* species are reported to be used as antipyretic, analgesic, diaphoretic, antiseptic, carminative and digestive agents, for the treatment of rheumatic disease, hypertension, epilepsy and diarrhea, lumbago, gastralgia and injuries from falls, contusions and strains (Akcin et al., 2013) and as wound healing (Tetik et al., 2013). One *Heracleum* species (*H.* candicans) is used as a source for xanthotoxin – a substance used in the composition of suntan lotions for its antileucodermal properties (Guleri et al., 2011) furanocoumarins and essential oil obtained from *H. crenatifolium* is reported to have anticonvulsant activity (Tosun et al., 2008). Some *Heracleum* species are reported to be used as flavoring, spices, carminative and antiseptic, digestive and analgesic in Iranian folk medicine (Sefidkon et al., 2002; Hajhashemi et al., 2009; Torbati et al., 2014; Amanpour et al., 2016); as a carminative herbal drug in Thai folk medicine (Kuljanabhagavad et al., 2010) and for inflammatory condition, as antiarthritic and nerve tonic in Indian folk medicine (Purushothaman and Ravi, 2013). *Heracleum platytaenium* is known with the names havlan, havlanotu, hometi, kekrer, romati, yabanlahanası (Kızılarslan and Özhatay, 2012) and yavşan otu (Bayrak Özbucak et al., 2007) in Turkish. In addition to its traditional usage as medicine, the species is also used for culinary purposes; e.g. the stems and stalks of the plant are consumed as pickles around İzmit (Kızılarslan and Özhatay, 2012); the stems of the plant are first pickled and then eaten as raw or as cooked with olive oil in the Black Sea region of Turkey (Bayrak Ozbucak et al., 2006) and leaves of the plant are coked as meal or eaten as fresh in salads around Nigde (Ozdemir and Alpınar, 2010-2011). Since this species (Koçak et Buruk et al., 2006) and different *Heracleum* species are also reported to have antiviral (Tkachenko, 2006), antibacterial and antifungal activities (Benli, et al., 2007; Ergene et al.,

2009; Kuljanabhagavad et al., 2010; Özçakmak, 2012; Jagannath et al., 2012; Miladinovic, et al., 2013), this species is tested against different strains of bacteria and fungi and the essential oil of the plant was determined to have inhibitory and toxic effect against a fungus called *Penicillium verrucosum* which was isolated from kashar cheese (Özçakmak, 2012), and against *Paenibacillus larvae* (Özkırım et al., 2012).

Though essential oils of different parts of various *Heracleum* species have been studied previously, studies of the composition of the roots are scarce. In this study, we isolated the essential oil of the roots and analyzed it by means of GC and GC-MS and reported the results.

Materials and Methods

Plant material

The plant was collected from the below mentioned locality and identified by Prof. Dr. Hayri Duman (Gazi University, Faculty of Science, Department of Biology) and the voucher specimen is kept in AEF (Herbarium of Ankara University Faculty of Pharmacy).

Collection locality*: Heracleum platytaenium*: A7: Trabzon: Maçka-Torul arası, Maçka çıkışında yol kenarları, 3/7/2006 (AEF: 23756)

Isolation of the essential oils

Air dried roots (50g) were subjected hydrodistillation for 3 h using a Clevenger apparatus. Essential oil, obtained with a yield of 4% was dried over anhydrous sodium sulfate and stored in a sealed vial at +4°C in the dark until analyzed and tested.

GC and GC/MS analyses

GC-MS analysis

The GC-MS analysis was carried out with an Agilent 5975 GC-MSD system. Innowax FSC column (60 m x 0.25 mm, 0.25 μm film thickness) was used with helium as carrier gas (0.8 ml/min). GC oven temperature was kept at 60°C for 10 min and programmed to 220°C at a rate of 4°C/min, and kept constant at 220°C for 10 min and then programmed to 240°C at a rate of 1°C/min. Split ratio was adjusted at 40:1. The injector temperature was set at 250°C. Mass spectra were recorded at 70 eV. Mass range was from *m/z* 35 to 450.

GC analysis

The GC analysis was carried out using an Agilent 6890N GC system. FID detector temperature was 300°C. To obtain the same elution order with GC-MS, simultaneous auto-injection was done on a duplicate of the same column applying the same operational conditions. Relative percentage amounts of the separated compounds were calculated from FID chromatograms.

Identification of the volatile compounds

Identification of the essential oil components were carried out by comparison of their relative retention times with those of authentic samples or by comparison of their relative retention index (RRI) to series of *n*-alkanes. Computer matching against commercial (Wiley GC/MS Library, Adams Library, MassFinder 3 Library), and in-house "Başer Library of Essential Oil Constituents" built up by genuine compounds and components of known oils, as well as MS literature data (Joulain and Koenig, 1998; ESO 2000, 1999) was used for the identification.

Results and Discussion

Analysis of the essential oil resulted in the characterization of 70 components, corresponding to the 89.4% of the total oil. The composition of the essential oil is given in Table 1 with major components in written in bold.

Table1. Composition of the Essential Oil of *Heracleum platytaenium* roots

RRI	Compounds	%
1032	α-Pinene	2.5
1035	α-Thujene	2.6
1076	Camphene	0.5
1093	Hexanal	0.2
1118	β-Pinene	0.3
1132	Sabinene	1.2
1159	δ-3-Carene	0.1
1174	Myrcene	1.2
1176	α-Phellandrene	tr
1188	α-Terpinene	0.2
1194	Heptanal	0.4
1203	Limonene	2.6
1218	β-Phellandrene	tr
1244	2-Pentyl furan	0.3
1246	(*Z*)-β-Ocimene	0.2
1255	**γ-Terpinene**	**7.1**
1266	(*E*)-β-Ocimene	0.3
1280	***p*-Cymene**	**33.9**
1290	**Terpinolene**	**14.3**
1296	Octanal	1.3
1483	Octyl acetate	0.1
1492	Cyclosativene	0.1
1497	α-Copaene	0.3
1548	(*E*)-2-Nonenal	0.2
1562	Octanol	0.3
1591	Bornyl acetate	0.2
1595	Isothymol methyl ether	tr
1596	α-Guaiene	0.2
1597	β-Copaene	0.3
1604	Thymol methyl ether (=*methyl thymol*)	0.3
1611	Terpinen-4-ol	0.2
1614	Carvacrol methyl ether (=*methyl carvacrol*)	1.1
1655	(*E*)-2-Decenal	0.7
1683	*trans*-Verbenol	tr
1704	γ-Muurolene	tr
1709	α–Terpinyl acetate	tr
1715	(*E,E*)-2,4-Nonadienal	tr

1726	Germacrene D	tr
1730	δ-Guaiene	0.4
1740	α-Muurolene	0.4
1758	(*E,E*)-α-Farnesene	0.1
1763	Naphthalene	0.2
1771	γ-Bisabolene	0.3
1773	δ-Cadinene	0.8
1779	(*E,Z*)-2,4-Decadienal	0.5
1827	(*E,E*)-2,4-Decadienal	0.8
1864	*p*-Cymen-8-ol	0.7
1868	(*E*)-Geranyl acetone	tr
1878	2,5-Dimethoxy-p-cymene	0.4
1900	*epi*-Cubebol	tr
1941	α-Calacorene	0.3
1957	Cubebol	0.4
2008	Caryophyllene oxide	0.3
2050	(*E*)-Nerolidol	0.4
2071	Humulene epoxide-II	0.5
2080	Cubenol	tr
2088	1-*epi*-Cubenol	tr
2144	Spathulenol	1.0
2187	T-Cadinol	0.6
2209	T-Muurolol	tr
2219	δ-Cadinol (=*α-muurolol*)	0.5
2239	Carvacrol	0.3
2245	**Elemicine**	**3.1**
2247	*trans*-α-Bergamotol	tr
2255	α-Cadinol	tr
2257	β-Eudesmol	tr
2296	Myristicine	**2.9**
2384	Hexadecanol	0.5
2822	Pentadecanoic acid	tr
2931	Hexadecanoic acid	0.8
	Total	89.4

RRI Relative retention indices calculated against *n*-alkanes; % calculated from FID data;tr Trace (< 0.1 %)

As it can be seen from the Table 1.; p-cymene (33.9%), terpinolene (14.3%), γ-terpinene (7.1%), elemicine (3.1%) and myristicine (2.9%) were identified as the major constituents of the essential oil of the roots of *H. platytaenium.* When we compare these results with the literature, we can see that myristicin was found to be present in two other species as the major component, however with a percentage much higher than the one we have in our study [(2.9%) vs. 95.15% for *H. anisactis,* and 96.87% for *H. transcaucasicum*,].

Table 2. Composition of the Essential Oil of roots of other *Heracleum* spp. found in the literature

Species	Used part	Compound	%	Ref.
H. anisactis	Roots	Myristicin	95.15	Torbati et.al. (2014)
H. candolleanum	Rhizomes	α-pinene	18.9	George et al. (2001)
		bornylene	18.6	
		octyl acetate	11.9	
H. hemsleyanum	Radix	(1S)-6-6,dimethyl-2-methylenebicyclo[3,1,1]heptane	12.60	Zhang et al. (2005)
		8-isopropenyl-1,5-dimethyl-cyclodeca-15-diene	10.42	
H. persicum	Roots	Viridiflorol	23.05	Mojab and Nickavar (2003).
H. sprengelianum	Rhizomes	1,8-cineole	23.10	Karuppusamy and Muthuraja (2011)
		β-pinene	21.84	
		β-phellandrene	15.19	
H. transcaucasicum	Roots	Myristicin	96.87	Torbati et.al., (2014)

When we searched the literature for the components of essential oils obtained from other parts of *Heracleum* spp., we have seen that myristicin was present in the aerial parts of *H. anisactis* and *H. transcaucasicum* species (2.9% vs. 93.54% and 70.12%, respectively) (Torbati et.al., 2013). Our other major compounds were found to be present in different *Heracleum* species are as follows:

***p*-cymene (33.9%)** was present in the essential oil of the fruits of *H. persicum* (37.3%), (Scheffer et al., 1984) and the stem of *H. rechingeri* (4.5%) (Habibi et al., 2010);
terpinolene (14.3%) was present in the fruits of *H. antasiaticum* (10.75%) (Ibadullaeva, 2000), in the leaves of *H. persicum* (9.86%) (Mojab et al., 2002), in the stems of *H. persicum* (11.3%) (Sefidkon et al., 2004), in the aerial parts of *H. thomsonii* (22.24%) (Guleria et al., 2011);
γ-Terpinene (7.1%) was present in the fruits of *H. persicum* (27.8%) (Scheffer et al., 1984), in the flowers of *H. persicum* (17.8%), (Sefidkon et al., 2002); in the stems of *H. persicum* (7.1%) (Sefidkon et al., 2004), in the stems of *H. rechingeri* (8.8%) (Habibi et al., 2010);
elemicine (23.1%) was not found to be present in the *Heracleum* species according to our literature search.

Though the major compounds that we have found in the essential oil of *H. platytaenium* roots may be present in different parts of some other *Heracleum* species (major components of the volatile oil isolated from different parts of various *Heracleum* species is given in Table. 3 for further information) , we can not conclude that these can be considered as chemotaxonomic markers for the genus. In order to make this assumption, essential oils of all *Heracleum* species should be analyzed and compared since the studies on the composition of the roots of *Heracleum* species are scarce in the literature. However, we can conclude that elemicine has been found to be present for the first time in a *Heracleum* species, though with no chemotaxonomic value.

ACKNOWLEDGEMENT

The authors would like to thank Prof. Dr. Hayri Duman (Gazi University, faculty of Science, Department of Biology) for the identification of the species.

REFERENCES

Akcin, A., Seyis, F., Aytas Akcin, T., Tanriverdi Cayci, Y., Coban, A.Y. (2013). Chemical composition and antimicrobial activity of the essential oil of endemic *Heracleum platytaenium* Boiss. from Turkey, J Essen. Oil Res., 16(2), pp 166-171. 2013.

Amanpour, A., Kelebek, H., Selli, S., Aroma components of Iranian dried *Heracleum persicum* fruit (golpar) using solvent-assisted flavor evaporation technique, Journal of Food and Nutrition Research, 55: 141-147, 2016.

Ashraf, M., Bhatty, M.K. (1978) Studies on the essential oils of Pakistan species of the family Umbellifeare. Part XVII. *Heracleum candicans* (Eng. Cowparsnip. var. morchar) seed oil, Pakistan Journal of Scientific and Industrial Research, 21(2), pp. 70-72.

Bahadori, M.B., Dinparast, L., Zengin, G. (2006). The genus *Heracleum*: A comprehensive review on its phytochemistry, pharmacology and ethnobotanical values as a useful herb, Comprehensive Reviews in Food Science and Food Safety, 15(6), pp. 1018-1039.

Baser, K.H.C., Kürkçüoğlu, M., Aytaç, Z. (1998). Composition of the essential oil of *Heracleum argaeum* Boiss. et bal., JEO J Essent. Oil Res., 10, pp. 561-562.

Başer, K.H.C., Kürkçüoğlu, M., Adıgüzel, N., Aytaç, Z., Joulain, D., Laurent, R. (2000). Composition of the essential oil of *Heracleum paphlagonicum* Czeczott, J Essent. Oil Res. 12(3), pp. 385-386.

Bayrak Ozbucak, T., Kutbay, H.G., Ergen Akcin, O. (2006). The contribution of wild edible plants to human nutrition in the black sea region of Turkey, Ethnobotanical Leaflets, 10, pp. 98-103.

Bayrak Özbucak, T., Ergen Akçin, Ö., Yalçın, S. (2007). Nutrition contents of some wild edible plants in Central Black Sea region of Turkey, Inernational Journal and Engineering Sciences, 1, pp. 11-13.

Benli, M., Güney, K., Bingöl, Ü., Geven, F., Yiğit, N. (2007). Antimicrobal activity of some endemic plant species from Turkey, African Journal of Biotechnology, 6(15), pp. 1774-1778.

Buruk, K., Sokmen, A., Aydin, F., Erturk, M. (2006). Antimocrobial activity of some endemic plants growing in the Eastern Black Sea region, Turkey, Fitoterapia, 77(5), pp. 388-391.

Davis, P.H. (ed.). (1972). *Flora of Turkey and the East Aegean Islands*, Volume 4, pp. 488-500.

Davis, P.H. (ed.) (1988). *Flora of Turkey and the East Aegean Islands*, Volume 10, pp. 144.

Davis, P.H. (ed.) (2000). *Flora of Turkey and the East Aegean Islands*, Volume 11, pp. 153-154.

Ergene, A., Tn, S., Mirici, S., Güler, P., Yildirim, S. (2009). Antimicrobial activity of *Heracleum antasiaticum*, Acta Horticulturae, 826, pp. 267-270.

ESO2000. (1999). *The Complete Database of Essential Oils*, Boelens Aroma Chemical Information Service, The Netherlands.

Firuzi, O., Asadollahi, M., Gholai, M., Javidnia, K. (2010). Composition and biological activities of essential oils from four *Heracleum* species, Food Chemistry, 122, pp. 117-122.

George, V., Chacko, S., Sethuraman, M.G., (2001). Chemical composition of the essential oil from the rhizomes of *Heracleum candolleanum*, J Essent. Oil Res., 13, pp. 80-81.

Guleria, S., Saini, R., Jaitak, V., Kaul, V.K., Lal, B., Rahi, P., Gulati, A., Singh, B. (2011). Composition and antimicrobial activity of the essential oil of *Heracleum thomsonii* Clarke from the cold dessert of the western Himalayas, Natural product Research, 25(13), pp. 1250-1260.

Habibi, Z., Eshaghi, R., Mohammadi, M., Yousefi, M. (2010). Chemical composition and antibacterial activity of essential oil of *Heracleum rechingeri* Manden from Iran, Nat Prod Res, 24(11), pp. 1013-1017.

Hajhashemi, V., Sajjadi, S.E., Heshmati, M. (2009). Anti-inflammatory and analgesic properties of *Heracleum persicum* essential oil and hydroalcoholic extract in animal models, Journal of Ethnopharmacology, 124, pp. 475-480.

Ibadullaeva, S.D. (2000). Essential oil of *Heracleum antasiaticum*, Chemistry of Natural Compound, 36(2), pp. 218.

İscan, G., Ozek, T., Ozek, G., Duran, A., Baser, K.H.C. (2004). Essential oils of three species of *Heracleum* anticandidal activity, Chemistry of Natural Compounds, 40(6), pp. 544-547.

İşcan, G., Demirci, F., Kürkçüoğlu, M., Kıvanç, M., Başer, K.H.C. (2003). The bioactive essential oil of *Heracleum sphondylium* L. subsp. *ternatum* (Velen.) Brummitt, Z. Naturforssch. 58(3-4), pp. 195-200.

Jagannath, N., Ramakrishnaiah, H., Krishna, V., Gowda, P.J., (2012). Chemical composition and antimicrobial activity of essential oil of *Heracleum rigens* , Nat prod. Commun., 7(7), pp. 943-946.

Joulain, D., Koenig, W.A. (1998). *The Atlas of Spectra Data of Sesquiterpene Hydrocarbons*, EB-Verlag, Hamburg.

Karimi, A.G., Ito, M. (2012). Sedative effect of vapor inhalation of essential oil from *Heracleum afghanicum* Kitamura seeds, The Journal of Essential Oil Research, 24(6), pp. 571-577.

Karuppusamy, S., Muthuraja, G. (2011). Chemical Composition and Antioxidant Activity of Heracleum sprengelianum (Wight and Arnott) Essential Oils Growing Wild in Peninsular India, Iranian Journal of Pharmaceutical Research, 10 (4), pp. 769-775.

Kızılarslan, Ç., Özhatay, N. (2012). An ethnobotanical study of the useful and edible plants of İzmit, Marmara Pharmaceutical Journal, 16, pp. 134-140.

Koenig, D., Joulain, D., Hochmuth, D.H. (2004). *Terpenoids and Related Constituents of Essential Oils*.

Kuljanabhagavad, T., Sriubolmas, N., Ruangrungs. (2010). Chemical composition and antimicrobial activity of the essential oil from *Heracleum siamicum*, J Health Res, 24(2), pp. 55-60.

Kürkçüoğlu, M., Özek, T., Baser, K.H.C., Malyer, H. (1995). Composition of the essential oil of *Heracleum platytaenium* Boiss. from Turkey, J Essent. Oil Res. 7, pp. 69-70.

Maimone, M., Manukyan, A., Tranchida, P.Q., Steinhaus, M., Odour-active compounds in the traditional Armenian soup seasoning herb *Heracleum transcaucasicum*, Eur Food Res Technol, doi: 10.1007/s00217-016-2815-9, 2016.

MassFinder 3. Hochmuth DH (ed). (2004). *Convenient and Rapid Analysis of GCMS*, incorporating W.A. Hamburg, Germany.

McLafferty, F.W., Stauffer, D B. (1989). *The Wiley/NBS Registry of Mass Spectral Data*, J Wiley and Sons: New York.

Miladinovic, D.L., Ilic, B.S., Mihajilov-Krstev, T.M., Nikolic, D.M., Cvetkovic, O.G., Markovic, M.S., Miladinovic, L.C. (2013). Antibacterial activity of the essential oil of *Heracleum sibiricum*, Nat Prod Commun. 8(9), pp. 1309-1311.

Mojab, F., Rustaiyan, A., Jasbi, A.R. (2002). Essential oils of *Heracleum persicum* Desf. ex. Fischer leaves, DARU, 10(1), pp. 6-8.

Mojab, F., Nickavar, B. (2003). Composition of the essential oil of the root of *Heracleum persicum* from Iran, Iranian Journal of Pharmaceutical Sciences, 2(4), pp. 245-247.

Ozdemir, E., Alpınar, K. (2010-2011). The wild edible plants of western Nigde Aladaglar Mountains (Central Turkey), Journal of Pharmacy of İstanbul University, 41, pp. 66-74.

Ozek, T., Demirci, B., Baser, K.H.C. (2002). Comparative study of the essential oils of *Heracleum sphondylium* ssp. *ternatum* obtained by micro-and hydro-distillation methods, Chemistry of Natural Compounds, 38(1), pp. 48-50.

Özçakmak, S. (2012). The effects of *Heracleum platytaenium* Boiss essential oil on the growth of ochratoxigenix *Penicillium verrucosum* (D-99756) isolated from Kashar Cheese, Journal of Applied Botany and Food Quality, 85, pp. 97-99.

Özek, T., Özek, G., Başer, K.H.C., Duran, A. (2005). Comparison of the essential oils of three endemic Turkish *Heracleum* species obtained by different isolation techniques, J Essent. Oil Res., 17, pp. 605-610.

Özkırım, A., Keskin, N., Kürkçüoğlu, M., Başer, K.H.C. (2012). Evaluation of some essential oils as alternative antibiotics against American foulbrood agent *Paenibacillus larvae* on honey bees *Apis mellifera* L., The Journal of Essential Oil Research, 24(5), pp. 465-470.

Papageorgiou, V.P., Ochir, G., Moti, O., Argyriadou, N., Dunkel, H. (1985). Composition of the essential oil from *heracleum dissectum*, Journal of Natural Products, 48(5), pp. 851-853.

Purushothaman, D.N., Ravi, S. (2013). GC-MS analysis of essential oil obtained from *Heracleum candolleanum* (Wight et Arn), Journal of Pharmacy Research, 6, pp. 155-157.

Scheffer, J.J.C., Hiltunen, R., Aynehchi, Y., von Schantz, M., Baerheim Svendsen, A. (1984). Composition of essential oil of *Heracleum persicum* fruits, Planta Medica, 50(1), pp. 56-60.

Sefidkon, F., Dabiri, M., Mohammad, N. (2002). Analysis of the oil of *Heracleum persicum* L. (Leaves and flowers), J Essent. Oil Res. 14, pp. 295-297.

Sefidkon, F., Dabiri, M., Mohammad, N. (2004). Analysis of the oil of *Heracleum persicum* L. (seeds and stems), J Essent. Oil Res. 16, pp. 296-298.

St-Gelais, A., Collin, G., Pichette, A. (2017). Aromas from Quebec. V. Essential oils from the fruits and stems of *Heracleum maximum* Bartram and their unsaturated aliphatic acetates, J Essent. Oil Res., 29(2), pp. 125-136.

Tetik, F., Civelek, S., Cakilcioglu, U. (2013). Traditional uses of some medicinal plants in Malatya (Turkey), Journal of Ethnopharmacology, 146(1), pp. 331-346.

Tkachenko, K.G. (1993). The essential oil of the flowers of *Heracleum* L. species, J Essent. Oil Res 5, pp. 687-689.

Tkachenko, K.G. (1994). Composition of the essential oils of *Heracleum stevenii* Manden, J Essent. Oil Res 6, pp. 535-537.

Tkachenko, K.G., Zenkevich, I.G. (1993). Constituents of essential oils from fruit of some *Heracleum antiasiaticum* Manden. Grown in Russia, J Essent. Oil Res 5, pp. 227-228.

Tkachenko, K.G. (2006). Antiviral activity of the essential oils of some *Heracleum* L. species, Journal of Herbs, Spices and Medicinal Plants, 3, pp. 1-12.

Torbati, M., Nazemiyehi H., Lotfipour, F., Asnaashari, S., Nemati, M., Fathiazad, F. (2013). Composition and antibacterial activity of *Heracleum transcaucasicum* and *Heracleum anisactis* aerial parts essential oil, Advanced Pharmaceutical Bulletin, 3(2), pp. 415-418.

Torbati, M., Nazemiyeh, H., Lotfipour,F., Nemati, M., Asnaashari, S., Fathiazad, F. (2014). Chemical composition and in vitro antioxidant and antibacterial activity of *Heracleum transcaucasicum* and *Heracleum anisactis* roots essential oil, Bioimpacts, 4(2), pp. 69-74.

Tosun, F., Akyüz Kızılay, Ç., Erol, K., Kılıç, F.S., Kürkçüoğlu, M., Başer, K.H.C. (2008). Anticonvulsant activity of furanocoumarins and the essential oil obtained from the fruits of *Heracleum crenatifolium*, Food Chemistry, 107, pp. 990-993.

Zhang, C., Zhang, B., Yang, X. (2005). GC-MS analysis of essential oil from the radix of *Heracleum hemsleyanum* Diels., Zongtao Yanjiu Yu Xinxi, 7(12), pp. 9-12.

Table 3. Composition of volatile oils obtained from different parts of different *Heracleum* species

Species name	**Organ**	**Major compounds (%)**		**Reference**
H. afghanicum	Fruits	Hexyl butyrate Octyl acetate	34.3 21.1	Karimi and Ito, 2012
H. anisactis	Aerial	Myristicin	93.5	Torbati et.al., 2013

H. anisactis	Fruits	Octyl acetate	48.1	Radjabian et al., 2014
H. anisactis	**Roots**	Myristicin	95.2	Torbati et.al., 2014
H. antiasiaticum	Flower	Octyl-4-methylvalerate Octyl acetate	86.0 5.9	Tkachenko and Zenkevich 1993
H. antasiaticum	Fruits	Ethlycaprylate Octyl acetate terpinolene	29.8 17.4 10.8	Ibadullaeva, 2000
H. argaeum	Fruits	Hexyl butyrate	39.1	Başer et al., 1998
H. candicans	Fruits	Bornyl acetate Amyl acetate Octyl acetate	21.5 19.6 6.0	Ashraf and Bhatty, 1978
H. candolleanum	**Rhizomes**	α-pinene bornylene octyl acetate	18.9 18.6 11.9	George et al., 2001
H. candolleanum	Fruits	Methyl cinnamate n-hexyl hexanoate octyl alcohol	22.4 21.7 11.8	Prushothaman and Ravi, 2013
H. crenatifolium	Fruits	Octyl acetate	93.7	İscan et al., 2004
H. crenatifolium	Fruits	Octyl acetate	93.7	Özek et al., 2005
H. crenatifolium	Fruits	Octyl acetate	88.4	Tosun et al., 2008
H. dissectum	Aerial	α-pinene myrcene kessan humulene	22.2 10.9 8.8 8.3	Papageorgiou et al., 1985
H. dulce	Fruits	Octyl acetate Octyl butyrate	40.0 26.0 20.0	Tkachenko, 1993
H. gorganicum	Fruits	Hexyl butanoate Octyl acetate	33.3 18.4	Radjabian et al., 2014
H. grandiflorum	Fruits	Octyl acetate Octyl hexanoate Hexyl butyrate	39.0 13.0 5.7	Tkachenko, 1993
H. hemsleyanum	**Radix**	(1*S*)-6-6,dimethyl-2-methylenebicyclo[3,1,1]heptane 8-isopropenyl-1,5-dimethyl-cyclodeca-15-diene	12.6 10.4	Zhang et al., 2005
H. leskovii	Fruits	Octyl acetate Octyl butyrate Octyl octanoate	65.0 9.3 6.1	Tkachenko, 1993
H. nanum	Fruits	Octyl acetate Octyl butyrate Hexyl butyrate	41.0 20.0 7.4	Tkachenko, 1993
H. mantegazzianum	Fruits	Octyl butyrate Octyl acetate	32.0 18.0	Tkachenko, 1993
H. maximum	Fruit	Octyl acetate Octyl butyrate	65.6 7.9	St-Gelais et al., 2016
	Stem	Limonene sabinene	45.2 9.5	
H. moellendorfii	Fruits	Octyl acetate Octyl butyrate Octyl octanoate octanal	51.0 13.4 10.2 6.0	Tkachenko, 1993
H. paphlagonicum	Fruits	Octyl acetate Hexyl butyrate Octyl hexanoate	31.5 17.0 10.2	Başer et al., 2000
H. pastinacifolium	Aerial	Myristicin (*Z*)-trans-α-bergamotene	53.6 10.6	Firuzi et al., 2010
H. pastinacifolium	Fruits	Octyl acetate	59.5	Radjabian et al., 2014
H. persicum	Fruit	*p*-cymene γ-terpinene	37.3 27.8	Scheffer et al., 1984

		α-pinene β-pinene	13.8 5.8	
H. persicum	Leaves	B-springene Spathulenol α-farnesene zingiberene α-bergamotene α- caryophyllene trans-anethole cis-anethole stragole terpinolene	37.7 23.8 22.0 21.5 20.3 19.9 15.6 14.4 12.7 9.9	Mojab et al., 2002
H. persicum	Leaves (at flowering)	(*E*)-anethole 1-(4-methoxy phenyl)-2-propanone anisaldehyde	47.5 18.1 8.9	Sefidkon et al., 2002
	Flowers	(*E*)-anethole γ-terpinene myrcene	38.6 17.8 13.5	
H. persicum	**Roots**	Viridiflorol	23.1	Mojab and Nickavar, 2003.
H. persicum	Stem	(*E*)-anethole Terpinolene γ-terpinene	60.2 11.3 7.1	Sefidkon et al., 2004
	Seed	Hexyl butyrate Octyl acetate Hexyl isobutyrate	35.5 27 3.2	Sefidkon et al., 2004
H. persicum	Fruits	Hexyl butyrate Octyl acetate	56.5 16.5	Hajhashemi et al., 2009
H. persicum	Aerial	(*E*)-anethole Octyl-2-methyl butanoate Hexyl butanoate	25.0 14.2 10.0	Firuzi et al., 2010
H. persicum	Fruits	Hexyl butanoate Octyl acetate	17.7 20.5	Radjabian et al., 2014
H. persicum	Fruits	Hexyl butyrate Octyl acetate	65.6 18.2	Amanpour et al., 2016
H. platytaenium	Fruits	Octyl acetate Octyl butyrate	72.3-76.7 11.3-16.7	Kürkçüoğlu et al., 1995
H. platytaenium	Fruits	Carvacrol Thymol Octyl octanoate Octyl hexanoate Decanol	29.9 29.4 26.9 24.4 23.6	Akcin et al., 2013
H. platytaenium	Fruits	Octyl acetate	87.6	İscan et al., 2004
H. platytaenium	Fruits	Octyl acetate	87.6	Özek et al., 2005
H. rawianum	Fruits	Octyl acetate	75.4	Radjabian et al., 2014
H. rechingeri	Aerial	Hexyl butanoate Octyl butanoate	29.7 10.1	Firuzi et al., 2010
H. rechingeri	Flower	Elemicin Octyl acetate (*E*)-caryophyllene (*E*)-β-ocimene	39.5 25.1 10.0 5.2	Habibi et al., 2010
	Fruit	Octyl acetate	95.3	
	Stem	Elemicin Octyl acetate γ-terpinene (*E*)-caryophyllene *p*-cymene	37.7 26.5 8.8 6.6 4.5	
H. rechingeri	Fruits	Hexyl butanoate Octyl acetate	38.4 13.9	Radjabian et al., 2014
H. rigens	Fruits	Bornyl acetate α-pinene	51.2 22.6	Jagannath et al., 2012

		limonene	9.6	
H. siamicum	Fruits	n-octyl acetate o-cymene limonene δ-2-carene	65.3 10.4 7.5 6.9	Kuljanabhagavad et al., 2010
H. sibiricum	Aerial	Octyl butanoate Hexyl butanoate 1-octanol Octyl hexanoate	36.8 16.1 13.6 8.1	Miladinovic et al., 2013
H. sphondylium	Fruits	Octyl butyrate Octyl acetate	37.7 31.6	İscan et al., 2004
H. sphondylium ssp. ternatum	Fruits	Octanol Octyl butyrate Octyl acetate	39.2 27.4 10.6	Ozek et al., 2002
H. sphondylium ssp. ternatum	Seeds	1-octanol Octyl butyrate	50.3 24.6	İşcan et al., 2003
H. sphondylium ssp. ternatum	Fruits	Octyl butyrate Octyl acetate	37.7 31.6	Özek et al., 2005
H. sphondylium ssp. ternatum	Fruits	Octyl acetate Octyl butyrate	54.9-60.2 10.1.-13.4	Maggi et al., 2014
H. sprengelianum	Leaves	1,8-cineole β-pinene β-phellandrene	21.2 16.2 11.4	Karuppusamy and Muthuraja, 2011
	Seeds	β-pinene 1,8-cineole β-phellandrene	22.3 20.3 12.4	
	Rhizomes	1,8-cineole β-pinene β-phellandrene	23.1 21.9 15.2	
H. stevenii	Buds	Octyl acetate Octyl hexanoate	49.0 8.2	Tkachenko, 1994
	Flowers	Octyl acetate Myrcene	73.0 5.1	
	Stems	Octyl acetate Octyl hexanoate Octyl octanoate	28.0 22.0 10.4	
	Leaves	Octyl acetate Octyl octanoate Octyl 4-methylvalerate	35.0 15.0 12.0	
	Roots	Octyl acetate limonene Octyl octanoate Octyl hexanoate	35.0 20.0 18.0 12.0	
H. transcaucasicum	Aerial	Elemicin	41.1	Firuzi et al., 2010
H. transcaucasicum	Aerial	Myristicin *n*-octanol	70.1 14.3	Torbati et.al., 2013
H. transcaucasicum	**Roots**	Myristicin	96.9	Torbati et.al., 2014
H. thomsonii	Aerial	Neryl acetate Terpinolene limonene	36.2 22.2 4.3	Guleria et al., 2011