Arabian Journal of Chemistry (2014) 7, 243–251

King Saud University

Arabian Journal of Chemistry

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ORIGINAL ARTICLE

Essential oil from *Artemisia herba-alba* Asso grown wild in Algeria: Variability assessment and comparison with an updated literature survey

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Received 9 December 2011; accepted 27 April 2012
Available online 7 May 2012

KEYWORDS

Asteraceae;
Artemisia herba-alba Asso;
Essential oil;
Chemical variability;
Algeria

Abstract The chemical variability of the essential oils of *Artemisia herba-alba* Asso aerial parts, collected at Algeria was evaluated. *A. herba-alba* populations were collected in four regions, Benifouda; Bougaa; Boussaada and Boutaleb, at two different periods, July (flowering phase), and October and November (vegetative phase). The essential oils were isolated by hydrodistillation and analyzed by Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS). The essential oils yield ranged between 0.2% and 0.9% (v/d.w.). Fifty components were identified in *A. herba-alba* oils, oxygen-containing monoterpenes being dominant in all cases (72–80%). Camphor (17–33%), α-thujone (7–28%) and chrysanthenone (4–19%) were the major oil components. Despite the similarity in main components, three types of oils could be defined, (a) α-thujone : camphor (23–28: 17–28%), (b) camphor : chrysanthenone (33:12%) and (c) α-thujone : camphor : chrysanthenone (24:19:19%). The comparison between the present data and an updated survey of the existing literature reinforces the major variability of *A. herba-alba* essential oils and stresses the importance of obtaining a defined chemical type crop production avoiding the wild harvest.

1. Introduction

Asteraceae Martinov (= Compositae Giseke) is a family of herbs, shrubs or trees, commonly known as Aster or Compositae family, comprising about 1535 genera and 23,000 species. *Artemisia* (wormwood, tarragon), one of the most economically important and widespread of this family genus, includes 400 species (Judd et al., 2002).

Dobignard, (1977) has shown the taxonomic complexity of *A. herba-alba lato sensu* described in North Africa, and the

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Peer review under responsibility of King Saud University.

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http://dx.doi.org/10.1016/j.arabjc.2012.04.042

Table 1 Previous studies on the essential oils of *Artemisia herba-alba*.

Country / Plant part	CS	PMS	IP	Oil yield	Main components (⩾5%)	Reference
Algeria						
Aerial part	Wild			0.1–0.7	Chrysanthenone 5–55, α-thujone t-26, β-thujone 6–16, camphor 6–16, bornyl acetate t-8, 1,8-cineole t-6	Boutekedjiret et al. 1992 in (a)
n.r.	Wild			0.7	Camphor 2–48, α-thujone 2–27, chrysanthenone 5–23, β-thujone 2–22, 1,8-cineole 8–18	Vernin et al. 1995 in (a)
Leaves and stems	Wild	Dry	H	1.0 (w/w)	Camphor 19, *trans*-pinocarveol 17, chrysanthenone 16, β-thujone 15	Dob and Benabdelkader (2006)
n.r.	Wild	n.r.	H	n.r.	β-Thujone 32–41, camphor 16–25, cineol 0.1–10	Benabdellah et al. (2006)
Aerial parts	Wild	n.r.	SD*	1.5–3.3 (w/w)	Chrysanthenone 31–54, camphor 11–27, filifolone 5–9, 1,8-cineole 2–9	Boutemak et al. (2009)
Aerial parts flowering phase	Wild	Dry	H	0.6 (w/w)	Camphor 49, 1,8-cineole 13, borneol 7, pinocarvone 6, camphene 5	Dahmani-Hamzaoui and Baaliouamer (2010)
Flowering tops	Wild	Dry	H	1.0 (v/w)	*cis*-Chrysanthenyl acetate 25, α-thujone 8, 2*E*,3*Z*-2-ethyliden-6-methyl-3,5-heptadienal 8, verbenone 7, myrtenyl acetate 7, chrysanthenone 5	Bezza et al. (2010)
Egypt						
Leaves	Wild	Fresh	SD	1.6 (v/w)	Carvone, piperitone (no% given)	Saleh et al. (2006)
Israel and Sinai						
Leaves, stems and flowers	Wild	Dry	SD	0.1–1.7 (v/w)	1,8-cineole 5–50, thujone n.d. 27, camphor 0.1–25, *cis*-chrysanthenol n.d. 25, *cis*-chrysanthenyl acetate n.d. 25, iso-thujone n.d. 12, borneol n.d. 11, artemisia alcohol n.d. 10, santolina alcohol n.d. 6, yomogi alcohol n.d. 9, xanthoxylin n.d. 9, lyratol n.d. 6, terpinen-4-ol 1–5	Feuerstein et al. (1986)
n.r.	Wild	Fresh	H	0.1–1.9	*cis*-Chrysanthenyl acetate n.d. 69, β-thujone t-44, camphor n.d. 42, α-thujone n.d. 41, *cis*-chrysanthenol n.d. 30, 1,8-cineole 0.2–27, *cis*-chrysanthenyl propionate n.d. 7, camphene n.d. 5	Fleisher et al. (2002)
Jordan						
Leaves, stems and flowers	UG	Dry	H	1.3 (v/w)	α-Thujone 16, santolina alcohol 13, artemisia ketone 12, β-thujone 9, trans-sabinyl acetate 5, germacrene-D 5, caryophyllene acetate 5	Hudaib and Aburjai (2006)
Morocco						
Aerial parts	Wild	Dry	H	n.r.	α-Thujone 2–74, β-thujone 1–84, camphor 5–70	Benjilali and Richard (1980)
Aerial parts	Wild	Dry	H	2.0	Chrysanthenone 31, camphor 24, camphene 5	Ouachikh et al. (2009)
Aerial parts flowering phase	Wild	Fresh	H	1.3–3.3 (v/w)	α-Thujone n.d. 74, chrysanthenone n.d. 53, camphor 9–46, β-thujone n.d. 16, borneol t-10, 1,8-cineole 0.3–8, camphene 0.2–8	Paolini et al. (2010)

Leaves	Wild	Dry	H	022	Verbenol 22, bisabolene oxide 18, farnesene epoxide 17, β-thujone 6, camphor 5	Tilaoui et al. (2011)
Spain						
Leaves	Wild	Dry	SD	0.6	Camphor 15, 1,8-cineole 13, α-terpineol 6, borneol 5, chrysanthenone 5, terpinen-4-ol 5	Feuerstein et al. (1988)
Aerial parts flowering phase**	Wild	Dry	H	0.8(w/w)	Davanone 18, *p*-cymene 14, 1,8-cineole 10, chrysanthenone 7, *cis*-chrysanthenyl acetate 6, γ-terpinene 6, myrcene 5	Salido et al. (2001)
Flowering tops	Wild	Dry	SD	0.4–2.3 (w/w)	Davanone n.d. 51, chrysanthenone n.d. 36, *cis*-chrysanthenol n.d. 28, 1,8-cineole 2–26, *p*-cymene 5–21, *cis*-chrysanthenyl acetate n.d. 18, α-pinene t-17, camphor n.d. 17, myrcene 1–11, bornyl acetate n.d. 9, γ-terpinene 1–6, γ-muurolene 1–5, spathulenol 1–5, davana ether n.d. n.d. 5	Salido et al. (2004)
Tunisia						
Leaves	Wild	n.r.	H	1.9 (v/w)	Pinocarvone 38, isoamyl 2-methylbutyrate 20, α-copaene 12, limonene 11	Neffati et al. (2008)
Leaves and flowers	S	Dry	H	0.7–1.9 (v/w)	α-Thujone n.d. 42, β-thujone n.d. 24, 1,8-cineole 1–28, sabinyl acetate n.d. 23, davanone n.d. 20, camphor n.d. 18, davana ether isomers n.d. 16, chrysanthenone n.d. 17, borneol n.d. 11, *cis*-chrysanthenyl acetate n.d. 10, yomogi alcohol n.d. 10, terpinen-4-ol 1–9, germacrene-D n.d. 7, bicyclogermacrene 1–6, *cis*-sabinol n.d. 6, davana ether n.d. 6, 3-hydroxyisodavanone n.d. 5, *trans*-pinocarveol n.d. 5	Mohsen and Ali (2009)
Leaves and flowers	EF	F/D	H	1.7–2.5 (v/w)	β-Thujone 18–25, α-thujone 13–23, camphor 9–13, chrysanthenone 7–11, 1,8-cineole 7–9, *trans*-sabinyl acetate 4–7, terpinen-4-ol 3–5	Mighri et al. (2009a)
Aerial parts (flowering phase and vegetative phase)	EF	Dry***	H	1.6–2.2 (v/w)	β-Thujone 16–34, α-thujone 14–24, 1,8-cineole 6–12, camphor 5–10, *trans*-sabinyl acetate 3–6, terpinen-4-ol 2–5	Mighri et al. (2009c)
Leaves and flowers	EF	Dry	H	0.9–2.4 (w/w)	β-Thujone 20–34, α-thujone 12–26, 1,8-cineole 6–23, camphor 5–12, chrysanthenone 1–9, *trans*-sabinyl acetate 1–7, terpinen-4-ol 2–5	Mighri et al. (2009b)
Leaves and flowers	Wild	Dry	H	1.1–2.3	β-Thujone 17–58, α-thujone 7–44, 1,8-cineole 6–17, camphor 4–11, *trans*-sabinyl acetate 5–7, chrysanthenone 3–7	Mighri et al. (2010a)

(continued on next page)

Table 1 (*continued*)

Country / Plant part	CS	PMS	IP	Oil yield	Main components (⩾5%)	Reference
Leaves and flowers	EF	Dry	H	n.r.	β-Thujone 14–58, α-thujone 6–49, 1,8-cineole 5–18, camphor 4–11, *trans*-sabinyl acetate 3–8	Mighri et al. (2010b)
Leaves and flowers	Wild	Dry	H	1.2–4.9 (v/w)	α-Thujone n.d. 80, chrysanthenone n.d. 65, camphor n.d. 48, *trans*-sabinyl acetate n.d. 44, 1,8-cineole 1–24, davanone n.d. 21, β-thujone n.d. 18, trans-pinocarveol n.d. 15, borneol n.d. 11, *cis*-chrysanthenyl acetate n.d. 11, camphene n.d. 10, *p*-cymene n.d. 9, germacrene-D 1–5, terpinen-4-ol n.d. 6, pinocarvone n.d. 5	Boukrich et al. (2010)
Leaves and flowers	Wild	Dry	H	1.5 (v/w)	*cis*-Chrysanthenyl acetate 11, α-thujone 9, sabinyl acetate 9, davana ether 6, chrysanthenone 5	Zouari et al. (2010)
Aerial parts	Wild	Dry	H	n.r.	α-Thujone 25, germacrene-D 15, camphor 11, 1,8-cineole 9, β-thujone 8, lepidozene 6, chrysanthenone 5, sabinyl acetate 5	Kadri et al. (2011)

* (a) data in Dob and Benabdelkader (2006). CS: Collection site. UG: University garden. S: Sub-cultured plants with different origins. EF: Experimental field. PMS: Plant material status. IP: Isolation Procedure. H: hydrodistillation. SD: steam-distillation. F/D: Fresh and different drying processes.

* SD: under different experimental conditions.

** *Artemisia herba-alba* Asso ssp. *valentine* (Lam.) Marcl. was evaluated in this case.

*** Dry: Different harvests. n.d.: not detected. n.r.: not reported. t = trace (<0.05%).

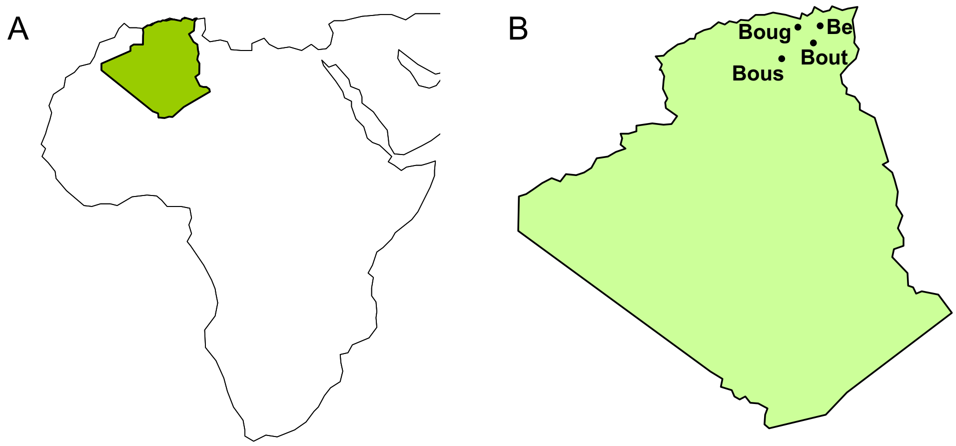

Figure 1 Algeria geographical location (a) and collection sites (b) of *Artemisia herba-alba*. Benifouda (Be); Bougaa (Boug); Boussaada (Bous) and Boutaleb (Bout).

need for a taxonomic study of the whole group. In the present study we followed the traditional criterion of this species delimitation. Eleven spontaneous *Artemisia* species are present in the Algerian flora (Quezel and Santa 1963). *Artemisia herba-alba* Asso = [*Artemisia aragonensis* Lam., *Seriphidium herba-alba* (Asso) Soják] (Greuter, 2006–2009), commonly known as white wormwood or desert wormwood (Arabic name *chih*), is a greyish-strongly aromatic dwarf shrub native to the South western Europe, Northern Africa, Arabian Peninsula and Western Asia.

The economic value, the local medicinal uses, the disappearance in some areas due to pasture and over-collection, as well as the potential use to restore degraded ecosystems support the large number of studies on *A. herba-alba*. A recent review detailed the distribution, taxonomy, morphology, phytochemistry and biological activities of *A. herba-alba* and its different extracts (Mohamed et al., 2010).

Among *A. herba-alba* phytochemical constituents, essential oils have been extensively studied, with several chemotypes being recognized. The variability from the essential oils isolated from *A. herba-alba* collected at Algeria, Israel, Morocco and Spain was revised by Dob and Benabdelkader in 2006, but, since then, many other studies reinforced its high chemical polymorphism (Table 1, and references therein). Plants were collected from wild in different countries, grown under controlled experimental field conditions, collected at different harvesting times, subject to different drying periods and processes, extracted fresh or dry, by hydrodistillation or steam-distillation under different experimental conditions, and different aerial plant parts have been used (Table 1).

The aim of the present study was both to evaluate the chemical composition of the essential oils isolated from *A. herba-alba* collected at different locations in Algeria, and to compare these data with an updated survey on the chemical variability of this species essential oils.

2. Experimental

2.1. Plant material

The aerial parts of *A. herba-alba* were collected during the flowering (July, 2008) and vegetative phase of the plant (October and November, 2008) at different localities in Algeria (Benifouda; Bougaa; Boussaada and Boutaleb), characterized by diverse geographic and climate conditions (Fig. 1, Table 2). Plant material was dried in the dark, at room temperature. Certified voucher specimens have been deposited in the Herbarium of the Faculty of Nature and Life Sciences at F. A. University, Setif, Algeria.

2.2. Essential oil isolation

The essential oils were isolated from the dried plant material by hydrodistillation for 3 h, at a distillation rate of 3 $ml.min^{-1}$, using a Clevenger-type apparatus according to the European Pharmacopoeia (Council of Europe, 2007). The essential oils were stored at −20 °C in the dark until analysis.

2.3. Essential oil analysis

2.3.1. Gas chromatography (GC)

Gas chromatographic analyses were performed using a Perkin Elmer Autosystem XL gas chromatograph equipped with two

Table 2 Data on altitude, precipitation and temperature range at the collection sites of Algerian *Artemisia herba-alba*.

Average/Year	*Artemisia herba-alba*			
	Benifouda (Be)	Bougaa (Boug)	Boussaada (Bous)	Boutaleb (Bout)
Altitude (m)	821	914	459	1321
Precipitation (mm)	500	500	17	300
Temperature (°C)	2–38	2–38	3–42	−2– 40

Data gathered from official Headquarter Maps [Carte d'État Major (CEM); CEM SoukNadjaa paper 169, CEM SaintArnaud, paper 98, CEM AinRoua, paper 69] and from the National Meteorology Office (Office National de la Météorologie).

Table 3 Percentage composition of the essential oils isolated by hydrodistillation from *Artemisia herba-alba* collected at different sites in Algeria.

Components	RI	*Artemisia herba-alba*			
		Benifouda Nov-08	Bougaa Jul-08	Boussaada Oct-08	Boutaleb Nov-08
Santolina triene	911	0.7	0.2	1.3	t
Tricyclene	921	0.2	0.3	0.2	t
α-Thujene	924	t	t	t	t
α-Pinene	930	0.4	0.8	0.8	t
Camphene	938	7.1	4.2	4.1	0.7
Sabinene	958	0.2	0.2	0.7	0.3
1-Octen-3-ol	961	t	t	t	t
β-Pinene	963	0.1	0.3	0.3	t
1,2,4-Trimethyl benzene	978	0.4	0.4	0.2	0.2
1-Decene	995	t	t	t	t
α-Phellandrene	995	0.2	0.8	0.3	t
1,2,3-Trimethyl benzene	1001	0.2	0.7	t	1.0
α-Terpinene	1002	0.3	0.1	0.1	0.6
p-Cymene	1003	0.8	0.9	0.4	0.6
1,8-Cineole	1005	8.6	8.2	9.8	3.0
Limonene	1009	t	t	t	t
Santolina alcohol	1011	t	t	0.7	t
γ-Terpinene	1035	0.3	0.8	0.6	0.3
trans-Sabinene hydrate	1037	t	0.8	0.4	0.2
Filifolene*	1074	3.9	1.0	1.1	2.8
α-Thujone	1074	6.9	28.1	27.7	23.5
β-Thujone	1081	1.9	7.8	3.4	3.0
Chrysanthenone*	1081	12.2	3.9	7.6	19.0
α-Campholenal	1088	t	0.1	0.4	0.3
trans-*p*-2-Menthen-1-ol	1095	0.7	0.5	1.0	0.5
Camphor	1095	33.1	22.8	17.3	18.7
trans-Pinocarveol	1106	1.1	0.7	0.5	0.3
cis-Verbenol	1110	0.9	0.3	t	0.4
trans-Verbenol	1114	1.1	0.1	0.7	t
Pinocarvone	1121	1.7	1.5	1.1	0.6
Borneol	1134	2.5	2.0	1.9	1.5
Terpinen-4-ol	1148	0.6	0.6	1.0	0.7
Myrtenal	1153	0.2	0.2	t	0.2
Myrtenol	1168	t	0.1	0.6	t
trans-Carveol	1189	t	0.1	0.3	t
cis-Carveol	1202	0.1	0.2	t	0.1
Carvone	1206	t	0.1	0.1	t
cis-Ocimenone	1206	t	0.1	0.2	t
Piperitone	1211	0.4	0.3	t	0.2
cis-Chrysanthenyl acetate	1241	0.5	0.2	1.2	t
Bornyl acetate	1265	0.3	0.3	0.2	0.2
Carvacrol	1286	0.3	0.7	t	t
β-Copaene	1426	t	t	0.1	0.1
β-Ylangene	1435	t	t	0.2	t
allo-Aromadendrene	1456	t	t	t	t
γ-Muurolene	1469	2.4	0.7	3.5	7.1
Bicyclogermacrene	1487	0.7	0.4	1.1	2.5
δ-Cadinene	1505	0.1	t	0.2	0.5
Spathulenol	1551	0.1	0.4	0.2	1.0
Ledol	1580	t	t	0.1	0.2
% of identification		91.2	91.9	91.6	90.3
Grouped components					
Monoterpene hydrocarbons		14.2	9.6	9.9	5.3
Oxygen-containing monoterpenes		73.1	79.7	76.1	72.4
Sesquiterpene hydrocarbons		3.2	1.1	5.1	10.2
Oxygen-containing sesquiterpenes		0.1	0.4	0.3	1.2
Others		0.6	1.1	0.2	1.2
Oil Yield (%, v/dry weight)		0.79	0.94	0.72	0.16

RI = Retention index relative to C_9–C_{16} *n*-alkanes on the DB-1 column, t = trace (< 0.05%).
* Identification based on mass spectra only.

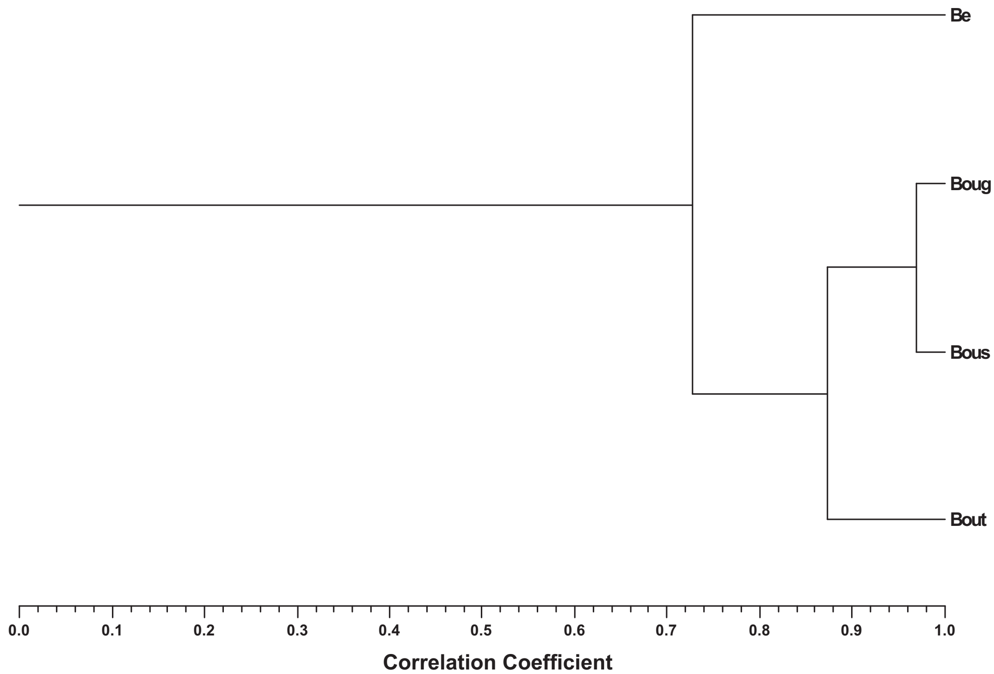

Figure 2 Dendrogram obtained by cluster analysis of the percentage composition of the essential oils isolated from *Artemisia herba-alba* samples based on correlation and using unweighted pair-group method with arithmetic average (UPGMA). Benifouda (Be); Bougaa (Boug); Boussaada (Bous) and Boutaleb (Bout).

polarities were installed: a DB-1 fused-silica column (polydimethylsiloxane, 30 m × 0.25 mm i.d., film thickness 0.25 μm; J & W Scientific Inc., Rancho Cordova, CA, USA) and a DB-17HT fused-silica column [(50% phenyl)-methylpolysiloxane, 30 m × 0.25 mm i.d., film thickness 0.15 μm; J & W Scientific Inc.]. Oven temperature was programed, 45–175 °C, at 3 °C min^{-1}, subsequently at 15 °C.min^{-1} up to 300 °C, and then held isothermal for 10 min; injector and detector temperatures, 280 °C and 300 °C, respectively; carrier gas, hydrogen, adjusted to a linear velocity of 30 cm.s^{-1}. The samples were injected using split sampling technique, ratio 1:50. The volume of injection was 0.1 μL of a pentane-volatiles solution (1:1). The percentage composition of the essential oils was computed by the normalization method from the GC peak areas, calculated as mean values of two injections from each sample, without using correction factors.

2.3.2. Gas chromatography–Mass spectrometry (GC-MS)

The GC–MS unit consisted of a Perkin Elmer Autosystem XL gas chromatograph, equipped with DB-1 fused-silica column (30 m × 0.25 mm i.d., film thickness 0.25 μm; J & W Scientific, Inc.), and interfaced with a Perkin–Elmer Turbomass mass spectrometer (software version 4.1, Perkin Elmer, Shelton, CT, USA). Injector and oven temperatures were as above; transfer line temperature, 280 °C; ion source temperature, 220 °C; carrier gas, helium, adjusted to a linear velocity of 30 cm.s^{-1}; split ratio, 1:40; ionization energy, 70 eV; scan range, 40-300 u; scan time, 1 s. The identity of the components was assigned by comparison of their retention indices, relative to C_9–C_{16} *n*-alkane indices and GC-MS spectra from a home-made library, constructed based on the analyses of reference oils, laboratory-synthesized components and commercial available standards.

2.4. Statistical analysis

The percentage composition of the isolated essential oils was used to determine the relationship between the different samples by cluster analysis using Numerical Taxonomy Multivariate Analysis System (NTSYS-pc software, version 2.2, Exeter Software, Setauket, New York) (Rohlf, 2000). For cluster analysis, correlation coefficient was selected as a measure of similarity among all accessions, and the Unweighted Pair Group Method with Arithmetical Averages (UPGMA) was used for cluster definition. The degree of correlation was evaluated according to Pestana and Gageiro (2000) and classified as very high (0.9-1), high (0.7-0.89), moderate (0.4-0.69), low (0.2-0.39) and very low (< 0.2).

3. Results and discussion

The aerial parts of *A. herba-alba* were collected at different localities in Algeria (Benifouda; Bougaa; Boussaada and Boutaleb), characterized by diverse geographic and climate conditions (Fig. 1, Table 2).

A. herba-alba populations studied afforded oils in a yield ranging from 0.2% (Boutaleb) to 0.9% (Bougaa) (v/d.w.), respectively, (Table 3). The oil yields recorded in the present study were within the ranges reported in the literature [0.1–4.9% (v/w), (Table 1)], and, as referred by Mighri et al. (2009b), where higher at the flowering phase.

A. herba-alba identified oil components are listed in Table 3 in order of their elution on the DB-1 column. Monoterpenes (78–89%) and particularly oxygen-containing monoterpenes (72–80%) dominated all oils. Sesquiterpenes ranged from 2–11% (Table 3).

A. herba-alba essential oils percentage composition was used to determine the relationship between the different samples, and allowed the definition of two clusters, Fig. 2. Cluster I was a one sample group as included only the Benifouda (Be) oil, which was dominated by camphor (33%) and chrysanthenone (12%), Table 3. Cluster II included the more correlated oil samples (S_{corr} > 0.88) from Bougaa (Boug), Boussaada (Bous) and Boutaleb (Bout). α-Thujone, which was < 7% in Be oil, was dominant in Cluster II sample oils (24–28%). Boug, Bous and Bout samples from Cluster II showed also large percentages of camphor (17–23%), and a wide range in chrysanthenone (4–19%) relative amount, Table 3.

Overall, the essential oil profiles of all samples were similar (S_{corr} > 0.7), although with some variation in the relative amount of the three main components, camphor (17–33%), α-thujone (7–28%) and chrysanthenone (4–19%). Despite the global resemblance, three types of oils could be defined, (a) α-thujone : camphor (Bougaa and Boussaada plants oils), (b) camphor : chrysanthenone (Benifouda plant oil) and (c) α-thujone : camphor : chrysanthenone (Boutaleb plant oil), Fig. 2.

No relationship could be drawn between the chemical composition of *A. herba-alba* essential oils and the four regions of Algeria (Benifouda; Bougaa; Boussaada and Boutaleb) where the samples were collected, nor with the altitude of the collection sites, temperature or humidity ranges (Tables 2 and 3, Fig. 2). This was confirmed by the fact that the most similar essential oil profiles were those isolated from plants collected during the flowering phase in Bougaa and during the vegetative phase in Boussaada (Tables 2 and 3, Fig. 2).

A review of the existing literature on *A. herba-alba* essential oils afforded a large number of studies, particularly in the last two years (Table 1). Although the isolation procedure was similar in most cases, the plant parts, the physiological stage, the plant status (fresh or dry), and the geographical origin were quite diverse, in addition to the use of collective samples and to the possibility of existing different subspecies. Only seldom studies have used individual plants, and even in those cases no clear correlation between plant oil types and environmental conditions was established (Fleisher et al., 2002).

With high percentage variability, α-thujone (n.d. 80%) and β-thujone (n.d. 58%) were reported in studies from all countries (Table 1). Although not mentioned in Table 1, because this table includes only components with a relative amount ⩾5%, the occurrence of α-thujone and β-thujone was also reported in one study from Spain (Villar et al., 1983; in Salido et al., 2001). With exception of the work published on Jordanian *A. herba-alba* (Hudaib and Aburjai, 2006) (Table 1), chrysantenone (n.d. 65%), camphor (n.d. 49%) and 1,8-cineole (n.d. 28%) occurrence was always mentioned in, at least, some studies from all other countries (Table 1). In addition, with a more restricted occurrence, davanone (Spain and Tunisia) and *cis*-chrysanthenyl acetate (Israel, Sinai, Spain and Tunisia) attained also relatively high percentages (n.d. 51% and n.d. 69%, respectively) (Table 1). Usually one of these seven compounds or some of them, in different proportions, dominate *A. herba-alba* essential oils, which is in agreement with the results here reported for samples collected at different Algerian sites.

The chemical variability of essential oils from Algerian *A. herba-alba* emphasizes the importance of evaluating individual plant samples, as well as the worth of avoiding wild plant material collection, not only due to the innate variation, which has a negative market impact, but also to impair biodiversity depletion. In view of this, it seems most adequate to recognize which chemovariety best fits the market demands and develop sustainable culture methodologies for local *A. herba-alba* crop production.

Acknowledgements

The invaluable help of Dr Carles Benedí (Universidade de Barcelona) on providing information on updated international Floras, and Dr Maria de Lurdes Saramago (Biblioteca de Biologia da Faculdade de Ciências da Universidade de Lisboa) on making available several references is greatly acknowledged. Rachid Belhattab acknowledges MESRS (Algeria) the financial support that allowed the training period at the FCUL/CBV/IBB, Portugal.

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