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VOLATILE COMPOUNDS IN OLEO-GUM RESIN OF SOCOTRAN SPECIES OF *BURSERACEAE*

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Abstract

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Socotra Island is well known for its high rate of plant species endemism and having the highest concentration of frankincense species in the world. Thirteen species in *Burseraceae* occur on the island, of which 12 are endemic. A total of only four species from the island have had the chemical compositions of their resins published. Moreover, in general, most studies on chemical composition of frankincense and myrrh resins have analysed samples that were not freshly collected (including some of considerable age). Our study therefore aimed at analysing the volatile compound composition of all Socotran *Burseraceae* species, using fresh resin sample analysis. We found a total of 103 volatile compounds in all the species, with 53 of them fully identified, 27 of them partially determined and 23 still unidentified. These include four compounds (*α*-fenchene, calarene, trans-*β*-farnesene, *α*-elemene) newly reported from *Boswellia* and two (phytol and ledene) newly reported from *Commiphora*. Our results suggested the huge potential to find new chemical compounds among endemic Burseracean species.

Keywords: *Boswellia*, *Commiphora*, oleo-gum resin, terpenes, GC-MS analysis

INTRODUCTION

Two genera, *Boswellia* and *Commiphora*, of the *Burseraceae* family occur on Socotra Island, on the border between the Indian Ocean and Gulf of Aden. Globally, genus *Boswellia* contains between 20 to 30 species (Daly, *et al.*, 2011; Weeks, *et al.*, 2005) according to different authors. These occur in the tropical arid zone of India, Arabia (Yemen, Oman) and Africa. In contrast, *Commiphora* is globally much more speciose, containing approximately 185 species found not only in Asia, Arabia and Africa but also in South America (Daly, *et al.*, 2011). Both genera are famous for their oleo-gum resin production (popular names frankincense or olibanum and myrrh) with commercial applications for pharmaceutical and cosmetic purposes, and some having long been used as incense for religious ceremonies (Shen, *et al.*, 2012; Mothana, 2011; Sun, *et al.*, 2011; Shen, *et al.*, 2008; Basar, 2005). The Socotra island wasn't exception and the frankincense was used and exported since ancient time (Miller, *et al.*, 2004; Naumkin, *et al.*, 1993)

From Socotra Island, eight species of *Boswellia* have been described, all of them endemic, and five species of *Commiphora*, four of them endemic (Brown, *et al.*, 2012; Miller, *et al.*, 2004). Socotra has the highest concentration of frankincense species in the world (Thulin, 2001).

However, the exploration of this subject has been quite unequal across species. Thus, although there have been a number of studies (Bekana, *et al.*, 2014; Hussain, *et al.*, 2013; Al-Saidi, *et al.*, 2012; Assefa, *et al.*, 2012; Paul, *et al.*, 2012; Shen, *et al.*, 2012; Woolley, *et al.*, 2012; Mothana, 2011; Mothana, *et al.*, 2011; Sun, *et al.*, 2011; Li, *et al.*, 2010; Van Vuuren, *et al.*, 2010; Mertens, *et al.*, 2009; Al-Harrasi, *et al.*, 2008; Shen, *et al.*, 2008; Camarda, *et al.*, 2007; Singh, *et al.*, 2007; Frank, *et al.*, 2006; Kubmarawa, *et al.*, 2006; Marongiu, *et al.*, 2006; Basar, 2005; Hamm, *et al.*, 2005; Mathe, *et al.*, 2004; Badria, *et al.*, 2003; Baser, *et al.*, 2003; Hammet, *et al.*, 2003; Mikhaeil, *et al.*, 2003; Dekebo, *et al.*, 2002e; Kasali, *et al.*, 2002; Dekebo, *et al.*, 1999; Verghese, *et al.*, 1987; Strappaghetti, *et al.*, 1982) on commercially important species (*Boswellia sacra/carterii, B. papyrifera, B. serrata, B. frereana, B. neglecta, B. rivae, B. dalzielli*), we have practically zero knowledge about the chemical composition of resin of species that have small geographical distributions, including various endemic species. For example, only one study of *Boswellia pirottae*, a species endemic to Ethiopia (Baser, *et al.*, 2003), has been published as has only one study of three endemic species (*B. elongata*, *B. socotrana* and *B. disoscorides*) from Socotra Island (Mothana, *et al.*, 2011). Their authors extracted essentials oils by hydrodistillation of tree bark. For genus *Commiphora*, an even smaller proportion of Socotra endemic species has been investigated, regarding their oleo-gum resin chemical composition of *Commiphora* species, as only that of *C. socotrana* is mentioned in the literature (Blitzke, *et al.*, 2001).

Due to the socio-economic and cultural-historical importance of oleo-gum resins, these substances have been subjected to a great deal of investigation. Using different chromatographic methods (Paul, *et al.*, 2012; Fei, *et al.*, 2011; Paul, *et al.*, 2011; Mertens, *et al.*, 2009; Pozharitskaya, *et al.*, 2006; Basar, 2005; Büchele, *et al.*, 2003a; 2003b; Hamm, *et al.*, 2003; Brody, *et al.*, 2002; Sane, *et al.*, 1998), 311 (Mertens, *et al.*, 2009) to 340 (Hussain, *et al.*, 2013) chemical compounds in *Boswellia* genus have been found in its oleo-gum resin, including compounds new to science (Büchele, *et al.*, 2003; Culioli, *et al.*, 2003; Dekebo, *et al.*, 2002a; 2002b; 2002c; 2002d; 2002e; Basar, *et al.*, 2001; Dekebo, *et al.*, 2000; Klein, *et al.*, 1978). Similarly, in *Commiphora*, more than 300 chemical compounds have been found (Shen, *et al.*, 2012). These analyses have mostly been done on samples that were not freshly collected, mostly including materials obtained commercially (Al-Saidi, *et al.*, 2012; Paul, *et al.*, 2012; Van Vuuren, *et al.*, 2010; Shah, *et al.*, 2008; Frank, *et al.*, 2006; Pozharitskaya, *et al.*, 2006; Mathe, *et al.*, 2004; Culioli, *et al.*, 2003), and often even from archaeological materials (Mathe, *et al.*, 2007; Modugno, *et al.*, 2006; Hamm, *et al.*, 2004; Mathe, *et al.*, 2004; Van Bergen, *et al.*, 1997).

The bio-degradation of frankincense hasn't yet been study. The subject of study are only the thermal degradation after burning (Mathe, *et al.*, 2007) and the products of degradation in archeological samples (Mathe, *et al.*, 2004; Modugno, *et al.*, 2006).

The aims of this study are to: (i) assess the feasibility of the methodology of fresh-resin sampling and analyse the fresh samples; and (ii) investigate the oleo-gum resin chemical compositions of Socotran endemic species of *Boswellia* and *Commiphora*, for which no data have yet been published.

MATERIAL AND METHODS

Socotra Island. Socotra Island is situated on the border between the Indian Ocean and Gulf Aden, 12°06′–12°42′N latitude and 52°03′–54°32′E longitude. The island belongs to the arid tropical climatological zone (Scholte, *et al.*, 2010; Culek, *et al.*, 2006), with corresponding character of local vegetation (Brown, *et al.*, 2012). Almost 900 plant species occur on the island, 38 % of them endemic (Miller, *et al.*, 2004).

Oleo-gum resin sampling (plant material). Oleo-gum resin sampling was done in May 2010, January 2011 and March 2012. The Environment Protection Authority of Republic of Yemen responsible for a Socotra UNESCO Biosphere Reserve issued the permission for samples collection and exportation.

Just after tapping the trees, freshly dripping resin was collected in glass vials, to which was immediately added 2 ml of methanol (Chromasolv®, Sigma-Aldrich). The tubes were closed with Teflon closing caps, to prevent samples degradation and contamination. The sample trees were identified and pictures of significant identifying features were taken. The geographic coordinates of each sampled tree were determined by GPS and recorded.

Oleo-gum resins of all *Boswellia* and *Commiphora* species growing on the island were sampled from 1–4 individuals of each, yielding totals of 22 samples of *Boswellia* and 5 samples of *Commiphora*.

Boswellia ameero (4 samples)

Boswellia sp.A (2 samples)

Boswellia bullata (1 sample)

Boswellia dioscorides (3 samples)

Boswellia elongata (4 samples)

Boswellia nana (1 sample)

Boswellia popoviana (4 samples)

Boswellia socotrana (3 samples)

Commiphora kua (1 sample) – non endemic

Commiphora ornifolia (1 sample)

Commpihora parvifolia (1 sample)

Commiphora planifrons (1 sample)

Commiphora socotrana (1 sample)

No herbarium specimens were not taken from any of the sample trees, because the island belongs to the UNESCO Biosphere Reserve, from which exportation of any natural product is strictly prohibited. Moreover, the endemic *Boswellia* and *Commiphora* species are mostly strongly threatened (Attorre, *et al.*, 2011; Miller, *et al.*, 2004), and their disturbance is undesirable. Therefore, instead photo-documentation was used.

Extract preparation. The oleo-gum resin samples in methanol were extracted directly in the sampling glass tubes using an ultrasonic bath (Sonic 2, Polsonic, Warsawa, Poland) at ambient laboratory temperature for 15 min. The extracts were diluted 1:49 with methanol before analyses.

Analytical Methods (GC-MS Analysis of Volatiles). GC-MS analysis was done using an Agilent 6890 gas chromatograph (Agilent Technologies, USA) coupled with an Agilent 5973 N mass selective detector (Agilent Technologies, USA) with quadrupole analyser. A DB-5MS, non-polar fused silica capillary GC column with a 5 % phenyl-methylsiloxan stationary phase (30 m × 0.32 mm i.d. × 1.0 μm film thickness - J and W Scientific, Agilent Technologies, USA), was used. The chromatograph was equipped with a split-splitless injector, and the split ratio was 1:40 or splitless as required. The injector temperature was set at 250 °C. A sample of 1 μl was injected manually by use of a microsyringe (Hamilton Company, USA). The carrier gas helium, with constant flow 1.2 ml/min, was used. The oven temperature was initially programmed at 40 °C for 2 min, then increased from 40 °C to 240 °C at 8 °C/min, and held at this temperature for 20 min. The temperatures of the ion source and the transfer line were set at 230°C and 280 °C , respectively. The MS was operated in a positive electron ionization mode at 70 eV, with the MS spectra recorded in SCAN mode within an m/z range from 25 to 550. Identification of the individual components was based on computer search using digital libraries of mass spectral data NIST 05 and Wiley 275k and on comparing the elution orders and retention times of the individual compounds on the DB-5MS column with data published in the literature (www.massfinder.com/wiki/Terpenoids_Library_List 2015; www.pherobase.com/database/kovats-index.php 2015; Camarda, *et al.*, 2007; Hamm, *et al.*, 2005; Hamm, *et al.*, 2003). The relative amount of each detected compound was calculated as the ratio of the individual peak area to the sum of areas of all peaks in the chromatogram expressed as area percentage.

RESULTS

In total, 103 volatile substances were distinguished (Tab. I). Of these, 53 volatile substances were fully identified, 27 were partially identified (i.e., their relatedness to mono-, di- or sesquiterpenes was found) and 23 compounds remained completely undetermined. However, the undetermined compounds were mostly present in very low amounts. The average content of fully identified compounds was 84 %, with the highest proportions of these compounds found in resins of *Boswellia dioscorides* (99 %), and the lowest in resins from *Commiphora parvifolia* (60.7 %). A total of 79 volatile compounds were distinguished in *Boswellia*, of which 19 compounds were determined only partially and 13 remained undetermined. Similarly, 78 volatile compounds were distinguished in *Commiphora*, of which 16 compounds were determined partially and 18 remained undetermined.

We identified 25 volatile compounds that in our samples were found only in *Boswellia* species, and 24 volatile compounds only in *Commiphora* species. We found 54 common compounds common to both genera. In *Boswellia*, 15 compounds occurred in more than 50 % of the samples, and the highest average concentrations (more than 1 %) were found for α-thujene, α-pinene, terpinen-4-ol, sabinene, trans-β-farnesene, p-cymene, β-myrcene, β-pinene, β-caryophyllene. In *Commiphora*, 19 compounds occurred with frequency higher than 50 %, and the highest average concentrations (more than 2 %) were reached by β-eudesmol, α-cadinol, terpinen-4-ol, limonene, α-humulene, p-cymene, phytol, α-thujene. While α-thujene was quite prevalent in *Boswellia* species, the quantitative composition of volatile compounds in *Commiphora* species was more balanced.

The main difference between the genera was in their quantitative proportions of particular groups of terpenic compounds, i.e. mono-, sesqui- and diterpenes. *Boswellia* had an average proportion of monoterpenes of 77 % (31 compounds, 24 fully identified, 5 partially identified, 2 unidentified), while *Commiphora* contained on average only 38 % monoterpenes (33 compounds: 21 fully identified, 4 partially identified, 8 unidentified). On average, sesquiterpenes constituted 10 % (40 compounds: 22 fully identified, 8 partially identified, 10 unidentified) in *Boswellia*, while in *Commiphora* these formed on average 51 % (39 compounds: 22 fully identified, 9 partially identified, 8 unidentified). Diterpenes occurred in both genera in low proportions, on average 13 % in *Boswellia* (8 compounds, 1 fully identified, 6 partially identified, 1 unidentified), and 9 % in *Commiphora* (6 compounds, 1 fully identified, 3 partially identified, 2 unidentified).

DISCUSSION

The review articles (Hussain, *et al.*, 2013; Shen, *et al.*, 2012; Mertens, *et al.*, 2009) mention more than 300 compounds in both genera. We found four compounds in the analysed Socotran *Boswellia* species that have not previously been reported from this genus. These comprise α-fenchene (*B.ameero*, *B.elongata*, *B.popoviana*), calarene (*B.bullata*), trans-β-farnesene (all *Boswellia* species except *B.dioscorides* and *B.socotrana*) a α-elemene (*B.sp.A*, *B.bullata*), all of which were found in low frequencies and concentrations except for trans-β-farnesene, which occurred with a frequency of 68.2 % and average concentration of 3.292 %. In *Commiphora* samples, we found two compounds, phytol (*C.parviflora*) and ledene (*C.socotrana*), that have not previously been reported from the genus.

Large variability in presence/absence of particular compounds was found not only among species but also within species. This variability could have been caused by different features of the site environment of sample trees or differences in the time of sampling (Mertens, *et al.*, 2009); it could also have been caused by different ages of sampled trees or stages of ontogenetic development of the tree part (stem base or annual shoots), from which the resins were taken (Assefa, *et al.*, 2012).

We compared our results with analyses of archaeological samples (Hamm, *et al.*, 2004), in which significantly lower proportions of more volatile monoterpenes were documented than by our fresh oleo-gum samples. To prevent the bio-degradation and loss of more volatile substances, we recommend the fresh resin sampling and analysing.

I: *Volatile compounds in oleo-gum resin of Socotran species of Burseraceae (BAM = Boswellia ameero, BA = B. sp. A, BB = B. bullata, BD = B. dioscoridis, BE = B. elongata, BN = B. nana, BP = B. popoviana, BS = B. socotrana, CO = Commiphora ornifolia, CPA = C. parviflora, CPL = C. planifrons, CK = C. kua, CS = C. socotrana; a = Compounds presented in order of elution on the DB5-MS capillary column, b = Retention time of compound on the DR5-MS capillary column, c = Percentage based on peak area)*

					BAM	BAM	BAM	BAM	BA	BA	BB
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]
1.	α-Thujene	136	C10H16	11.140	37,5 %	26,4 %	41,6 %	72,1 %	38,0 %	59,9 %	3,4 %
2.	α-Pinene	136	C10H16	11.440	20,5 %	7,2 %	1,7 %	2,8 %	15,5 %	5,1 %	
3.	α-Fenchene	136	C10H16	11.841	2,5 %						
4.	Camphene	136	C10H16	11.887	1,4 %						
5.	MT1	136	C10H16	11.939	0,1 %						
6.	Sabinene	136	C10H16	12.325	6,8 %	1,0 %	2,6 %	6,1 %	3,1 %	4,7 %	0,2 %
7.	β-Pinene	136	C10H16	12.453	1,2 %	0,4 %		0,3 %	0,3 %		
8.	β-Myrcene	136	C10H16	12.546	1,3 %	0,9 %	2,1 %	0,7 %	0,5 %	0,9 %	
9.	α-Phellandrene	136	C10H16	13.019					5,1 %		
10.	3-δ-Carene	136	C10H16	13.203							
11.	α-Terpinene	136	C10H16	13.269							
12.	MT2	134	C10H14	13.316							
13.	p-Cymene	134	C10H14	13.425	6,0 %	2,4 %	3,7 %	1,4 %	0,2 %	1,0 %	0,1 %
14.	Limonene	136	C10H16	13.543	0,2 %	0,1 %	2,5 %				
15.	MT3	136	C10H16	13.584	0,5 %	0,4 %	0,7 %				
16.	β-Phellandrene	136	C10H16	13.589				0,3 %	0,2 %	0,3 %	
17.	γ-Terpinene	136	C10H16	14.232				0,7 %	0,3 %	0,8 %	
18.	cis-Sabinene hydrate	154	C10H18O	14.348		0,4 %	0,5 %				
19.	Terpinolene	136	C10H16	14.746		0,3 %	0,5 %				
20.	MT4	132	C10H12	14.758							
21.	unknown 1	166		14.772				0,2 %	1,0 %	0,1 %	0,2 %
22.	trans-Sabinene hydrate	154	C10H18O	15.020		0,3 %	0,3 %				
23.	MT5	132	C10H12	15.066							
24.	unknown 2			15.301						0,2 %	
25.	Fenchol	154	C10H18O	15.384	0,2 %						
26.	MT6	154	C10H18O	15.417							
27.	cis-Verbenol	152	C10H16O	15.810							
28.	trans-Verbenol	152	C10H16O	16.019							
29.	Borneol	154	C10H18O	16.541							
30.	α-Phelandrene epoxide	152	C10H16O	16.702							
31.	4-Terpineol	154	C10H18O	16.740	0,3 %	26,1 %	14,1 %				
32.	α-Terpineol	154	C10H18O	16.945			0,4 %				
33.	Myrtenol	152	C10H16O	17.058							

					BAM	BAM	BAM	BAM	BA	BA	BB
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]
34.	unknown 3			17.184							
35.	unknown 4	136		17.880							
36.	unknown 5			18.434							
37.	Bornyl acetate	196	C12H20O2	18.630							
38.	MT7	136	C10H16	18.673							
39.	unknown 6	150		19.056							
40.	unknown 7			19.081							
41.	unknown 8			19.304							
42.	α-Terpinenyl acetate	196	C12H20O2	19.690							
43.	δ-Elemene	204	C15H24	19.698							0,3 %
44.	α-Cubenene	204	C15H24	19.919							0,4 %
45.	MT8	152	C10H16O	20.360	0,6 %						
46.	α-Ylangene	204	C15H24	20.370							2,2 %
47.	α-Copaene	204	C15H24	20.390							2,6 %
48.	β-Bourbonene	204	C15H24	20.605					0,3 %		0,5 %
49.	α-Gurjunene	204	C15H24	21.035							
50.	Calarene	204	C15H24	21.230							3,3 %
51.	β-Caryophyllene	204	C15H24	21.239	1,2 %	0,7 %	1,0 %		0,2 %	0,3 %	7,2 %
52.	ST1	204	C15H24	21.272							1,2 %
53.	ST2	204	C15H24	21.275					5,2 %		7,3 %
54.	trans-β-Farnesene	204	C15H24	21.347	3,1 %	6,1 %	8,9 %	5,0 %	8,2 %	4,3 %	7,5 %
55.	unknown 9	236		21.750							0,2 %
56.	α-Humulene	204	C15H24	21.761	0,3 %	0,2 %	0,2 %				3,2 %
57.	Aromadendrene	204	C15H24	21.842							0,3 %
58.	α-Amorphene	204	C15H24	22.094					0,3 %		1,3 %
59.	ST3	204	C15H24	22.153							1,5 %
60.	unknown 10			22.301	1,1 %	0,4 %	0,2 %				
61.	ST4	204	C15H24	22.417					1,3 %		0,2 %
62.	Germacrene D	204	C15H24	22.513					4,3 %		3,3 %
63.	α-Elemene	204	C15H24	22.525					4,3 %		3,4 %
64.	unknown 11			22.627						0,2 %	2,1 %
65.	Ledene	204	C15H24	22.714							
66.	ST5	220	C15H24O	22.955							
67.	γ-Cadinene	204	C15H24	22.987							2,0 %
68.	unknown 12	236		23.009							4,7 %
69.	δ-Cadinene	204	C15H24	23.018					0,3 %		8,6 %
70.	unknown 13	180		23.042							
71.	unknown 14	236		23.279							0,8 %
72.	ST6	204	C15H24	23.401					0,2 %		
73.	Elemol	222	C15H26O	23.422					0,1 %		0,3 %
74.	unknown 15	236		23.714							
75.	unknown 16	236		23.882							0,1 %
76.	Caryophyllene oxide	220	C15H24O	23.892	0,3 %						
77.	Guaiol	222	C15H26O	23.932							8,4 %
78.	Viridiflorol	222	C15H26O	24.027							
79.	unknown 17	236		24.044							0,3 %
80.	ST7	204	C15H24	24.090							

					BAM	BAM	BAM	BAM	BA	BA	BB
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]
81.	ST8	204	C15H24	24.243							0,4 %
82.	ST9	204	C15H24	24.589							
83.	unknown 18	236		24.599							0,3 %
84.	α-Cadinol	222	C15H26O	24.646							6,9 %
85.	ST10	204	C15H24	24.697							
86.	ST11	204	C15H24	24.709							
87.	a-Eudesmol	222	C15H26O	24.945							1,8 %
88.	unknown 19	264		25.053							6,2 %
89.	unknown 20	264	C17H28O2	25.094							
90.	unknown 21			25.388							
91.	ST12	204	C15H24	27.208							
92.	β-Eudesmol	222	C15H26O	27.261							
93.	DT1	272	C20H32	28.140	0,3 %	0,5 %	0,4 %				
94.	DT2	272	C20H32	28.985							
95.	DT3	272	C20H32	29.546	1,6 %	2,2 %	2,1 %	0,6 %	0,3 %	1,2 %	0,4 %
96.	DT4	272	C20H32	29.547				0,1 %		0,3 %	0,1 %
97.	DT5	272	C20H32	29.776							
98.	DT6	272	C20H32	30.348	0,2 %	0,2 %					
99.	Phytol	296	C20H40O	32.448							
100.	unknown 22	262		32.475							
101.	Cerbrene	272	C20H32	33.772			9,2 %	5,2 %	2,7 %	9,3 %	3,0 %
102.	DT7	272	C20H32	33.893	3,9 %	7,1 %					
103.	unknown 23	306		34.486	7,4 %	16,4 %	7,0 %	3,9 %	7,6 %	10,9 %	3,7 %
	Identified				98,4 %	99,7 %	99,6 %	99,5 %	99,6 %	99,5 %	99,8 %

					BD	BD	BD	BE	BE	BE	BE
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]
1.	α-Thujene	136	C10H16	11.140	56,6 %	60,3 %	69,5 %	59,1 %		49,2 %	16,2 %
2.	α-Pinene	136	C10H16	11.440	8,3 %	1,3 %	10,5 %	0,3 %	34,3 %	1,0 %	0,9 %
3.	α-Fenchene	136	C10H16	11.841					2,0 %		
4.	Camphene	136	C10H16	11.887							
5.	MT1	136	C10H16	11.939					0,3 %		
6.	Sabinene	136	C10H16	12.325	10,0 %	4,6 %	7,4 %	4,8 %		3,6 %	16,1 %
7.	β-Pinene	136	C10H16	12.453		0,3 %	6,0 %	0,4 %	12,5 %		
8.	β-Myrcene	136	C10H16	12.546	6,0 %	0,7 %	1,2 %	2,1 %	4,1 %	5,3 %	1,5 %
9.	α-Phellandrene	136	C10H16	13.019							
10.	3-δ-Carene	136	C10H16	13.203							
11.	α-Terpinene	136	C10H16	13.269							0,3 %
12.	MT2	134	C10H14	13.316							0,6 %
13.	p-Cymene	134	C10H14	13.425	1,3 %	2,2 %	2,3 %	0,8 %	6,4 %	9,4 %	3,2 %
14.	Limonene	136	C10H16	13.543	0,2 %				0,3 %	0,2 %	
15.	MT3	136	C10H16	13.584	1,1 %	0,5 %			2,0 %		
16.	β-Phellandrene	136	C10H16	13.589			0,5 %	0,3 %			0,2 %
17.	γ-Terpinene	136	C10H16	14.232			0,7 %	0,7 %			0,7 %
18.	cis-Sabinene hydrate	154	C10H18O	14.348	0,4 %	1,0 %			2,2 %	0,3 %	
19.	Terpinolene	136	C10H16	14.746	0,5 %	0,3 %			0,8 %		
20.	MT4	132	C10H12	14.758					0,1 %		

					BD	BD	BD	BE	BE	BE	BE
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]
21.	unknown 1	166		14.772			0,7 %	0,2 %			0,7 %
22.	trans-Sabinene hydrate	154	C10H18O	15.020	0,2 %	0,5 %			0,9 %	0,2 %	
23.	MT5	132	C10H12	15.066							
24.	unknown 2			15.301				0,2 %			
25.	Fenchol	154	C10H18O	15.384							
26.	MT6	154	C10H18O	15.417							
27.	cis-Verbenol	152	C10H16O	15.810						0,2 %	
28.	trans-Verbenol	152	C10H16O	16.019						0,1 %	
29.	Borneol	154	C10H18O	16.541							
30.	α-Phelandrene epoxide	152	C10H16O	16.702							
31.	4-Terpineol	154	C10H18O	16.740	14,0 %	26,5 %	0,2 %		15,8 %	13,1 %	
32.	α-Terpineol	154	C10H18O	16.945	0,2 %				0,2 %		
33.	Myrtenol	152	C10H16O	17.058							
34.	unknown 3			17.184							
35.	unknown 4	136		17.880							
36.	unknown 5			18.434							
37.	Bornyl acetate	196	C12H20O2	18.630	0,2 %		0,3 %			0,1 %	
38.	MT7	136	C10H16	18.673							
39.	unknown 6	150		19.056							
40.	unknown 7			19.081							
41.	unknown 8			19.304							
42.	α-Terpinenyl acetate	196	C12H20O2	19.690							
43.	δ-Elemene	204	C15H24	19.698							
44.	α-Cubenene	204	C15H24	19.919							
45.	MT8	152	C10H16O	20.360						1,7 %	
46.	α-Ylangene	204	C15H24	20.370							
47.	α-Copaene	204	C15H24	20.390							
48.	β-Bourbonene	204	C15H24	20.605							
49.	α-Gurjunene	204	C15H24	21.035							0,6 %
50.	Calarene	204	C15H24	21.230							
51.	β-Caryophyllene	204	C15H24	21.239	0,6 %	1,1 %	0,5 %	0,4 %	3,4 %	1,2 %	0,7 %
52.	ST1	204	C15H24	21.272							
53.	ST2	204	C15H24	21.275							
54.	trans-β-Farnesene	204	C15H24	21.347				5,9 %	7,7 %	2,3 %	0,2 %
55.	unknown 9	236		21.750							
56.	α-Humulene	204	C15H24	21.761		0,2 %			0,7 %	0,4 %	0,1 %
57.	Aromadendrene	204	C15H24	21.842							
58.	α-Amorphene	204	C15H24	22.094							
59.	ST3	204	C15H24	22.153							
60.	unknown 10			22.301					0,6 %	0,3 %	
61.	ST4	204	C15H24	22.417							
62.	Germacrene D	204	C15H24	22.513							
63.	α-Elemene	204	C15H24	22.525							
64.	unknown 11			22.627							
65.	Ledene	204	C15H24	22.714							
66.	ST5	220	C15H24O	22.955							
67.	γ-Cadinene	204	C15H24	22.987							

					BD	BD	BD	BE	BE	BE	BE
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	%[c]	%[c]	%[c]	%[c]	%[c]	%[c]	%[c]
68.	unknown 12	236		23.009							
69.	δ-Cadinene	204	$C_{15}H_{24}$	23.018							
70.	unknown 13	180		23.042							
71.	unknown 14	236		23.279							
72.	ST6	204	$C_{15}H_{24}$	23.401				0,1 %			
73.	Elemol	222	$C_{15}H_{26}O$	23.422							
74.	unknown 15	236		23.714							
75.	unknown 16	236		23.882							
76.	Caryophyllene oxide	220	$C_{15}H_{24}O$	23.892						1,8 %	0,2 %
77.	Guaiol	222	$C_{15}H_{26}O$	23.932							
78.	Viridiflorol	222	$C_{15}H_{26}O$	24.027							
79.	unknown 17	236		24.044							
80.	ST7	204	$C_{15}H_{24}$	24.090							0,2 %
81.	ST8	204	$C_{15}H_{24}$	24.243							
82.	ST9	204	$C_{15}H_{24}$	24.589							
83.	unknown 18	236		24.599							
84.	α-Cadinol	222	$C_{15}H_{26}O$	24.646							
85.	ST10	204	$C_{15}H_{24}$	24.697							
86.	ST11	204	$C_{15}H_{24}$	24.709							
87.	a-Eudesmol	222	$C_{15}H_{26}O$	24.945							
88.	unknown 19	264		25.053							
89.	unknown 20	264	$C_{17}H_{28}O_2$	25.094							0,1 %
90.	unknown 21			25.388							
91.	ST12	204	$C_{15}H_{24}$	27.208							
92.	β-Eudesmol	222	$C_{15}H_{26}O$	27.261							
93.	DT1	272	$C_{20}H_{32}$	28.140					0,7 %		0,4 %
94.	DT2	272	$C_{20}H_{32}$	28.985						0,8 %	
95.	DT3	272	$C_{20}H_{32}$	29.546				1,4 %	3,5 %	0,4 %	5,5 %
96.	DT4	272	$C_{20}H_{32}$	29.547				0,3 %			
97.	DT5	272	$C_{20}H_{32}$	29.776							
98.	DT6	272	$C_{20}H_{32}$	30.348					1,2 %		
99.	Phytol	296	$C_{20}H_{40}O$	32.448							
100.	unknown 22	262		32.475							
101.	Cerbrene	272	$C_{20}H_{32}$	33.772				13,1 %		1,0 %	28,5 %
102.	DT7	272	$C_{20}H_{32}$	33.893						1,1 %	
103.	unknown 23	306		34.486				9,6 %		1,5 %	22,6 %
	Identified				99,5 %	99,6 %	99,7 %	99,7 %	99,5 %	95,1 %	99,7 %

					BN	BP	BP	BP	BP	BS	BS
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	%[c]	%[c]	%[c]	%[c]	%[c]	%[c]	%[c]
1.	α-Thujene	136	$C_{10}H_{16}$	11.140	57,6 %	55,3 %	29,9 %	51,5 %	67,3 %		46,0 %
2.	α-Pinene	136	$C_{10}H_{16}$	11.440	5,9 %		2,7 %	1,7 %	0,4 %	55,2 %	5,4 %
3.	α-Fenchene	136	$C_{10}H_{16}$	11.841		1,2 %				2,0 %	
4.	Camphene	136	$C_{10}H_{16}$	11.887		1,2 %					
5.	MT1	136	$C_{10}H_{16}$	11.939							
6.	Sabinene	136	$C_{10}H_{16}$	12.325	10,4 %	1,2 %	2,0 %	3,0 %	3,9 %		1,7 %
7.	β-Pinene	136	$C_{10}H_{16}$	12.453	10,2 %	0,7 %	0,9 %		0,3 %	1,3 %	

					BN	BP	BP	BP	BP	BS	BS
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	%[c]	%[c]	%[c]	%[c]	%[c]	%[c]	%[c]
8.	β-Myrcene	136	C10H16	12.546		0,7 %	0,9 %	2,2 %	0,6 %	11,4 %	18,5 %
9.	α-Phellandrene	136	C10H16	13.019							
10.	3-δ-Carene	136	C10H16	13.203		0,5 %					
11.	α-Terpinene	136	C10H16	13.269					0,1 %		
12.	MT2	134	C10H14	13.316							
13.	p-Cymene	134	C10H14	13.425	0,2 %	9,0 %	10,9 %	3,4 %	0,5 %	0,7 %	7,1 %
14.	Limonene	136	C10H16	13.543	0,3 %		0,1 %	3,0 %		8,0 %	0,4 %
15.	MT3	136	C10H16	13.584		0,2 %	0,3 %	0,8 %		6,8 %	1,3 %
16.	β-Phellandrene	136	C10H16	13.589	0,5 %				0,2 %		
17.	γ-Terpinene	136	C10H16	14.232					1,0 %		
18.	cis-Sabinene hydrate	154	C10H18O	14.348							
19.	Terpinolene	136	C10H16	14.746		0,2 %	0,3 %	0,6 %		1,3 %	0,8 %
20.	MT4	132	C10H12	14.758							0,2 %
21.	unknown 1	166		14.772	7,9 %				0,4 %		
22.	trans-Sabinene hydrate	154	C10H18O	15.020							
23.	MT5	132	C10H12	15.066							
24.	unknown 2			15.301					0,2 %		
25.	Fenchol	154	C10H18O	15.384		0,1 %	0,2 %			0,4 %	
26.	MT6	154	C10H18O	15.417							
27.	cis-Verbenol	152	C10H16O	15.810					0,1 %		
28.	trans-Verbenol	152	C10H16O	16.019							
29.	Borneol	154	C10H18O	16.541						1,1 %	
30.	α-Phelandrene epoxide	152	C10H16O	16.702							
31.	4-Terpineol	154	C10H18O	16.740		6,4 %	8,0 %	7,0 %		6,8 %	15,8 %
32.	α-Terpineol	154	C10H18O	16.945			0,1 %	0,2 %		2,5 %	0,1 %
33.	Myrtenol	152	C10H16O	17.058							
34.	unknown 3			17.184							
35.	unknown 4	136		17.880							
36.	unknown 5			18.434							
37.	Bornyl acetate	196	C12H20O2	18.630	0,5 %					0,2 %	
38.	MT7	136	C10H16	18.673							
39.	unknown 6	150		19.056							
40.	unknown 7			19.081							
41.	unknown 8			19.304							
42.	α-Terpinenyl acetate	196	C12H20O2	19.690							0,4 %
43.	δ-Elemene	204	C15H24	19.698							
44.	α-Cubenene	204	C15H24	19.919							
45.	MT8	152	C10H16O	20.360		0,3 %					
46.	α-Ylangene	204	C15H24	20.370							
47.	α-Copaene	204	C15H24	20.390							
48.	β-Bourbonene	204	C15H24	20.605	0,1 %						
49.	α-Gurjunene	204	C15H24	21.035					0,3 %		
50.	Calarene	204	C15H24	21.230							
51.	β-Caryophyllene	204	C15H24	21.239	0,6 %	1,7 %	4,3 %	1,0 %	2,2 %		0,2 %
52.	ST1	204	C15H24	21.272	0,2 %						
53.	ST2	204	C15H24	21.275							
54.	trans-β-Farnesene	204	C15H24	21.347	0,2 %		3,7 %	9,2 %	0,3 %		

					BN	BP	BP	BP	BP	BS	BS
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]
55.	unknown 9	236		21.750					0,5 %		
56.	α-Humulene	204	C15H24	21.761		0,4 %	1,9 %	0,2 %			
57.	Aromadendrene	204	C15H24	21.842							
58.	α-Amorphene	204	C15H24	22.094							
59.	ST3	204	C15H24	22.153							
60.	unknown 10			22.301		0,7 %	2,4 %	0,2 %			
61.	ST4	204	C15H24	22.417							
62.	Germacrene D	204	C15H24	22.513							
63.	α-Elemene	204	C15H24	22.525							
64.	unknown 11			22.627							
65.	Ledene	204	C15H24	22.714							
66.	ST5	220	C15H24O	22.955							
67.	γ-Cadinene	204	C15H24	22.987							
68.	unknown 12	236		23.009							
69.	δ-Cadinene	204	C15H24	23.018					0,1 %		
70.	unknown 13	180		23.042							
71.	unknown 14	236		23.279							
72.	ST6	204	C15H24	23.401							
73.	Elemol	222	C15H26O	23.422							
74.	unknown 15	236		23.714							
75.	unknown 16	236		23.882							
76.	Caryophyllene oxide	220	C15H24O	23.892		0,8 %	0,9 %				
77.	Guaiol	222	C15H26O	23.932							
78.	Viridiflorol	222	C15H26O	24.027							
79.	unknown 17	236		24.044							
80.	ST7	204	C15H24	24.090							
81.	ST8	204	C15H24	24.243							
82.	ST9	204	C15H24	24.589		0,2 %	1,0 %				
83.	unknown 18	236		24.599							
84.	α-Cadinol	222	C15H26O	24.646							
85.	ST10	204	C15H24	24.697							
86.	ST11	204	C15H24	24.709							
87.	a-Eudesmol	222	C15H26O	24.945							
88.	unknown 19	264		25.053							
89.	unknown 20	264	C17H28O2	25.094							
90.	unknown 21			25.388							
91.	ST12	204	C15H24	27.208							
92.	β-Eudesmol	222	C15H26O	27.261							
93.	DT1	272	C20H32	28.140		0,6 %	0,7 %	0,4 %		0,4 %	0,4 %
94.	DT2	272	C20H32	28.985						1,2 %	1,2 %
95.	DT3	272	C20H32	29.546	0,2 %	2,8 %	3,0 %	2,0 %	0,8 %		
96.	DT4	272	C20H32	29.547					0,2 %		
97.	DT5	272	C20H32	29.776							
98.	DT6	272	C20H32	30.348		0,4 %	0,7 %				
99.	Phytol	296	C20H40O	32.448							
100.	unknown 22	262		32.475							
101.	Cerbrene	272	C20H32	33.772	1,3 %	12,8 %			6,3 %		

					BN	BP	BP	BP	BP	BS	BS
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]
102.	DT7	272	C20H32	33.893			5,0 %	5,3 %			
103.	unknown 23	306		34.486	3,7 %		17,0 %	7,6 %	13,9 %		
	Identified				99,9 %	97,6 %	97,0 %	99,4 %	99,6 %	99,3 %	99,5 %

					BS	Frequency	Mean
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**	**%**
1.	α-Thujene	136	C10H16	11.140		86,4	40,8 %
2.	α-Pinene	136	C10H16	11.440	92,4 %	90,9	12,4 %
3.	α-Fenchene	136	C10H16	11.841		18,2	0,3 %
4.	Camphene	136	C10H16	11.887	0,3 %	13,6	0,1 %
5.	MT1	136	C10H16	11.939		9,1	0,0 %
6.	Sabinene	136	C10H16	12.325		86,4	4,2 %
7.	β-Pinene	136	C10H16	12.453	2,9 %	63,6	1,7 %
8.	β-Myrcene	136	C10H16	12.546	0,3 %	90,9	2,8 %
9.	α-Phellandrene	136	C10H16	13.019		4,5	0,2 %
10.	3-δ-Carene	136	C10H16	13.203		4,5	0,0 %
11.	α-Terpinene	136	C10H16	13.269		9,1	0,0 %
12.	MT2	134	C10H14	13.316		4,5	0,0 %
13.	p-Cymene	134	C10H14	13.425		95,5	3,3 %
14.	Limonene	136	C10H16	13.543	1,4 %	54,5	0,8 %
15.	MT3	136	C10H16	13.584		50,0	0,7 %
16.	β-Phellandrene	136	C10H16	13.589		36,4	0,1 %
17.	γ-Terpinene	136	C10H16	14.232		31,8	0,2 %
18.	cis-Sabinene hydrate	154	C10H18O	14.348		27,3	0,2 %
19.	Terpinolene	136	C10H16	14.746		45,5	0,3 %
20.	MT4	132	C10H12	14.758		9,1	0,0 %
21.	unknown 1	166		14.772	2,4 %	45,5	0,6 %
22.	trans-Sabinene hydrate	154	C10H18O	15.020		27,3	0,1 %
23.	MT5	132	C10H12	15.066		0,0	0,0 %
24.	unknown 2			15.301		13,6	0,0 %
25.	Fenchol	154	C10H18O	15.384		18,2	0,0 %
26.	MT6	154	C10H18O	15.417		0,0	0,0 %
27.	cis-Verbenol	152	C10H16O	15.810		9,1	0,0 %
28.	trans-Verbenol	152	C10H16O	16.019		4,5	0,0 %
29.	Borneol	154	C10H18O	16.541		4,5	0,1 %
30.	α-Phelandrene epoxide	152	C10H16O	16.702		0,0	0,0 %
31.	4-Terpineol	154	C10H18O	16.740		59,1	7,0 %
32.	α-Terpineol	154	C10H18O	16.945		31,8	0,2 %
33.	Myrtenol	152	C10H16O	17.058		0,0	0,0 %
34.	unknown 3			17.184		0,0	0,0 %
35.	unknown 4	136		17.880		0,0	0,0 %
36.	unknown 5			18.434		0,0	0,0 %
37.	Bornyl acetate	196	C12H20O2	18.630		22,7	0,1 %
38.	MT7	136	C10H16	18.673		0,0	0,0 %
39.	unknown 6	150		19.056		0,0	0,0 %
40.	unknown 7			19.081		0,0	0,0 %
41.	unknown 8			19.304		0,0	0,0 %

					BS	Frequency	Mean
No.[a]	Compounds	MW	Molecular formula	RT[b]	%[c]	%	%
42.	α-Terpinenyl acetate	196	C12H20O2	19.690		4,5	0,0 %
43.	δ-Elemene	204	C15H24	19.698		4,5	0,0 %
44.	α-Cubenene	204	C15H24	19.919		4,5	0,0 %
45.	MT8	152	C10H16O	20.360		13,6	0,1 %
46.	α-Ylangene	204	C15H24	20.370		4,5	0,1 %
47.	α-Copaene	204	C15H24	20.390		4,5	0,1 %
48.	β-Bourbonene	204	C15H24	20.605		13,6	0,0 %
49.	α-Gurjunene	204	C15H24	21.035		9,1	0,0 %
50.	Calarene	204	C15H24	21.230		4,5	0,2 %
51.	β-Caryophyllene	204	C15H24	21.239		86,4	1,3 %
52.	ST1	204	C15H24	21.272		9,1	0,1 %
53.	ST2	204	C15H24	21.275		9,1	0,6 %
54.	trans-β-Farnesene	204	C15H24	21.347		68,2	3,3 %
55.	unknown 9	236		21.750		9,1	0,0 %
56.	α-Humulene	204	C15H24	21.761		50,0	0,3 %
57.	Aromadendrene	204	C15H24	21.842		4,5	0,0 %
58.	α-Amorphene	204	C15H24	22.094		9,1	0,1 %
59.	ST3	204	C15H24	22.153		4,5	0,1 %
60.	unknown 10			22.301		36,4	0,3 %
61.	ST4	204	C15H24	22.417		9,1	0,1 %
62.	Germacrene D	204	C15H24	22.513		9,1	0,3 %
63.	α-Elemene	204	C15H24	22.525		9,1	0,3 %
64.	unknown 11			22.627		9,1	0,1 %
65.	Ledene	204	C15H24	22.714		0,0	0,0 %
66.	ST5	220	C15H24O	22.955		0,0	0,0 %
67.	γ-Cadinene	204	C15H24	22.987		4,5	0,1 %
68.	unknown 12	236		23.009		4,5	0,2 %
69.	δ-Cadinene	204	C15H24	23.018		13,6	0,4 %
70.	unknown 13	180		23.042		0,0	0,0 %
71.	unknown 14	236		23.279		4,5	0,0 %
72.	ST6	204	C15H24	23.401		9,1	0,0 %
73.	Elemol	222	C15H26O	23.422		9,1	0,0 %
74.	unknown 15	236		23.714		0,0	0,0 %
75.	unknown 16	236		23.882		4,5	0,0 %
76.	Caryophyllene oxide	220	C15H24O	23.892		22,7	0,2 %
77.	Guaiol	222	C15H26O	23.932		4,5	0,4 %
78.	Viridiflorol	222	C15H26O	24.027		0,0	0,0 %
79.	unknown 17	236		24.044		4,5	0,0 %
80.	ST7	204	C15H24	24.090		4,5	0,0 %
81.	ST8	204	C15H24	24.243		4,5	0,0 %
82.	ST9	204	C15H24	24.589		9,1	0,1 %
83.	unknown 18	236		24.599		4,5	0,0 %
84.	α-Cadinol	222	C15H26O	24.646		4,5	0,3 %
85.	ST10	204	C15H24	24.697		0,0	0,0 %
86.	ST11	204	C15H24	24.709		0,0	0,0 %
87.	a-Eudesmol	222	C15H26O	24.945		4,5	0,1 %
88.	unknown 19	264		25.053		4,5	0,3 %

No.[a]	Compounds	MW	Molecular formula	RT[b]	BS %[c]	Frequency %	Mean %
89.	unknown 20	264	C17H28O2	25.094		4,5	0,0 %
90.	unknown 21			25.388		0,0	0,0 %
91.	ST12	204	C15H24	27.208		0,0	0,0 %
92.	β-Eudesmol	222	C15H26O	27.261		0,0	0,0 %
93.	DT1	272	C20H32	28.140		45,5	0,2 %
94.	DT2	272	C20H32	28.985		13,6	0,1 %
95.	DT3	272	C20H32	29.546		72,7	1,3 %
96.	DT4	272	C20H32	29.547		22,7	0,0 %
97.	DT5	272	C20H32	29.776		0,0	0,0 %
98.	DT6	272	C20H32	30.348		22,7	0,1 %
99.	Phytol	296	C20H40O	32.448		0,0	0,0 %
100.	unknown 22	262		32.475		0,0	0,0 %
101.	Cerbrene	272	C20H32	33.772		50,0	4,2 %
102.	DT7	272	C20H32	33.893		22,7	1,0 %
103.	unknown 23	306		34.486		63,6	6,0 %
	Identified				99,6 %		

No.[a]	Compounds	MW	Molecular formula	RT[b]	CO %[c]	CPA %[c]	CPL %[c]	CK %[c]	CS %[c]	Frequency %	Mean %
1.	α-Thujene	136	C10H16	11.140	14,5%			0,2%	0,2%	60,0	3,0%
2.	α-Pinene	136	C10H16	11.440	4,2%	1,2%	0,4%	2,3%	0,3%	100,0	1,7%
3.	α-Fenchene	136	C10H16	11.841						0,0	0,0%
4.	Camphene	136	C10H16	11.887						0,0	0,0%
5.	MT1	136	C10H16	11.939						0,0	0,0%
6.	Sabinene	136	C10H16	12.325			1,5%		2,0%	40,0	0,7%
7.	β-Pinene	136	C10H16	12.453	0,6%	1,1%		0,2%		60,0	0,4%
8.	β-Myrcene	136	C10H16	12.546	1,2%					20,0	0,2%
9.	α-Phellandrene	136	C10H16	13.019					0,2%	20,0	0,0%
10.	3-δ-Carene	136	C10H16	13.203			9,3%			20,0	1,9%
11.	α-Terpinene	136	C10H16	13.269			0,9%		0,5%	40,0	0,3%
12.	MT2	134	C10H14	13.316						0,0	0,0%
13.	p-Cymene	134	C10H14	13.425	2,2%		13,5%		6,7%	60,0	4,5%
14.	Limonene	136	C10H16	13.543	0,4%	10,9%		5,3%	5,5%	80,0	4,4%
15.	MT3	136	C10H16	13.584	0,4%					20,0	0,1%
16.	β-Phellandrene	136	C10H16	13.589		3,8%	0,7%	0,3%	0,3%	80,0	1,0%
17.	γ-Terpinene	136	C10H16	14.232			2,9%		1,5%	40,0	0,9%
18.	cis-Sabinene hydrate	154	C10H18O	14.348						0,0	0,0%
19.	Terpinolene	136	C10H16	14.746	0,1%		2,9%		0,7%	60,0	0,7%
20.	MT4	132	C10H12	14.758						0,0	0,0%
21.	unknown 1	166		14.772			0,2%		0,2%	40,0	0,1%
22.	trans-Sabinene hydrate	154	C10H18O	15.020						0,0	0,0%
23.	MT5	132	C10H12	15.066			0,4%		0,3%	40,0	0,1%
24.	unknown 2			15.301			4,4%		2,9%	40,0	1,5%
25.	Fenchol	154	C10H18O	15.384			2,2%		0,3%	40,0	0,5%
26.	MT6	154	C10H18O	15.417			3,5%		0,6%	40,0	0,8%
27.	cis-Verbenol	152	C10H16O	15.810			8,8%		2,8%	40,0	2,3%
28.	trans-Verbenol	152	C10H16O	16.019						0,0	0,0%

					CO	CPA	CPL	CK	CS	Frequency	Mean
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**	**%**
29.	Borneol	154	C10H18O	16.541	0,9%					20,0	0,2%
30.	α-Phelandrene epoxide	152	C10H16O	16.702			1,4%			20,0	0,3%
31.	4-Terpineol	154	C10H18O	16.740	10,6%		20,4%		3,0%	60,0	6,8%
32.	α-Terpineol	154	C10H18O	16.945	0,5%					20,0	0,1%
33.	Myrtenol	152	C10H16O	17.058			1,9%			20,0	0,4%
34.	unknown 3			17.184			6,7%		2,3%	40,0	1,8%
35.	unknown 4	136		17.880			3,1%		0,2%	40,0	0,7%
36.	unknown 5			18.434			2,4%			20,0	0,5%
37.	Bornyl acetate	196	C12H20O2	18.630	0,3%					20,0	0,1%
38.	MT7	136	C10H16	18.673		0,9%				20,0	0,2%
39.	unknown 6	150		19.056			0,7%		0,2%	40,0	0,2%
40.	unknown 7			19.081		3,5%			1,9%	40,0	1,1%
41.	unknown 8			19.304		2,3%			1,5%	40,0	0,8%
42.	α-Terpinenyl acetate	196	C12H20O2	19.690						0,0	0,0%
43.	δ-Elemene	204	C15H24	19.698				0,7%		20,0	0,1%
44.	α-Cubenene	204	C15H24	19.919				0,2%		20,0	0,0%
45.	MT8	152	C10H16O	20.360						0,0	0,0%
46.	α-Ylangene	204	C15H24	20.370		7,8%			0,2%	40,0	1,6%
47.	α-Copaene	204	C15H24	20.390		9,2%		0,7%	0,2%	60,0	2,0%
48.	β-Bourbonene	204	C15H24	20.605				2,2%		20,0	0,4%
49.	α-Gurjunene	204	C15H24	21.035						0,0	0,0%
50.	Calarene	204	C15H24	21.230				0,3%		20,0	0,1%
51.	β-Caryophyllene	204	C15H24	21.239	8,2%			0,7%	0,6%	60,0	1,9%
52.	ST1	204	C15H24	21.272		0,8%				20,0	0,2%
53.	ST2	204	C15H24	21.275		2,1%				20,0	0,4%
54.	trans-β-Farnesene	204	C15H24	21.347		1,5%				20,0	0,3%
55.	unknown 9	236		21.750			0,2%	0,1%	0,2%	60,0	0,1%
56.	α-Humulene	204	C15H24	21.761	24,8%					20,0	5,0%
57.	Aromadendrene	204	C15H24	21.842				0,4%		20,0	0,1%
58.	α-Amorphene	204	C15H24	22.094		1,2%		1,8%		40,0	0,6%
59.	ST3	204	C15H24	22.153		1,3%				20,0	0,3%
60.	unknown 10			22.301						0,0	0,0%
61.	ST4	204	C15H24	22.417						0,0	0,0%
62.	Germacrene D	204	C15H24	22.513				2,0%		20,0	0,4%
63.	α-Elemene	204	C15H24	22.525				0,1%		20,0	0,0%
64.	unknown 11			22.627						0,0	0,0%
65.	Ledene	204	C15H24	22.714					1,1%	20,0	0,2%
66.	ST5	220	C15H24O	22.955					0,2%	20,0	0,0%
67.	γ-Cadinene	204	C15H24	22.987		0,5%		10,0%	0,2%	60,0	2,1%
68.	unknown 12	236		23.009		0,5%		3,3%	0,2%	60,0	0,8%
69.	δ-Cadinene	204	C15H24	23.018		0,4%		3,3%		40,0	0,7%
70.	unknown 13	180		23.042		12,2%	0,3%		2,2%	60,0	3,0%
71.	unknown 14	236		23.279		0,5%				20,0	0,1%
72.	ST6	204	C15H24	23.401						0,0	0,0%
73.	Elemol	222	C15H26O	23.422			0,2%		0,4%	40,0	0,1%
74.	unknown 15	236		23.714				0,2%		20,0	0,0%
75.	unknown 16	236		23.882				0,1%		20,0	0,0%

					CO	CPA	CPL	CK	CS	Frequency	Mean
No.[a]	**Compounds**	**MW**	**Molecular formula**	**RT**[b]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**[c]	**%**	**%**
76.	Caryophyllene oxide	220	C15H24O	23.892	1,2%	4,7%	0,8%		2,3%	80,0	1,8%
77.	Guaiol	222	C15H26O	23.932						0,0	0,0%
78.	Viridiflorol	222	C15H26O	24.027				0,2%	8,8%	40,0	1,8%
79.	unknown 17	236		24.044						0,0	0,0%
80.	ST7	204	C15H24	24.090						0,0	0,0%
81.	ST8	204	C15H24	24.243				2,2%		20,0	0,4%
82.	ST9	204	C15H24	24.589	1,0%		0,4%	0,4%	1,7%	80,0	0,7%
83.	unknown 18	236		24.599						0,0	0,0%
84.	α-Cadinol	222	C15H26O	24.646			0,4%	35,2%	2,5%	60,0	7,6%
85.	ST10	204	C15H24	24.697		6,8%	1,1%		3,8%	60,0	2,3%
86.	ST11	204	C15H24	24.709		6,8%			3,8%	40,0	2,1%
87.	a-Eudesmol	222	C15H26O	24.945		2,7%	7,0%	12,3%	35,4%	80,0	11,5%
88.	unknown 19	264		25.053				3,3%		20,0	0,7%
89.	unknown 20	264	C17H28O2	25.094						0,0	0,0%
90.	unknown 21			25.388		1,4%				20,0	0,3%
91.	ST12	204	C15H24	27.208			1,2%		1,7%	40,0	0,6%
92.	β-Eudesmol	222	C15H26O	27.261			0,2%		0,3%	40,0	0,1%
93.	DT1	272	C20H32	28.140						0,0	0,0%
94.	DT2	272	C20H32	28.985	1,0%					20,0	0,2%
95.	DT3	272	C20H32	29.546						0,0	0,0%
96.	DT4	272	C20H32	29.547						0,0	0,0%
97.	DT5	272	C20H32	29.776				7,4%		20,0	1,5%
98.	DT6	272	C20H32	30.348	15,7%					20,0	3,1%
99.	Phytol	296	C20H40O	32.448		15,7%				20,0	3,1%
100.	unknown 22	262		32.475				4,0%		20,0	0,8%
101.	Cerbrene	272	C20H32	33.772						0,0	0,0%
102.	DT7	272	C20H32	33.893						0,0	0,0%
103.	unknown 23	306		34.486	0,1%			0,1%		40,0	0,1%
	Identified				88,1%	100,0%	100,0%	99,6%	99,9%		

CONCLUSIONS

The thirteen species of *Burseraceae* family occurring naturally on Socotra Island were studied, of which twelve species are endemic. In total, 103 volatile compounds were found in oleo-gum resins, including four compounds in *Boswellia* and two compounds in *Commiphora* that have not previously been mentioned in scientific publications.

The result set contains a large proportion of compounds that we have not succeeded in identifying. Because most of the analysed species are endemic, there is a high probability of finding, by more detailed investigation, new natural compounds for science. Those, the structural investigation should follow.

Our method of fresh oleo-gum-resin sampling proved suitable with respect to field sampling and sample transport to the laboratory, as the samples are resistant to bio-degradation. The selected extraction technique that followed prevented volatile substances loss.

The oleo-gum resin of endemic species of frankincense and myrrh trees is locally used (Miller, *et al.*, 2004) and could become a relatively important export article for Socotra Island. The oleo-gum resin harvesting could increase the interest of local people in artificial reforestation and plantation (Lvončík, *et al.*, 2013) of the endangered endemic *Boswellia* (Attorre, *et al.*, 2011) and *Commiphora* species and thereby improve the protection and rescue of its populations. However, in such case we recommend to Yemeni state structure to introduce strict rules for plantation certification and thoroughly implement their adherence in order to prevent the risk of plunder of residual populations (Scholte, *et al.*, 2011).

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