Composition of Essential Oils from *Satureja darwinii* (Benth.) Briq. and *S. multiflora* (R. et P.) Briq. (Lamiaceae). Relationship Between Chemotype and Oil Yield in *Satureja* spp.

H. M. Niemeyer

Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile

Abstract

Air-dried aerial parts of *Satureja darwinii* (Benth.) Briq. and *Satureja multiflora* (R. et P.) Briq. (Lamiaceae) collected in Chile at full flowering stage were hydrodistilled. The yields of essential oils were 0.68% and 0.57% v/w, respectively. GC-FID and GC/MS analyses showed that the major constituents of the oils were piperitenone (57.8%) and isomenthone (83.1%) in *S. darwinii* and *S. parvifolia*, respectively. These results are compared with others reported for the genus *Satureja*.

Key Word Index

Satureja darwinii, Satureja multiflora, Lamiaceae, savory, essential oil composition, piperitenone, isomenthone, chemotypes.

Introduction

The genus *Satureja* (Lamiaceae) has a wide distribution which includes Europe, Asia, tropical Africa, and the Americas (1). They are mainly aromatic herbs and shrubs, some of which are used as flavoring agents and some for medicinal purposes. The composition of numerous *Satureja* oils has been reported. Among the four *Satureja* species which occur in Chile (2), and to the best of this author's knowledge only *S. gilliesii* (3) and *S. parvifolia* (4) have been studied. In this report the composition of the essential oils of the other two species, *S. darwinii* and *S. multiflora*, is reported.

Experimental

Plant material: Samples of above-ground tissue of the two *Satureja* species (three samples of ca. 200 g fr. wt each) were collected at the full flowering stage, *S. darwinii* at the Pali Aike National Park near Punta Arenas, Chile (52°04.8'S, 69°47.1'W), and *S. multiflora* by the shores of Lago Colico, near Temuco, Chile (39°04.3'S, 71°53.2'W). The material was identified by Sebastián Teillier, Universidad Central de Chile. Voucher specimens are stored at the Herbarium of Universidad de Concepción (CONC).

Oil isolation and analysis: Plant samples were air-dried, cut into small pieces, and submitted to hydrodistillation for 3 h using a modified Clevenger-type apparatus. Oils were dried over anhydrous sodium sulphate and stored in glass ampoules at 4°C until analyzed. All oils were yellowish. Each sample was processed independently.

Qualitative analyses were performed in a Hewlett-Packard 5891 gas chromatograph linked to a Hewlett-Packard 5972 mass spectrometric detector with an integrated data system (Hewlett Packard, Palo Alto, CA, USA), and quantitative analyses were performed in a Shimadzu GC-9A gas chromatograph fitted with an FID-9 detector (Shimadzu Corporation, Kyoto, Japan). The same capillary column (SPB-5, film thickness 0.25 μm, 30 m x 0.25 mm, Supelco, Deerfield IL, USA) was used in both instruments. The operating conditions were as follows: on-column injection; injector temperature, 150°C; detector temperature, 280°C; carrier gas, He; oven temperature program: 50°C for 10 min, increase to 280°C at 5°C/min, and then 280°C for 45 min. In the mass detector, ionization was by electron impact at 70 eV; scan time, 1.5 s; and acquisition mass range, 50–500 amu. The identification of compounds in the chromatographic profiles was achieved by: i) comparison of mass spectra with those in the NIST-98 library database using a reverse search technique

*Address for correspondence: niemeyer@abulafia.ciencias.uchile.cl

Rec: December 2007
Rev: November 2008
Acc: March 2009
Post-rev: August 2010

1041-2905/10/0006-0477$14.00/0—© 2010 Allured Business Media

Table I. Chemical composition (%) of the essential oils of *Satureja darwinii* and *S. multiflora*.

Compound	RI [a]	Concentration (%) [b] *S. darwinii*	Concentration (%) [b] *S. multiflora*	Identification [c]
3-methylcyclohexanone	955	0.1	- [d]	RI, MS, ST
hexanoic acid	989	0.5	-	RI, MS, ST
3-octanol	995	0.7	-	RI, MS, ST
phenylacetaldehyde	1046	1.8	0.3	RI, MS, ST
6-methylheptanol	1051	0.6	-	RI, MS
trans-linalool oxide[e]	1090	0.4	-	RI, MS
cis-linalool oxide[e]	1092	0.4	-	RI, MS
linalool	1105	1.3	3.7	RI, MS, ST
trans-p-mentha-2,8-dien-1-ol	1124	0.6	-	RI, MS
menthone	1162	-	1.9	RI, MS
isomenthone	1174	-	83.1	RI, MS
borneol	1176	2.7	-	RI, MS, ST
terpinen-4-ol	1187	2.8	-	RI, MS
α-terpineol	1189	2.4	-	RI, MS, ST
neoisomenthol	1193	-	5.4	RI, MS
verbenone	1215	1.3	-	RI, MS, ST
pulegone	1249	11.4	0.7	RI, MS, ST
piperitone	1260	2.1	1.3	RI, MS
thymol	1304	0.8	-	RI, MS, ST
carvacrol	1307	4.8	-	RI, MS, ST
p-vinylguaiacol	1323	0.9	-	RI, MS
piperitenone	1360	57.8	-	RI, MS
Oxygenated monoterpenes (%)		89.7	96.1	
Other compounds		3.7	0.3	
Total identified		93.4	96.4	
Oil yield (ml/100 g dry weight)		0.68	0.52	

[a] Relative retention indices on an SPB-5 column in reference to *n*-alkanes.
[b] Peak areas relative to total peak area (means of three samples).
[c] MS, NIST MS library, and the literature; RI, retention index; ST, authentic standard compound.
[d] Not detected.
[e] furanoid form

which verifies that main peaks in the reference spectrum are present in the unknown spectrum (5); and ii) comparison of retention indexes (RI) with those reported in the literature, or with those of available standards. Quantitation was achieved by integration of peak areas in the chromatogram from the FID-fitted gas chromatograph.

Results and Discussion

Twenty-six compounds were characterized, 19 in *S. darwinii* and 7 in *S. multiflora*, representing 93.4% and 96.4% of the oils, respectively (Table I). Both oils were isolated in moderate yields (0.68% and 0.57% v/w, respectively). They contained almost exclusively oxygenated monoterpenes, mostly of the p-menthane family, the major ones being piperitenone and pulegone in *S. darwinii*, and isomenthone in *S. multiflora*.

The composition of the essential oils of more than 50 species of *Satureja* have been reported. On the basis of the data accumulated, *Satureja* oils can be assigned to one of three main chemotypes defined on the basis of the major compounds they contain, i.e., aromatic p-menthane monoterpenes, mainly carvacrol, thymol, and p-cymene (chemotype I); aliphatic p-menthane monoterpenes, mainly menthone, isomenthone, pulegone, and piperitone (chemotype II); or various mono- and sesquiterpenes (chemotype III) (Table II) (6-60). *Satureja atropatana* (7,34), *S. mutica* (7,17,34), *S. subspicata* (29,30), *S. cuneifolia* (11,50), *S. macrantha* (6,17,56), *S. obovata* (18,57), *S. wiedemanniana* (32,60) and *S. kitaibelii* (19,55) appear as exceptions to this rule because they can be assigned to more than one chemotype. However, the first three cases involve collections performed at different times of the year, the next four cases involve collections performed at different places, and the last case is well known for being an infraspecific systematic category within the extremely polymorphous species, *S. montana* (55). As discussed below, the oil composition can be greatly affected by ontogenetic stage of the plant and its place of growth. In general, while most species studied from the Mediterranean region belong to the first chemotype, most species from South and Central America belong to the last two chemotypes. The essential oil of *S. robusta* is unique in the sense that the four major compounds found are associated to chemotypes II (menthone, 38.0%), I (thymol, 14.1%) and III (germacrene D and geraniol, 13.4% and 11.1%, respectively) (45); it thus constitutes an interesting species for the study of the regulation of terpene biosynthetic pathways.

Several reports have addressed the variability of the composition of *Satureja* oils as a function of plant origin (4,26,48,57,61-63), ontogenesis (24,57,62,64,65), plant part (24), growth environment (57,66,67), time of collection (48,57), and processing conditions (15,25,68). The yield of essential

Table II. Chemotypes of essential oils of *Satureja* species (only the latest references on each species are given).

Main components	*Satureja* species	References
Aromatic p-menthane monoterpenes (chemotype I)	*aintabensis*	6
	atropatana	7
	bachtiarica	8
	boissieri	9
	cilicica	10
	cuneifolia	11
	edmondi	12
	hortensis	13
	horvatii	14
	horvatii ssp. macrophylla	15
	icarica	16
	intermedia	17
	intricata	18
	kitaibelii f. aristata	19
	khuzistanica	20
	laxiflora	21
	macrantha	6,17
	mutica	7,17
	montana	22
	montana ssp. kitaibelii	23
	obovata	18
	parnassica ssp. parnassica	24
	pilosa	16,23
	rechingeri	25
	sahendica	26
	spicigera	27
	spinosa	28
	subspicata	29
	subspicata ssp. liburnica	30
	thymbra	31
	wiedemanniana	32
Aliphatic p-menthane monoterpenes (chemotype II)	*abyssinica ssp. abbysinica*	33
	atropatana	34
	boliviana	35
	brevicalyx	36
	brownei	37
	douglasii	38
	fruticosa	39
	gilliesii	3
	glabella	40
	grandiflora	41
	mutica	34
	odora	42
	paradoxa	33
	parnassica ssp. sipylea	43
	parvifolia	35
	pseudosimensis	44
	robusta	45
	viminea	46,47
Various monoterpenes and sesquiterpenes (chemotype III)	*adamovicii*	48
	alpina	40
	biflora	44,49
	boliviana	4
	coerulea	16
	cuneifolia	50
	forbesii	51
	fukarekii	48
	glabrata	52
	innota	53
	isophylla	12
	juliana	54
	kitaibelii	55
	macrantha	56
	masukensis	44
	obovata	57
	punctata	58
	salzmannii	53
	spinosa	59
	subspicata	29
	visianii	22
	wiedemanniana	60

oil has also shown considerable variability. The relationship between composition and yield of essential oils can best be assessed in studies which have used similar extraction procedures on comparable biological material. Most studies which have reported both the yield and composition of *Satureja* oils have used hydrodistillation of dry aerial plant material originally collected at the flowering stage; these studies are listed in Table III (6,7,11,12,17,20,23-26,36,40,42,43,48,56,59,60,62,63,68-82). Three yield groups may be distinguished: i) with yields higher than 1%, containing only chemotype I; ii) with intermediate yields (between 0.5% and 1%) containing chemotypes III, I and II, with the latter predominating; and iii) with low yields (< 0.5%) containing chemotypes I and III, with the latter predominating. To assess whether affiliation to a yield group can be used for chemotype assignment, the expected and observed chemotype frequencies within each yield group were compared using the chi-squared test. The frequencies were not significantly different (chi-squared = 2.6166, $P > 0.25$, $N = 53$), showing that the affiliation of an oil to a yield group can be confidently used to assign its chemotype. It is interesting to note that this trend holds even within species. Thus, when particular collections of *S. cuneifolia*, *S. macrantha* and *S. parnassica* ssp. *parnassica* produce oils in low yields, those oils belong to chemotype III, whereas when collections of the same species produce high yield of oils, they belong to chemotype I (Table III).

In conclusion, *Satureja* oils may be assigned to three different chemotypes depending on the nature of their main

Table III. Yield and composition of *Satureja* oils obtained by hydrodistillation of dry aerial plant material originally collected at the flowering stage.

Species	Chemotype	Main components (%)	Reference	Yield (%)
rechingeri	I	carvacrol (86.6)	25	4.2
spicigera	I	thymol (35.1), p-cymene (22.1), γ-terpinene (13.7)	69	3.8
khuzistanica	I	p-cymene (39.6), carvacrol (29.6), γ-terpinene (18.9)	70	3.0
hortensis	I	carvacrol (36.2), γ-terpinene (30.9), thymol (11.5)	63	2.5[a]
cuneifolia	I	thymol (65.5), p-cymene (9.8), carvacrol (7.2)	11	2.5
thymbra	I	thymol (41.0), γ-terpinene (22.2), p-cymene (11.8)	24	2.4
mutica	I	carvacrol (30.9), thymol (26.5), γ-terpinene (14.9), p-cymene (10.3)	17	2.3
sahendica	I	p-cymene (30.2), thymol (29.6), γ-terpinene (27.7)	26	2.3
cuneifolia	I	thymol (43.6), carvacrol (31.2), p-cymene (11.5)	71	2.2
thymbra	I	thymol (17.2), γ-terpinene (12.5), carvacrol (29.2), p-cymene (10.9)	72	2.2
pilosa var. pilosa	I	thymol (46.1), p-cymene (12.7), γ-terpinene (8.7)	23	2.1
boissieri	I	carvacrol (40.8), γ-terpinene (26.4), p-cymene (14.5)	73	2.1
aintabensis	I	p-cymene (59.0), thymol (17.5)	6	2.0
cuneifolia	I	carvacrol (46.4), p-cymene (15.8), γ-terpinene (13.0)	74	1.9
subspicata	I	carvacrol (16.8), α-pinene (13.6), p-cymene (10.8), thymol methyl ester (8.8)	75	1.8
cuneifolia	I	carvacrol (59.3), thymol (15.7), p-cymene (9.7)	76	1.7
macrantha	I	p-cymene (25.8), limonene (16.3), thymol (8.1)	17	1.5
intermedia	I	thymol (32.3), γ-terpinene (29.3), p-cymene (14.7)	17	1.5
parnassica ssp. sipylea	I	carvacrol (42.9), *p*-cymene (20.1)	43	1.5
parnassica ssp. parnassica	I	thymol (20.3), carvacrol (34.6), γ-terpinene (16.7), p-cymene (6.9)	24	1.4
montana	I	carvacrol (29.8), p-cymene (14.6), thymol (7.7)	62	1.3[a]
khuzistanica	I	carvacrol (80.6)	20	1.2
spicigera	I	thymol (25.8), p-cymene (32.0), carvacrol (5.5)	77	1.2[a]
hortensis	I	thymol (40.5), γ-terpinene (18.6), carvacrol (14.0)	78	1.1
icarica	I	carvacrol (53.4), p-cymene (14.8)	79	1.1[a]
parvifolia	I	carvacrol (34.0), carvacryl acetate (14.7), p-cymene (14.0), γ-terpinene (11.3)	42	1.1
pilosa	I	carvacrol (53.5), p-cymene (17.4)	79	1.1
glabella	II	isomenthone (39.9), pulegone (33.3),	40	1.1[a]
boliviana	II	isomenthone (29.7), menthone (24.2)	36	1.0
edmondi	I	p-cymene (61.1), γ-terpinene (9.6)	12	1.0
brevicalix	II	menthone (37.5), isomenthone (25.2)	36	1.0
hortensis	I	γ-terpinene (38.5), carvacrol (47.0)	68	1.0[a]
visianii	III	linalool (68.6), thymol (5.6)	48	0.80
odora	II	pulegone (61.5), isomenthone (5.8), menthone (3.4)	42	0.70
darwinii	II	piperitenone (57.8), pulegone (11.4)	this work	0.68
khuzistanica	I	carvacrol (93.9)	20	0.60
multiflora	II	isomenthone (83.1), neoisomenthol (5.4)	this work	0.57
horvatii	I	p-cymene (27.6), thymol (27.4), carvacrol (17.8)	80	0.53
parnassica ssp. parnassica	III	β-caryophyllene (20.9), carvacrol (20.4), spathulenol (17.2), p-cymene (13.0)	81	0.44
cuneifolia	III	α-pinene (10.5), limonene (8.5), carvacrol (7.7), p-cymene (6.4), borneol (6.4), β-cubebene (5.8), β-caryophyllene (6.0)	62	0.43[a]
boissieri	I	carvacrol (70.1), γ-terpinene (6.8), p-cymene (6.3)	82	0.30
spicigera	I	thymol (37.3), p-cymene (14.6), γ-terpinene (14.5), carvacrol (9.2)	56	0.30
isophylla	III	α-eudesmol (11.3), camphor (7.1), β-caryophyllene (6.1), γ-eudesmol (5.8), geranial (5.5)	12	0.29
fukarekii	III	α-phellandrene (17.3), *iso*-longifolene aldehyde (13.2), limonene (12.6)	48	0.25
adamovicii	III	α-phellandrene (13.0), *iso*-longifolene aldehyde (13.3), limonene (8.1)	48	0.20
macrantha	III	spathulenol (14.0), vanillin (13.4), *p*-cymene (12.3), caryophyllene oxide (7.2)	56	0.20
mutica	I	thymol (62.6), p-cymene (9.4), carvacrol (6.6)	7	0.20
subspicata subsp. subspicata	I	carvacrol (58.1), terpinen-4-ol (18.5)	80	0.19
montana ssp. kitaibelii	III	limonene (15.7), p-cymene (13.1), germacrene D (8.1)	23	0.19
spinosa	III	linalool (47.4), germacrene D (4.2), bicyclogermacrene (4.8)	59	0.12
atropatana	I	thymol (62.1), p-cymene (6.1)	7	0.10
wiedemanniana	III	caryophyllene oxide (8.5), borneol (8.3), germacrene D (8.1), limonene (7.7), spathulenol (7.7), β-caryophyllene (6.5), β-bisabolene (6.0)	60	0.06
alpina	III	germacrene D (33.2), α-muurolene (6.1), β-caryophyllene (4.4), β-bourbonene (4.1)	40	<0.01

[a] Mean of values reported.

constituents. The yield of oil is correlated with the nature of the chemotype. The oils of the two *Satureja* species described in this paper conform to these general trends.

Acknowledgements

This work was supported by Fundación para la Innovación Agraria (FIA-PI-C-2002-1-A-001). The assistance of Cecilia Fernández in plant collection and of Claudia Cabrillana in chemical analysis is gratefully acknowledged.

References

1. P.D. Cantino, R.M. Harley and S.J. Wagstaff, Genera of the Labiatae: status and classification. In: *Advances in Labiatae Science*. Edits., R.M. Harley and T. Reynolds, pp. 511-522, Royal Botanical Gardens, Kew, London, UK (1992).
2. C. Marticorena and M. Quezada, Catalog of the vascular flora of Chile. *Gayana Botánica*, **42**, 3-157 (1985).
3. R. Vila, B. Milo, S. Cañigueral, A. Adzet, C. Labbé and O. Muñoz, Chemical composition of the essential oil of *Satureja gilliesii*. *J. Essent. Oil Res.*, **8**, 183-184 (1996).
4. C.I. Viturro, A. Molina, I. Guy, B. Charles, H. Guinaudeau and A. Fournet, Essential oils of *Satureja boliviana* and *S. parvifolia* growing in the region of Jujuy, Argentina. *Flav. Fragr. J.*, **15**, 377-382 (2000).
5. G.M. Pesyna, R. Ventakaraghavan, H.E. Dayringer and F.W. McLafferty, Probability based matching system using a large collection of reference mass spectra. *Anal. Chem.*, **48**, 1362-1368 (1976).
6. A.D. Azaz, M. Kürkcüoglu, F. Satil, K.H.C. Baser and G. Tümen, In vitro antimicrobial activity and chemical composition of some *Satureja* essential oils. *Flav. Fragr. J.*, **20**, 587-591 (2005).
7. A.R. Gohari, A. Hadjiakhoondi, A. Shafiee, E.S. Ebrahimi and V. Mozaffarian, Chemical composition of the essential oils of *Satureja atropatana* and *Satureja mutica* growing wild in Iran. *J. Essent. Oil Res.*, **17**, 17-18 (2005).
8. F. Sefidkon and Z. Jamzad, Essential oil of *Satureja bachtiarica* Bunge. *J. Essent. Oil Res.*, **12**, 545-546 (2000).
9. F. Sefidkon and Z. Jamzad, Essential oil composition of *Satureja boissieri*. *J. Essent. Oil Bear. Plants*, **9**, 287-291 (2006).
10. G. Tümen, K.H.C. Baser and N. Kirimer, The essential oil of *Satureja cilicica* P.H. Davies. *J. Essent. Oil Res.*, **5**, 547-548 (1993).
11. F. Oke, B. Aslim, S. Ozturk and S. Altundag, Essential oil composition, antimicrobial and antioxidant activities of *Satureja cuneifolia* Ten. *Food Chem.*, **112**, 874 (2009).
12. F. Sefidkon and Z. Jamzad, Essential oil analysis of Iranian *Satureja edmondi* and *S. isophylla*. *Flav. Fragr. J.*, **21**, 230-233 (2006).
13. A. Alizadeh, M. Khoshkhui, K. Javidnia, O. Firuzi, E. Tafazoli and A. Khalighi, Effects of fertilizer on yield, essential oil composition, total phenolic content and antioxidant activity in *Satureja hortensis* L. (Lamiaceae) cultivated in Iran. *J. Med. Plants Res.*, **4**, 33-40 (2010).
14. B. Lakusic, M. Ristic, V. Slavkovska, J.A. Stankovic and M. Milenkovic, Chemical composition and antimicrobial activity of the essential oil from *Satureja horvatii* Silic (Lamiaceae). *J. Serbian Chem. Soc.*, **73**, 703-711 (2008).
15. A. Dardioti, C.M. Cook, S. Kokkini and T. Lanaras, Composition of *Satureja horvatii* subsp. *macrophylla* oil isolated by hydrodistillation and micro-simultaneous distillation. *J. Essent. Oil Res.*, **9**, 663-666 (1997).
16. D. Azaz, F. Demirci, F. Satil, M. Kürkcüoglu and K.H.C. Baser, Antimicrobial activity of some *Satureja* essential oils. *Zeit. Naturforsch.*, **C57**, 817-821 (2002).
17. F. Sefidkon and Z. Jamzad, Chemical composition of the essential of three Iranian *Satureja* species *(S. mutica, S. macrantha and S. intermedia)*. *Food Chem.*, **91**, 1-4 (2005).
18. M.J. Jordán, P. Sánchez-Gómez, J.F. Jiménez, M. Quilez and J.A. Sotomayor, Chemical composition and antiradical activity of the essential oil from *Satureja intricata*, *S. obovata* and their hybrid *Satureja* x delpozoi. *Nat. Prod. Comm.*, **5**, 629-634 (2010).
19. J.-C. Chalchat, M.S. Gorunovic and Z.A. Maksimovic, Essential oil of *Satureja kitaibelii* Wiezb. f. *aristata* (Vand.) Hayek, Lamiaceae from Eastern Serbia. *J. Essent. Oil Res.*, **11**, 691-692 (1999).
20. H. Farsam, M. Amanlou, M.R. Radpour, A.N. Salehinia and A. Shafiee, Composition of the essential oils of wild and cultivated *Satureja khuzistanica* Jamzad from Iran. *Flav. Fragr. J.*, **19**, 308-310 (2004).
21. A. Sonboli, A. Fakhari, M.R. Kanini and M. Yousefzadi, Antimicrobial activity, essential oil composition and micromorphology of trichomes of *Satureja laxiflora* C. Koch from Iran. *Z. Naturforsch.*, **59C**, 777-781 (2004).
22. D. Vidic, M. Maksimovic, S. Cavar and M.E. Solic, Comparison of essential oil profiles of *Satureja montana* L. and endemic *S. visianii* Silic. *J. Essent. Oil Bear. Plants*, **12**, 273-281 (2009).
23. A. Konakchiev and E. Tsankova, The essential oils of *Satureja montana* ssp. *kitaibelii* Wierzb. and *Satureja pilosa* var. *pilosa* Velen from Bulgaria. *J. Essent. Oil Res.*, **14**, 120-121 (2002).
24. N. Chorianopoulos, E. Evergetis, A. Mallouchos, E. Kalpoutzakis, G.-J. Nychas and S.A. Haroutounian, Characterization of the essential oil volatiles of *Satureja thymbra and Satureja parnassica*: influence of harvesting time and antimicrobial activity. *J. Agric. Food Chem.*, **54**, 3139-3145 (2006).
25. F. Sefidkon, K. Abbasi, Z. Jamzad and S. Ahmadi, The effect of distillation methods and stage of plant growth on the essential oil content and composition of *Satureja rechingeri* Jamzad. *Food Chem.*, **100**, 1054-1058 (2007).
26. F. Sefidkon and A. Akbari-nia, Essential oil content and composition of *Satureja sahendica* Bornm. at different stages of plant growth. *J. Essent. Oil Res.*, **21**, 112-114 (2009).
27. F. Eftekhar, F. Raei, M. Yousefzadi, S.N. Ebrahimi and J. Hadian. Antibacterial activity and essential oil composition of *Satureja spicigera* from Iran. *Z. Naturforsch.*, **C64**, 20-24 (2009).
28. M. Skoula and R.J. Grayer, Volatile oils of *Coridothymus capitatus, Satureja thymbra, Satureja spinosa* and *Thymbra calostachya* (Lamiaceae) from Crete. *Flav. Fragr. J.*, **20**, 573-576 (2005).
29. S. Cavar, M. Maksimovic, M.E. Solic, A. Jerkovic-Mujkic and R. Besta, Chemical composition and antioxidant and antimicrobial activity of two *Satureja* essential oils. *Food Chem.*, **111**, 648-653 (2008).
30. V. Dunkic, N. Bezic, N. Ljubesic and I. Bocina, Glandular hair ultrastructure and essential oils in *Satureja subspicata* Vis. ssp. *subspicata* and ssp. *liburnica* Silic. *Acta Biol. Cracov. Ser. Bot.*, **49**, 45-51 (2007).
31. J. Glamoclija, M. Sokovic, J. Vukojevic, I. Milenkovic and L.J.L.D. van Griensven, Chemical composition and antifungal activities of essential oils of *Satureja thymbra* L. and *Salvia pomifera* ssp. *calycina* (Sm.) Hayek. *J. Essent. Oil Res.*, **18**, 115-117 (2006).
32. A. Ugur, N. Sarac and M.E. Duru, Antimicrobial activity and chemical composition of the essential oil of *Satureja thymbra* L. from Mugla (Turkey). *Acta Horticulturae*, **826**, 405-412 (2009).
33. K. Tolossa, K. Asres, F.K. El-Fiky, A.N.B. Singab and F. Bucar. Composition of the essential oils of *Satureja abyssinica* ssp. *abyssinica* and *Satureja paradoxa:* Their antimicrobial and radical scavenging activities. *J. Essent. Oil Res.*, **19**, 295-300 (2007).
34. A. Rustayian, A. Feizbakhsh, S. Masoudi and N. Ameri, Comparison of the volatile oils of *Satureja atropatana* Bung. and *Satureja mutica* Fisch. et C.A. Mey. from Iran. *J. Essent. Oil Res.*, **16**, 594-596 (2004).
35. J.S. Dambolena, M.P. Zunino, E.I. Lucini, J.A. Zygadlo, A. Rotman, O. Ahumada and F. Biurrun, Essential oils of plants used in home medicine in North of Argentina. *J. Essent. Oil Res.* **21**, 405-409 (2009).
36. F. Senatore, E. Urrunaga-Soria, R. Urrunaga-Soria, G. Della Porta and V. De Feo, Essential oils from two Peruvian *Satureja* species. *Flav. Fragr. J.*, **13**, 1-4 (1998).
37. L.B. Rojas and A. Usubillaga, Composition of the essential oil of *Satureja brownei* (SW.) Briq. from Venezuela. *Flav. Fragr. J.*, **15**, 21-22 (2000).
38. B. M. Lawrence, C.A. Bromstein and J.H. Langenheim, Terpenoids in *Satureja douglasii*. *Phytochemistry*, **13**, 1014 (1974).
39. J.A. Coelho, C. Grosso, A.P. Pereira, J. Burillo, J.S. Urieta, A.C. Figueiredo, J.G. Barroso, R.L. Mendes and A.M.F. Palavra, Supercritical carbon dioxide extraction of volatiles from *Satureja fruticosa* Béguinot. *Flav. Fragr. J.*, **22**, 438-442 (2007).
40. B.M. Lawrence, Labiatae oils–mother nature's chemical factory. In: *Essential Oils 1988-1991*. Edit., B.M. Lawrence, pp. 188-206. Allured Publ. Corp., Carol Stream, IL (1992).
41. A.-P. Carnat, A. Chossegros and J.-L. Lamaison, The essential oil

of *Satureja grandiflora* (L.) Scheele from France. *J. Essent. Oil Res.*, **3**, 361-362 (1991).

42. L. Muschietti, C. van Baren, J. Coussio, R. Vila, M. Clos, S. Cañigueral and T. Adzet, Chemical composition of the leaf oil of *Satureja odora* and *Satureja parvofolia*. *J. Essent. Oil Res.*, **9**, 681-684 (1996).
43. G. Tümen, E. Sezik and K.H.C. Baser, The essential oil of *Satureja parnassica* Heldr. & Sart. ex Boiss subsp. sipylea P.H. Davies. *Flav. Fragr. J.*, **7**, 43-46 (1992).
44. K. Vagionas, K. Graikou, O. Ngassapa, D. Runyoro and I. Chinou, Composition and antimicrobial activity of the essential oils of three *Satureja* species growing in Tanzania. *Food Chem.*, **103**, 319-324 (2007).
45. F. Tchoumbougnang, P.M.J. Dongmo, M.L. Sameza, F.F. Boyom, E.G.N. Mbanjo, P.H.A. Zollo and C. Menut, Essential oil analysis and antifungal activity of three *Satureja* species from Cameroon against *Aspergillus niger. J. Essent. Oil Bear. Plants*, **12**, 404-410 (2009).
46. R. Vila, J. Iglesias, S. Canigueral S. and J.F. Ciccio, Essential oil of *Satureja viminea* L. from Costa Rica. *J. Essent. Oil Res.*, **12**, 279-282 (2000).
47. A.O. Tucker, M.J. Maciarello and L.M. Libbey, Essential oil of *Satureja viminea* L. (Lamiaceae). *J. Essent. Oil Res.*, **12**, 283-284 (2000).
48. R. Palic, N. Simic, S. Andelkovic and G. Stojanovic, Composition of essential oil of selected Balkan's *Satureja* species and chemotaxonomic implications. *J. Essent. Oil Bear. Plants*, **1**, 66-81 (1998).
49. J.C. Matasyoh, J.J. Kiplimo, N.M. Karubiu and T.P. Hailstorks, Chemical composition and antimicrobial activity of the essential oil of *Satureja biflora* (Lamiaceae). *Bull. Chem. Soc. Ethiopia*, **21**, 249-254 (2007).
50. K.P. Savidkin, N.R. Menkovic, G.M. Zdunic, S.R. Tasic, M.S. Ristic, T.R. Stevic and P. Dajic-Stevanovic, Chemical composition and antimicrobial activity of the essential oils of *Micromeria thymifolia* (Scop.) Fritsch., *M. dalmatica* Benth., and *Satureja cuneifolia* Ten. and its secretory elements. *J. Essent. Oil Res.*, **22**, 91-96 (2010).
51. R. Ortet, E.L. Regalado, O.P. Thomas, J.A. Pino, M.D. Fernandez and J.J. Filippi, Composition and antioxidant properties of the essential oil of the endemic Cape Verdean *Satureja forbesii. Nat. Prod. Comm.*, **4**, 1277-1280 (2009).
52. O. Malagón, R. Vila, J. Iglesias, T. Zaragoza and S. Cañigueral, Composition of the essential oils of four medicinal plants from Ecuador. *Flav. Fragr. J.*, **18**, 527-531 (2003).
53. A. Velasco-Negueruela and M.J. Pérez-Alonso, Estudio químico del aceite esencial de diversas *Saturejae* ibéricas. *Anales Jard. Bot. Madrid*, **40**, 107-118 (1983).
54. H.D. Skaltsa, D.M. Lazaris and A.E. Loukis, Composition of the essential oil of *Satureja juliana* (L.) Bentham ex Reichenb. from Greece. *J. Essent. Oil Res.*, **10**, 641-642 (1998).
55. V. Slavkovska, R. Jancic, S. Bojovic, S. Milosavljevic and D. Djokovic, Variability of essential oils of *Satureja montana* L. and *Satureja kitaibelii* Wierz. ex Heuff. from the central part of the Balkan peninsula. *Phytochemistry*, **57**, 71-76 (2001).
56. A.R. Gohari, A. Hadjiakhoondi, E. Sadat-Ebrahimi, S. Saeidnia and A. Shafiee, Composition of the volatile oils of *Satureja spicigera* C. Koch Boiss. and *S. macrantha* C.A. Mey from Iran. *Flav. Fragr. J.*, **21**, 510-512 (2006).
57. M.L. Arrebola, M.C. Navarro, J. Jiménez and F.A. Ocaña, Variations in yield and composition of the essential oil of *Satureja obovata. Phytochemistry*, **35**, 83-93 (1994).
58. Y. Tariku, A. Hymete, A. Hailu and J. Rohloff, Essential-oil composition, antileishmanial, and toxicity study of *Arthemisia abyssinica* and *Satureja punctata* ssp. *punctata* from Ethiopia. *Chem. Biodiv.*, **7**, 1009-1017 (2010).
59. N. Tabanca, M. Kürkcüoglu, K.H.C. Baser, G. Tümen and H. Duman, Composition of the essential oils of *Satureja spinosa* L. *J. Essent. Oil Res.*, **16**, 127-128 (2004).
60. N. Ezer, R. Vila, S. Cañigueral and T. Adzet, Essential oil of *Satureja wiedemanniana* (Lallem.) Velen. *J. Essent. Oil Res.*, **7**, 91-93 (1995).
61. K.H.C. Baser, G. Tümen, N. Tabanca and F. Demirci, Composition and antibacterial activity of the essential oils from *Satureja wiedemanniana* (Lallem.) *Velen. Zeit. Naturforsch.*, **56c**, 731-738 (2001).
62. M. Milos, A. Radonic, N. Bezic and V. Dunkic, Localities and seasonal variations in the chemical composition of essential oils of *Satureja montana* L. and *S. cuneifolia* Ten. *Flav. Fragr. J.*, **16**, 157-160 (2001).
63. K.H.C. Baser, T. Ozek, N. Kirimer and G. Tümen, A comparative study of the essential oils of wild and cultivated *Satureja hortensis* L. *J. Essent. Oil Res.*, **16**, 422-424 (2004).
64. M. Skocibusic and N. Bezic, Chemical composition and antimicrobial variability of *Satureja montana* L. Essential oils produced during ontogenesis. *J. Essent. Oil Res.*, **16**, 387-391 (2004).
65. S. Kizil, M. Turk, M. Ozguven and K.M. Khawar, Full blooming stage is suitable for herbage yield and essential oil content of summer savory *(Satureja hortensis L.)*, *J. Essent. Oil Bear. Plants*, **12**, 620-629 (2009).
66. Z.F. Baher, M. Mirza, M.Ghorbanli and M.B. Rezaii, The influence of water stress on plant height, herbal and essential oil yield and composition in *Satureja hortensis L. Flav. Fragr. J.*, **17**, 275-277 (2002).
67. L. Tommasi, C. Negro, L. De Bellis and A. Miceli, Essential oil variability of *Satureja cuneifolia* Ten. growing wild in Southern Puglia (Italy). *J. Essent. Oil Res.*, **20**, 295-302 (2008).
68. F. Sefidkon, K. Abbasi and G. Bakhshi-Khaniki, Influence of drying and extraction methods on yield and chemical composition of the essential oil of *Satureja hortensis. Food Chem.*, **99**, 19-23 (2006).
69. F. Sefidkon and Z. Jamzad, Essential oil composition of *Satureja spicigera* (C. Koch) Boiss. from Iran. *Flav. Fragr. J.*, **19**, 571-573 (2004).
70. F. Sefidkon and S. Ahmadi, Essential oil of *Satureja khuzistanica* Jamzad. J. Essent. Oil Res., **12**, 427-428 (2000).
71. A. Akgül, M. Ozcan, F. Chialva and F. Monguzzi, Essential Oils of four Turkish wild-growing Labiatae herbs: *Salvia cryptantha* Montbr. et Auch., *Satureja cuneifolia* Ten., *Thymbra spicata* L and *Thymus cilicicus* Boiss. et Bal. *J. Essent. Oil Res.*, **11**, 209-214 (1999).
72. N. Chorianopoulos, E. Kalpoutzakis, N. Aligiannis, S. Mitaku, G.-J. Nychas and S.A. Haroutounian, Essential oils of *Satureja*, and *Thymus* species: chemical composition and antibacterial activities against foodborne pathogens. *J. Agric. Food Chem.*, **52**, 8261-8267 (2004).
73. M. Kürkcüoglu, G.Tumen and K.H.C. Baser, Essential oil constituents of *Satureja boissieri* from Turkey. *Chem. Nat. Comp.*, **37**, 329-331 (2001).
74. G. Tümen, The volatile constituents of *Satureja cuneifolia. J. Essent. Oil Res.*, **3**, 365-366 (1991).
75. M. Skocibusic, N. Bezic and V. Dunkic, Phytochemical composition and antimicrobial activities of the essential oils from *Satureja subspicata* Vis. Growing in Croatia. *Food Chem.*, **96**, 20-28 (2006).
76. Y. Kan, U.S. Ucan, M. Kartal, M.L. Altun, S. Aslan, E. Sayar and T. Ceyhan, GC-MS analysis and antibacterial activity of cultivated *Satureja cuneifolia* Ten. Essential oil. *Turkish J. Chem.*, **30**, 253-259 (2006).
77. G. Tümen and K.H.C. Baser, Essential oil of *Satureja spicigera* (C. Koch) Boiss. from Turkey. *J. Essent. Oil Res.*, **8**, 57-58 (1996).
78. A. Adiguzel, H. Ozer, H. Kilic and B. Cetin, Screening of antimicrobial of essential oil and methanol extract of *Satureja hortensis* on foodborne bacteria and fungi. *Czech J. Food Sci.*, **25**, 81-89 (2007).
79. G. Tümen, N. Kirimer, N. Ermin and K.H.C. Baser, The essential oils of two new *Satureja* species from Turkey: *Satureja pilosa and S. icarica. J. Essent. Oil Res.*, **10**, 524-526 (1998).
80. M.J. Gasic and R. Palic, Monoterpenoids in *Satureja horvatii* Siilic and *Satureja subspicata* Bartl. ex Vis. subsp. *subspicata. Bull. Soc. Chim. Beograd*, **48**, 677-679 (1983).
81. O. Tzakou and H. Skaltsa, Composition and antibacterial activity of the essential oil of *Satureja parnassica* subsp. *parnassica. Planta Med.*, **69**, 282-284 (2002).
82. S.E. Sajjadi and M. Baluchi, Chemical composition of the essential oil of *Satureja boissieri* Hausskn. ex Boiss. *J. Essent. Oil Res.*, **14**, 49-50 (2002).