Revista CENIC. Ciencias Químicas
ISSN: 1015-8553
editorial.cenic@cnic.edu.cu
Centro Nacional de Investigaciones Científicas
Cuba

Solis-Quispe, Leoncio; Solis-Quispe, Jorge A.; Aragon-Alencastre, Luz J.; Fernández, Miguel D.; Hernández, Ivones; Rodeiro, Idania; Pino, Jorge A.
Composición química y actividad antioxidante de aceites esenciales de Tanacetum vulgare y Mentha x piperita L. var. vulgaris cultivados en Cusco, Perú
Revista CENIC. Ciencias Químicas, vol. 48, núm. 1, 2017, pp. 41-47
Centro Nacional de Investigaciones Científicas
La Habana, Cuba

Disponible en: http://www.redalyc.org/articulo.oa?id=181654080007

Cómo citar el artículo
Número completo
Más información del artículo
Página de la revista en redalyc.org

Sistema de Información Científica
Red de Revistas Científicas de América Latina, el Caribe, España y Portugal
Proyecto académico sin fines de lucro, desarrollado bajo la iniciativa de acceso abierto

Composición química y actividad antioxidante de aceites esenciales de *Tanacetum vulgare* y *Mentha* x *piperita* L. var. *vulgaris* cultivados en Cusco, Perú

Leoncio Solis-Quispe, Jorge A. Solis-Quispe, Luz J. Aragon-Alencastre, Miguel D. Fernández,* Ivones Hernández,* Idania Rodeiro,* and Jorge A. Pino**

Universidad Nacional de San Antonio Abad del Cusco, Peru; *Centro de Bioproductos Marinos, Havana, Cuba; **Food Industry Research Institute, Carretera a Guatao km 3 ½, Havana 19200, Cuba. Email: jpino@iiia.edu.cu

Recibido: 05 de abril de 2017. Aceptado: 06 de julio de 2017.

Palabras clave: *Tanacetum vulgare*, *Mentha* x *piperita* var. *vulgaris*, aceites esenciales, composición, actividad antioxidante.
Key words: *Tanacetum vulgare*, *Mentha* x *piperita* var. *vulgaris*, essential oils, composition, antioxidant activity.

RESUMEN. Se estudió la composición química y actividad antioxidante de los aceites esenciales de las hojas de *Tanacetum vulgare* L. (comúnmente llamado tansi) y *Mentha* x *piperita* L. var. *vulgaris* (comúnmente llamado menta) cultivados en Cusco (Perú). Tres muestras de plantas de cada especie, recién cortadas, se extrajeron mediante hidrodestilación durante 3 h con un aparato Clevenger. Los análisis de los aceites esenciales se hicieron por cromatografía de gases con detectores de llama de hidrógeno y selectivo de masas. Se identificaron cincuenta y setenta compuestos en los aceites esenciales de *T. vulgare* y *M. x piperita* var. *vulgare*, respectivamente. En el aceite esencial de *T. vulgare*, los monoterpenos oxigenados fueron la clase más representada de compuestos volátiles (92,6 %), con *trans*-tuyona como mayoritario. Esta composición química sugiere que la planta tansi analizada pertenece al quimotipo *trans*-tuyona más común. En el aceite esencial de *M.* x *piperita*, los monoterpenos oxigenados (76,7 %) fueron la clase mayoritaria; entre ellos el mentol (35,4 %), acetato de mentilo (19,6 %) y mentona (7,1 %). La capacidad de secuestrar radicales fue evaluada en los aceites esenciales mediante el método del 1,1-difenil-2-picril-hidrazilo (DPPH). Ambos aceites esenciales fueron capaces de reducir los radicales DPPH y esta actividad fue dosis-dependiente. Sin embargo, *Mentha* x *piperita* var. *vulgare* tiene mayor actividad antioxidante que el aceite esencial de *T.* v*ulgare*.

ABSTRACT. The chemical composition and antioxidant activity of essential oils from leaves of *Tanacetum vulgare* L. (commonly named tansy) and *Mentha* x *piperita* L. var. *vulgaris* (commonly named peppermint) grown in Cuzco (Peru) was studied. In each species, three samples of fresh chopped plants were extracted using hydrodistillation for 3 h in a Clevenger-type apparatus. Analyses of the essential oils were performed by gas chromatography with a flame ionization detector and mass selective detector. Fifty and seventy compounds were identified in the essential oils from *T. vulgare* and *M. x piperita* var. *vulgare*, respectively. In *T. vulgare* essential oil, oxygenated monoterpenes were the most represented class of volatiles (92.6 %), including *trans*-thujone as the major compound. This chemical composition suggests that the analyzed tansy plant belong to the most common *trans*-thujone chemotype. In *M.* x *piperita*, oxygenated monoterpenes (76.7 %) were the major class of volatiles; among them menthol (35.4 %), menthyl acetate (19.6 %), and menthone (7.1 %) were the main compounds. The radical scavenging capacity was evaluated by measuring the scavenging of the essential oils on the 1,1-diphenyl-2-picryl-hydrazyl (DPPH). Both essential oils were able to reduce DPPH radicals and this activity was dose-dependent. However, *Mentha* x *piperita* var. *vulgare* has higher antioxidant activity than *T. vulgare* essential oil.

INTRODUCTION

Tanacetum vulgare L. (Asteraceae), known as "tansy" in Europe and "Palma real" in Peru, is an aromatic plant widely used in folk medicine as a vermifuge and anti-inflammatory.[1,2] Also, the aerial parts of this plant are popularly used to treat migraine, neuralgia, and rheumatism, and as an anthelmintic and insect repellent.[3] Tansy extract has been reported to exhibit antitumor,[4] anti-inflammatory,[5] antioxidant,[6] and antimicrobial activity.[7] Papers on the composition of the oils of this species published up to 1996 have been reviewed.[8] Twenty-three chemotypes of the oils of tansy plants have been determined according to the most dominant constituent in the essential oils.[8] The most

common, a β-thujone chemotype was identified in nine countries: Argentina, Belgium, Canada, Holland, Poland, Hungary, Finland, India and Italy, while an α-thujone chemotype occurred in three countries: France, Germany and Italy. Camphor type oils were collected in plants from seven countries (Belgium, Germany, Holland, Hungary, Finland, Kazakhstan and USA) and of *trans*-chrysanthenyl acetate chemotype – in five ones (Belgium, Finland, Holland, Hungary and Italy). The 1,8-cineole and artemisia ketone chemotypes were present in Holland, Hungary and Finland. Other 16 chemotypes in which the dominant constituent is one of the following α-pinene, sabinene, γ-terpinene, thujyl alcohol, thujyl acetate, umbellulone, chrysanthenone, chrysanthenone oxide, isopinocamphone, borneol, piperitone, *trans*-dihydrocarvone, lyratol, lyratyl acetate, davanone or germacrene D occurred in few countries.[8] Papers on the composition of tansy oils published later,[9-13] only found one new chemotype in which dominant components were β-thujone-*trans*-chrysanthenyl acetate.[14,15]

The well-known and widely used peppermint (*Mentha* x *piperita* L.) (Lamiaceae) is a cultivated natural hybrid of *Mentha aquatica* L. (water mint) and *Mentha spicata* L. (spearmint). Although is native to the Mediterranean region, it is cultivated all over the world for its fragrant oil. Peppermint essential oil is used in flavor, fragrance, medicinal, and pharmaceutical applications.[16-19] More than 300 constituents have been identified in the essential oil, where the major constituents are menthol (35-60 %), menthone (2-44 %), menthyl acetate (0.7-23 %), 1,8-cineole (1-13 %), menthofuran (0.3-14 %), isomenthone (2-5 %), neomenthol (3-4 %) and limonene (0.1-6 %).[20,21]

Despite the medicinal potential of plants in Peru being considerable, knowledge of this area and studies on the biological activities of these plants remained scarce. Furthermore, as far as our literature survey could as certain, antioxidant activities of the Peruvian aromatic plants *Tanacetum vulgare* L. and *Mentha* x *piperita* L. var. *vulgaris* have not previously been published, although, there are many reports concerning essential oils from these species in other countries. Moreover, knowing that the chemical composition and activity of essential oils from aromatic plants depends on several factors such as the geographical origin, the aims of this study were (i) to determine the composition of the essential oils isolated from the leaves of *Tanacetum vulgare* L. and *Mentha* x *piperita* L. var. *vulgaris* grown wild at high height above sea level and (ii) to assess the antioxidant activities of these essential oils.

MATERIALS AND METHODS

Plant material and isolation of essential oil

Leaves of *T. vulgare* and *Mentha* x *piperita* var. *vulgaris* were collected in summer (February 2015) in the Cuzco region, in southeast Peru (3,618 m height above sea level). The species were identified, and the voucher specimens (accession numbers 24273 CUZ and 24274B CUZ, for *T. vulgare* and *M.* x *piperita* var. *vulgaris*, respectively) were deposited at the herbarium of the National University of San Antonio Abad del Cusco. Three samples of fresh chopped plants (ca. 200 g) were extracted using hydrodistillation for 3 h in a Clevenger-type apparatus.

GC-FID and GC-MS

Analyses of the essential oils were performed by gas chromatography with a flame ionization detector (GC-FID) on a Konik 4000A (Konik, Barcelona) equipped with a 30 m x 0.25 mm i.d. x 0.25 mm DB-Wax (Agilent Technologies, Santa Clara, CA, USA) or 30 m x 0.25 mm i.d. x 0.25 mm DB-5MS fused-silica capillary columns (J & W Scientific, Folsom, CA, USA). The analyses were conducted under the following conditions for both columns: oven temperature program, 60 ºC (2 min), 60-220 ºC (4 ºC/min) and 220 ºC (5 min); carrier gas Helium flow rate 1 mL/min; injector and detector temperatures 250 ºC, injection volume 0.2 µL and split ratio 20:1.

Essential oils were also analyzed by gas chromatography-mass spectrometry (GC–MS) using a Hewlett Packard 6890, fitted with the same columns interfaced with an Hewlett Packard mass-selective detector 5973 (Agilent Technologies, Palo Alto, CA, USA). GC parameters were similar to GC-FID and interface temperature: 250 ºC; MS source temperature: 230 ºC; MS quadrupole temperature: 150 ºC; ionization energy: 70 eV; mass range: 35-400 *m/z*.

The different components were identified using their retention indices and mass spectra. Retention indices, calculated using linear interpolation relative to retention times of C_8-C_{24} of *n*-alkanes, were compared with those standards and data from the literature.[22] Mass spectra were compared with corresponding reference standard data reported in the literature[22] and mass spectra from NIST 05, Wiley 6, NBS 75 k, and in-house Flavorlib libraries. Moreover, the retention indices of authentic compounds and marker constituents of known essential oils were also used to authenticate the constituent's identification.

The quantification of compounds was performed using relative percentage abundance and normalization method with correction response factors based on grouping the essential oil components by their functional groups.[23] Percentage data are the mean values of three injections per sample.

Assay of 2,2-diphenyl-2-picrylhydrazyl (DPPH•) scavenging activity

The antioxidant capacity of the essential oils was measured determining by DPPH• scavenging ability according to the method previously described[24] with minor modifications. In the test tubes, 1 500 µL of DPPH (0.075 mg/mL) in ethanol was mixed with 750 µL of five concentrations of the oil sample to evaluate in a range between 100-5 000 µg/mL. A control sample (absolute ethanol) and a reference sample (750 µL absolute ethanol plus 1 500 µg/mL of DPPH solution) were also used. The decrease in the absorbance (Abs) at 515 nm was determined until the reaction plateau step was reached. Triplicate measurements were carried out. Then, the IC_{50} values were determined by using

GraphPad Prism program (ver. 5) and it was defined as the total antioxidant compound necessary to decrease the initial DPPH radical concentration by 50 %. Their scavenging effect of the product was calculated based on the percentage of DPPH scavenged using the followed formula:
% DPPH inhibition = (control Abs – sample Abs)/(control Abs) x 100, where control Abs represent: ethanol Abs + DPPH and sample Abs: sample Abs + DPPH

RESULTS AND DISCUSSION

The extraction yield of *T. vulgare* and *M.* x *piperita* var. *vulgaris* essential oils were 0.4 % and 0.8 % (v/m), respectively.

Quantitative data expressed as average percentage values and standard deviations, of single components in the essential oils are listed in Table 1. Fifty components were identified in the essential oil from *T. vulgare* leaves. As can be seen, oxygenated monoterpenes were the most represented class of volatile with 92.6 %. Amongst their derivative, *trans*-thujone or β-thujone was the major compound. This chemical composition suggests that the analyzed tansy plant belong to the most common *trans*-thujone chemotype. This monoterpenic ketone is a bioactive compound with medicinal properties, but at high concentrations it exhibits toxicity.[25-28]

Seventy constituents were identified in the essential oil from *Mentha* x *piperita* leaves (Table 1). The essential oil contains basically oxygenated monoterpenes (67.7 %) being the major constituents menthol, menthyl acetate, and menthone. Menthofurane was not detected in the present study, but developmental and environmental factors are known to influence greatly the yield and composition of peppermint essential oils.[18] The composition found in the present study is according to the general criteria that high quality peppermint essential oils have higher quantities of menthol and menthone, and lower amounts of pulegone and menthofuran.[18]

DPPH is a free radical compound which is usually used as in vitro test to evaluate the ability of the several compounds to free radical scavenging. At this work, the antioxidant effect of the essential oils from *T. vulgare* and *M. x piperita* var. *vulgaris* was tested by using this assay.

Tansy antioxidants have been studied rather scarcely and mainly as extracts.[6,29,30] The essential oils from *T. vulgare* had the capacity to scavenge the DPPH radical, showing a maximal effect of 58.26 ± 0.9 % at the concentration of the 4 500 µg/mL. On the other way, usually DPPH scavenging is presented by the IC_{50} value, concentration of antioxidant needed to scavenged 50 % of the DPPH radical present into the test solution. For this tansy essential oil the IC_{50} value was 3 525 ± 123 µg/mL. But, as can be seen, this effect was very lower than the observed for *M.* x *piperita* var. *vulgaris* essential oil and the ascorbic acid, the positive control used in the assay, which showed a percentage of inhibition of 89.0 ± 4.3 % at 100 µg/mL (Table 2).

Table 2. Scavenging effect of *Tanacetum vulgare* and *Mentha* x *piperita* var. *vulgare* essential oils on DPPH radical.

Product	Concentration range (µg/mL)	IC_{50} (µg/mL)	Maximum inhibitory effect (%)
Tanacetum vulgare	100-5 000	3 525 ± 123	58.26 ± 0.9
Mentha piperita var. *vulgare*	10-1 500	136.4 ± 35	69.1 ± 3.4
Ascorbic acid	1-100	51.2 ± 2.9	89.0 ± 4.3

Antioxidant effectiveness expressed as IC_{50}, the total antioxidant capacity necessary to decrease the initial DPPH radical concentration by 50 %. Values represent average of three determinations with ± standard deviation. Ascorbic acid was used as standard.

In addition, *M.* x *piperita* var. *vulgaris* essential oil exhibited concentration dependent increase to DPPH radical scavenging effect, the maximum effect observed was 69.1 ± 3.4 % at 500 µg/mL. On the other hand, the IC_{50} value for this tested product was 136.4 ± 35 µg/mL. Studies performed for evaluating the free radical scavenging capacity of essential oils from other species of *Mentha* showed the antioxidant properties of this species, where one variety of *M.* x *piperita* var. *vulgaris* expressed IC_{50} values of 2.53 µg/mL.[31] At this study the most powerful scavenging compounds associated to antioxidant activity of *M.* x *piperita* were monoterpene ketones, particularly the menthone and *iso*-menthone. Comparison of the DPPH scavenging property from oils present in the *M.* x *piperita* var. *vulgaris* evaluated by us and previously reported[31] for *M.* x *piperita* and the found for ascorbic acid (51.2 ± 2.9 µg/mL at 100 µg/mL) in our study, the essential oil evaluated at the present study exhibited weakest antioxidant effects than the previously report for the specie and the standard antioxidant.

CONCLUSIONS

The essential oil from *Tanacetum vulgare* has lower antioxidant activity than *Mentha* x *piperita* var. *vulgaris*, but both have potential use in food industry, cosmetic or pharmaceutical industries.

BIBLIOGRAPHIC REFERENCES

1. Lahlou S, Tangi KC, Lyoussi B, Morel N. Vascular effects of *Tanacetum vulgare* L. leaf extract: In vitro pharmacological study. J Ethnopharm. 2008; 120: 98-102.

2. Rosselli S, Bruno M, Raimondo FM, Spadaro V, Varol M, Koparal AT, Maggio A. Cytotoxic effect of eudesmanolides isolated from flowers of *Tanacetum vulgare* ssp. *Siculum*. Molecules 2012; 17: 8186-95.

3. Onozato T, Nakamura CV, Garcia Cortez DA, Dias Filho BP, Ueda-Nakamura T. *Tanacetum vulgare:* antiherpes virus activity of crude extract and the purified compound parthenolide. Phytotherapy Res. 2009; 23 (6): 791-6.

4. Konopa J, Jereczek E, Matuszkiewicz A, Nazarewicz T. Screening of antitumor substances from plants. Arch Immunology Therapy Expression (Warsz) 1996; 15: 129-32.

5. Williams CA, Harborne JB, Geiger H, Hoult JR. The flavonoids of *Tanacetum arthenium* and *T. vulgare* and their anti-inflammatory properties. Phytochem. 1999; 51: 417-23.

6. Bandonienė D, Pukalskas A, Venskutonis PR, Gruzdienė D. Preliminary screening of antioxidant activity of some plant extracts in rapeseed oil. Food Res Int. 2000; 33: 785-91.

7. Holetz FB, Pessini GL, Sanches NR, Cortez Diogenes AG, Nakamura CV. Screening of some plants used in the Brazilian folk medicine for the treatment of infectious diseases. Memorias do Instituto Oswaldo Cruz. 2002; 97: 1027- 1031.

8. Lawrence BM. Progress in essential oils: tansy oil. Perfum. Flavor. 2000; 25: 33-47.

9. Chiasson H, Belanger A, Bostanian N, Vincent C, Poliquin A. Acaricidal properties of *Artemisia absinthium* and *Tanacetum vulgare* (Asteraceae) essential oils obtained by three methods of extraction. Hortic Entomol. 2001; 94 (1): 167-71.

10. Keskitalo M, Pehu E, Simon JE. Variation in volatile compounds from tansy (*Tanacetum vulgare* L.) related to genetic and morphological differences of genotypes. Biochem Syst Ecol. 2001; 29: 267-85.

11. Mockute D, Judzentiene A. Composition of the essential oils of *Tanacetum vulgare* L. growing wild in Vilnius district (Lithuania). J Essent. Oil Res. 2004; 16: 550-53.

12. Judzentiene A, Mockute D. The inflorescence and leaf essential oils of *Tanacetum vulgare* L. var. *vulgare* growing wild in Lithuania. Biochem Syst Ecol. 2005; 33: 487-98.

13. Baranauskienė R, Kazernavičiūtė R, Pukalskienė M, Maždžierienė R, Venskutonis PR. Agrorefinery of *Tanacetum vulgare* L. into valuable products and evaluation of their antioxidant properties and phytochemical composition. Ind Crops Prod. 2014; 60: 113-22.

14. Raal A, Orav A, Gretchushnikova T. Essential oil and composition in *Tanacetum vulgare* L. herbs growing wild in Estonia. J Essent. Oil-Bearing Plants 2014; 17 (4): 670-75.

15. Szołyga B, Gniłka R, Szczepanik M, Szumny A. Chemical composition and insecticidal activity of *Thuja occidentalis* and *Tanacetum vulgare* essential oils against larvae of the lesser mealworm, *Alphitobius diaperinus*. Entomologia Experimentalis et Applicata 2014; 151: 1-10.

16. McKay DL, Blumberg JB. A review of the bioactivity and potential health benefits of peppermint tea (*Mentha piperita* L.). Phytother Res. 2006; 20: 619-33.

17. Shrivastava A. A review on peppermint oil. Asian J Pharm Clin Res. 2009; 2 (2): 27-33.

18. Riachi LG, De Maria CAB. Peppermint antioxidants revisited. Food Chem. 2015; 176: 72-81.

19. Calo JR, Crandall PG, O'Bryan CA, Ricke SC. Essential oils as antimicrobials in food systems - A review. Food Control 2015; 54: 111-19.

20. Güntert M, Krammer G, Lambrecht S, Sommer H, Surburg H, Werkhoff P. 2001. Flavor chemistry of peppermint oil (*Mentha piperita* L.). En: Takeoka GR, Güntert M, Engel KH, editores. Compounds in foods: Chemistry and sensory properties. Washington, DC.: American Chemical Society: 2001: p. 119-37.

21. Lawrence BM. 2007. The composition of commercially important mints. En: Lawrence BM, 1st edition, editor. Mint. The genus *Mentha*. Boca Raton, FL.: CRC Press, Taylor and Francis Group.: 2007: p. 217-324.

22. Adams RP. Identification of Essential Oil Components by Gas Chromatography/Quadrupole Mass Spectroscopy. Carol Stream, IL. Allured Publishing, Co 1st edition: 2000: 804 pags

23. Costa R, Zellner BdA, Crupi ML, Fina MRD, Valentino MR, Dugo P, Dugo G, Mondello L. GC–MS, GC-O and enantio-GC investigation of the essential oil of *Tarchonanthus camphoratus* L. Flavour Fragr. J. 2008; 23: 40-8.

24. Tabart J. Comparative antioxidant capacities of phenolic compounds measured by various test. Food Chem. 2008; 40: 123-28.

25. Sivropoulou A, Nikolaou C, Papanikolaou E, Kokkini S, Lanaras T, Arsenakis M. Antimicrobial, cytotoxic, and antiviral activities of *Salvia fructicosa* essential oil. J Agric Food Chem. 1997; 45: 3197-201.

26. Lawless J. The illustrated Encyclopedia of Essential Oils. Element Books, Imago, 1st ed, Singapore. 1995: p. 225.

27. Woolf A. Essential oil poisoning. J. Toxic. Clin. Toxic. 1999; 37: 721-27.

28. Sirisoma NS, Hold KM, Casida JE. α- and β-Thujones (herbal medicines and food additives): synthesis and analysis of hydroxy and dehydrometabolites. J Agric Food Chem. 2001; 49: 1915-22.

29. Dragland S, Senoo H, Wake K, Holte K, Blomhoff R. Several culinary and medicinal herbs are important sources of dietary antioxidants. J Nutr. 2003; 133: 1286-90.

30. Juan-Badaturuge M, Habtemariam S, Jackson C, Thomas M. Antioxidant principles of *Tanacetum vulgare* L. aerial parts. Nat Prod Commun. 2009; 4: 1561-64.

31. Mimica-Dukić N, Bozin B, Soković, M, Mihajlović B, Matavulj M. Antimicrobial and antioxidant activities of three *Mentha* species essential oils. Planta Med. 2003; 69 (5): 413-19.

Table 1. Composition of the essential oils of *Tanacetum vulgare* and *Mentha* x *piperita* var. *vulgaris* leaves.

Compound	RI_A[a]	RI_A[Oa]	RI_P[b]	RI_P[Ob]	*T. vulgare* (%)	*Mentha* x *piperita* (%)
Ethyl 2-methylbutanoate	851	853	1047	1050	-	tr[c]
(*E*)-2-Hexenal	854	856	1201	1204	-	tr
(*Z*)-Salvene	856	857	-	-	0.2±0.0	-
(*Z*)-3-Hexenol	860	859	1350	1353	0.1±0.0	tr
1-Hexanol	869	871	1360	1363	-	tr
Santolina triene*	908	909	1042	1044	-	tr
α-Thujene	930	931	1020	1018	tr	tr
α-Pinene	940	939	1031	1033	tr	0.4±0.0
Camphene	954	956	1076	1075	-	tr
Benzaldehyde	961	960	1495	1499	tr	-
Sabinene	973	972	1125	1121	2.8±0.2	0.2±0.0
β-Pinene	979	979	1114	1117	tr	0.7±0.1
Myrcene	987	989	1162	1160	tr	1.9±0.1
3-Octanol	991	992	1386	1384	-	0.2±0.0
Octanal	999	1000	1288	1284	tr	-
α-Terpinene	1017	1014	1178	1180	0.1±0.0	-
p-Cymene	1023	1024	1270	1268	1.3±0.1	1.0±0,1
Limonene	1027	1029	1201	1203	tr	5.9±0.2
β-Phellandrene	1030	1031	1209	1210	tr	-
1,8-Cineole	1033	1033	1215	1213	1.1±0.1	4.8±0.2
(*Z*)-β-Ocimene	1037	1035	1225	1227	-	tr
Phenylacetaldehyde	1040	1042	1625	1623	tr	-
γ-Terpinene	1060	1059	1244	1242	0.3±0.0	-
1-Phenyethanol	1064	1063	1825	1820	tr	-
cis-Sabinene hydrate	1070	1069	1558	1560	0.7±0.0	1.5±0.1
cis-Linalool oxide (furanoid)	1074	1075	1449	1450	tr	-
Terpinolene	1089	1086	1280	1282	tr	-
3-Nonanol	1091	1090	1492	1496	-	tr
Linalool	1095	1097	1353	1355	-	0.2±0.0
trans-Sabinene hydrate	1098	1098	1469	1467	0.6±0.0	-
6-Methyl-3,5-heptadien-2-one	1100	1099	1602	1604	-	tr
3-Methylbutyl 3-methylbutanoate	1101	1102	1292	1296	-	tr
cis-Thujone	1103	1102	1429	1431	2.5±0.1	-
trans-Thujone	1113	1114	1443	1441	**83.5±3.2**	0.2±0.0
3-Methyl-3-butenyl 3-methylbutanoate	1116	1115	1378	1379	-	tr
3-Octyl acetate	1123	1124	1340	1338	-	0.2±0.0
Dehydro-sabina ketone*	1124	1121	-	-	tr	-
iso-3-Thujanol	1134	1138	1732	1735	1.1±0.1	-
cis-p-Mentha-2,8-dien-1-ol	1136	1139	1628	1629	-	tr
trans-Sabinol*	1140	1141	1720	1719	0.4±0.0	-
cis-Sabinol*	1143	1143	1780	1783	0.2±0.0	-
(*E*)-Myroxide*	1146	1145	1473	1474	-	tr
Camphene hydrate*	1150	1150	1585	1589	0.2±0.0	-
Menthone	1153	1151	1478	1476	-	**7.1±0.8**
Sabina ketone*	1157	1159	1680	1683	0.2±0.0	-
iso-Menthone	1161	1163	1475	1476	-	0.7±0.1
Pinocarvone	1164	1165	1571	1575	0.2±0.0	-

Table 1. (Continued)

Compound	RI_A[a]	RI_A[Oa]	RI_P[b]	RI_P[Ob]	*T. vulgare* (%)	*Mentha* x *piperita* (%)
neo-Menthol	1167	1166	1572	1574	-	2.9±0.3
Borneol	1169	1167	1701	1700	tr	0.1±0.0
Menthol	1172	1170	1637	1636	-	**35.4±3.2**
Terpinen-4-ol	1175	1177	1595	1600	1.0±0.1	1.9±0.1
Thuj-3-en-10-al	1181	1183	1621	1624	0.2±0.0	-
p-Methylacetophenone	1182	1184	1795	1791	-	tr
iso-Menthol	1183	1184	1757	1759	-	0.2±0.0
neoiso-Menthol*	1186	1187	1641	1645	-	tr
α-Terpineol	1191	1192	1698	1695	tr	0.1±0.0
Myrtenol	1194	1196	1785	1789	0.3±0.0	-
Myrtenal	1196	1196	1623	1626	0.1±0.0	-
trans-Carveol	1217	1219	1835	1836	-	0.1±0.0
(*Z*)-3-Hexenyl 2-methylbutanoate	1231	1232	1470	1472	-	tr
(*Z*)-3-Hexenyl 3-methylbutanoate	1234	1235	1477	1480	-	0.2±0.0
Hexyl 2-methylbutanoate	1236	1237	1435	1433	-	tr
trans-Chrysanthenyl acetate*	1236	1238	1564	1568	0.1±0.0	-
Pulegone	1238	1238	1642	1644	-	tr
Cumin aldehyde	1241	1242	1787	1789	0.1±0.0	-
Carvone	1244	1244	1725	1723	-	0.1±0.0
Carvotanacetone	1248	1247	1695	1697	0.2±0.0	-
cis-Piperitone epoxide*	1255	1254	1732	1733	-	1.8±0.0
neo-Menthyl acetate*	1272	1274	1565	1569	-	0.7±0.1
Thymol	1291	1290	2167	2169	-	0.2±0.0
p-cymen-7-ol	1292	1291	2111	2108	tr	-
Menthyl acetate	1293	1293	1574	1573	-	**19.6±2.0**
p-Menth-1-en-9-ol*	1295	1295	-	-	-	tr
Carvacrol	1299	1300	2190	2189	tr	tr
iso-Menthyl acetate	1302	1305	1543	1547	-	0.1±0.0
neoiso-Isopulegol acetate*	1310	1313	-	-	-	0.5±0.1
Presilphiperfol-7-ene*	1333	1337	1393	1391	tr	-
Piperitenone	1342	1340	1949	1950	-	tr
p-Menthane-3,8-diol*	1347	-	2165	2165	-	0.1±0.0
Eugenol	1361	1359	2140	2141	tr	-
α-Copaene	1375	1374	1483	1480	-	0.1±0.0
Silphiperfol-6-ene*	1378	1379	1486	1482	0.1±0.0	-
β-Bourbonene	1388	1384	1507	1504	-	0.9±0.1
β-Cubebene*	1389	1388	1606	1610	0.2±0.0	-
(*E*)-Jasmone*	1392	1391	1948	1948	-	tr
p-Menthane-1,2,3-triol*	1405	1408	-	-	-	1.8±0.1
α-Gurjunene	1410	1408	1530	1527	-	0.3±0.0
(*E*)-Caryophyllene	1419	1418	1580	1576	-	1.8±0.1
β-Copaene	1432	1430	1570	1567	-	0.1±0.0
(*Z*)-β-Farnesene	1443	1445	1652	1648	-	0.7
α-Humulene	1453	1455	1660	1663	-	0.1±0.0
allo-Aromadendrene	1460	1459	1639	1642	-	0.1±0.0
cis-Muurola-4(14),5-diene*	1466	1467	-	-	-	tr
Germacrene D	1486	1485	1704	1702	-	0.1±0.0
Mint furanone*	1496	1499	-	-	-	0.1±0.0
γ-Cadinene	1514	1516	1762	1759	-	tr

Table 1. (Continued)

Compound	RI_A[a]	RI_A^{Oa}	RI_P[b]	RI_P^{Ob}	*T. vulgare* (%)	*Mentha* x *piperita* (%)
δ-Cadinene	1523	1525	-	-	tr	tr
Spathulenol	1579	1578	1803	1806	-	1.1±0.01
Caryophyllene oxide	1583	1584	1985	1988	0.1±0.0	1.4±0.1
Viridiflorol	1595	1593	2106	2109	-	1.3±0.0
cis-Cadin-4-en-7-ol*	1637	1640	-	-	0.2	-
Caryophylla-4(14),8(15)-dien-5-.β-ol*	1642	1641	-	-	0.1	-
Valeranone*	1670	1675	2108	2107	0.5	-
Monoterpene hydrocarbons					4.7	10.1
Oxygenated monoterpenes					92.6	76.7
Sesquiterpene hydrocarbons					0.2	4.2
Oxygenated sesquiterpenes					0.9	3.8
Other compounds					0.3	4.1
Total identified					98.7	98.9

Note: [a]RI_A and RI_P, experimental linear retention indices on DB-5ms and DB-Wax column, respectively.
[b]RI_A^O and RI_P^O, linear retention indices from standard or literature on DB-5ms and DB-Wax column, respectively.
[c]trace (<0.1%).
*tentatively identified compound by comparison with literature data.