

Extractable Components of the Aerial Parts of *Salvia lavandulifolia* and Composition of the Liquid Smoke Flavoring Obtained from Them

María D. Guillén* and María J. Manzanos

Tecnología de los Alimentos, Facultad de Farmacia, Universidad del País Vasco, Paseo de la Universidad 7, 01006 Vitoria, Spain

The fraction extractable with dichloromethane of the aerial parts of sage (*Salvia lavandulifolia*) and the liquid smoke obtained from this plant are studied by means of gas chromatography/mass spectrometry and gas chromatography. The extract of the aerial parts of the sage plant contains not only terpene, sesquiterpene hydrocarbons, and their oxygenated derivatives, which are interesting compounds both for their organoleptic properties and for their antioxidant activity, but also a large group of phenolic compounds with abietatriene or related structure, the mass spectra of which are given, many of them having antioxidant, antiviral, and antibacterial properties. The liquid sage smoke obtained is slightly acidic and contains common smoke components in specific proportions, and a large group of aromatic nitrogenated derivatives such as pyrazine and pyridine derivatives in small proportions, together with the main oxygenated terpene derivatives present in the plant; some of the compounds detected in this liquid smoke have not been described as smoke components before.

Keywords: *Salvia lavandulifolia*; aerial parts extract; components; liquid sage smoke; composition; gas chromatography/mass spectrometry

INTRODUCTION

The composition of commercial smoke flavorings is greatly varied from the point of view of the nature and concentration of their aromatic components. Among these preparations there is a group having a composition that is characterized by a higher proportion of carbonyl derivatives than of phenol, guaiacol, syringol, and their derivatives (Guillén and Manzanos, 1996a,b); the composition of these smoke flavorings is very similar to that of the smoke. However, there are also smoke flavorings constituted basically of phenol, guaiacol, syringol, and their derivatives, with irrelevant proportions of acids, esters, and carbonyl derivatives; the composition of these smoke flavorings is considerably different from that of the smoke (Guillén and Ibargoitia, 1998). Finally, there are commercial smoke flavorings constituted of acids, carbonyl derivatives, phenol, guaiacol, syringol, and their derivatives, these three latter groups being in a higher proportion than the former (Guillén et al., 1995); the composition of this type of smoke flavoring is also not in agreement with the composition of the smoke. Furthermore, some commercial smoke flavorings are constituted of blends with salt or with small proportions of plant material from aromatic plants or spices (Guillén and Manzanos, 1997); these flavoring preparations contain, in addition to the typical smoke components, other aromatic compounds proceeding from the plant material.

The plant raw material used traditionally to smoke foods varies widely depending on the resources in each region (Thorsteinsson, 1969; Tóth and Potthast, 1984;

Maga, 1986; Akpan et al., 1994; Ward, 1995). Some authors (Pallu, 1971) have commented that smoked foods with smoke from aromatic plants take on special, fine, and perfumed flavors. Aromatic plants are a source of compounds with organoleptic properties and on some occasions with antioxidant and antimicrobial activities. If these components of the plant cross to form part of the smoke obtained, it will be enriched in components with very interesting properties from the preserving and organoleptic points of view. However, to the best of our knowledge, studies on the composition of smoke generated from aromatic plants are very scarce (Ishihara et al., 1993; Guillén and Manzanos, 1999). Among aromatic plants, sage has been studied due to its potential as a source of flavoring compounds (Iconomou et al., 1982; Maurer and Hauser, 1983; Vernin et al., 1986; Belkamel et al., 1990; Tucker and Maciarello, 1990; Lawrence, 1991; Baser et al., 1993; Piccaglia and Marotti, 1993; Guillén and Ibargoitia, 1995) as well as for the antioxidant and preservative activity of some of its species (Brieskorn and Dömling, 1969; Bracco et al., 1981; Zhang et al., 1990; Weng et al., 1992; Schwarz and Ternes, 1992a,b; Tsimidou and Boskou, 1994; Okamura et al., 1994; Cuvelier et al., 1994a,b, 1996).

In this paper the study of the composition of a liquid smoke preparation obtained from sage (*Salvia lavandulifolia*) is shown, as well as the study of the composition of the fraction extractable in dichloromethane of the aerial parts of the aromatic plant used to obtain the smoke, to evaluate the influence of the nature of the plant on the characteristics of the smoke generated and to test the usefulness of obtaining smoke flavorings from aromatic plants. With this aim, both the aerial parts of the sage plant and the liquid smoke obtained from them

* Author to whom correspondence should be addressed (fax 34-945-130756; e-mail knpgulod@vf.ehu.es).

were extracted with an organic solvent and studied by gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS).

MATERIALS AND METHODS

Sample and Extraction of the Aerial Parts of the Plant. Wild-growing sage (*S. lavandulifolia*) plants were harvested in the spring of 1993 in Zaragoza (Aragón, Spain). Their entire aerial parts were air-dried and ground in a refrigerated mill (Janke & Kunkel IKA-Labortechnik A10), to avoid the loss of the most volatile components, to a particle size <0.5 mm.

The extraction from 1 g of the ground sage was carried out, in several steps, with 15 mL of dichloromethane as organic solvent, using an ultrasonic bath for 1 h to ensure an exhaustive extraction, as in previous studies (Guillén and Manzanos, 1998a,b). The soluble fraction was separated from the plant material by filtration and was studied by GC/MS. Multiple sage sample extraction experiments were performed.

Obtention and Extraction of the Smoke Flavoring. The smoke flavoring was obtained from the pyrolysis of 75 g of ground sage with a particle size <0.5 mm. The process was carried out in a laboratory round-bottom flask smoke generator made of quartz, as in previous experiments (Guillén and Ibargoitia, 1996; Guillén and Manzanos, 1999). The pyrolysis was started with the use of a rheostat-controlled heating mantle. The temperature was measured with a Crison thermometer 639K positioned in the center of the charge, and the maximum temperature reached was 338 °C. The experiment finished when the sage was totally pyrolyzed. The smoke resulting was filtered by means of a glass wool filter to eliminate solid particles and collected in 150 mL of distilled water. The 165 mL of aqueous liquid smoke obtained was again filtered through a paper filter. The acidity of the liquid smoke flavoring was determined by titration with 0.01 N NaOH.

Twenty-five milliliters of sage liquid smoke was extracted with 25 mL of dichloromethane by liquid-liquid extraction, in several steps, as in previous studies (Guillén et al., 1995; Guillén and Manzanos, 1996a,b, 1997). The volume of the extract was reduced to 10 mL, and the extract was kept in a refrigerator for its subsequent study. This organic solvent was selected for its low boiling point and for its high effectiveness in extracting polycyclic aromatic compounds (Guillén et al., 1991; Guillén, 1994) and aromatic compounds in general (Guillén and Manzanos, 1994, 1996c; Guillén and Ibargoitia, 1995). Parallel experiments of the smoke generation, the liquid smoke acidity determination, and this sample extraction experiment were carried out.

Identification and Quantification of the Aromatic Compounds. The study of the extract of the aerial parts of the plant was carried out by means of GC/MS; however, the separation, identification, and quantification of the aromatic components contained in the extract of the liquid smoke was studied by GC/MS and by GC with flame ionization detector (FID) techniques. Replicate chromatographic analyses of the different extracts were performed.

In both cases, the GC/MS study was performed using a Hewlett-Packard chromatograph, model 6890 series, equipped with a mass spectrometer selective detector 5973, and a Hewlett-Packard Vectra Pentium computer. A fused-silica capillary column (30 m long, 0.25 mm i.d., 0.25 μ m thickness), coated with a nonpolar stationary phase (Hewlett-Packard 5, cross-linked 5% phenyl methyl silicone) was used. The temperature program began at 50 °C (0.5 min) with an increase of 5 °C min⁻¹ up to 300 °C (10 min). Helium was used as the gas carrier. Injector and detector temperatures were 250 and 280 °C, respectively. The injection technique used was split with a split ratio 1:10, and the injection volume was 1 μ L. Mass spectra were recorded at an ionization energy of 70 eV.

Components were identified by their retention times, by their mass spectra, by comparing their mass spectra with those in a commercial library (Wiley138k, Mass Spectral Database,

1990), and, in some cases, by using standards, as in previous studies (Guillén et al., 1995; Guillén and Manzanos, 1996a,b, 1997). However, in the extract of the plant some components remained unidentified and others were only tentatively identified. Compounds used as standards for identification, available from Aldrich, Fluka, and Sigma, are asterisked in Tables 1 and 2. Components with volatility higher than or similar to that of CH₂Cl₂ were not analyzed by this technique.

The quantification of the components of the extract in dichloromethane of the aerial parts of the plant was carried out taking into account only the area of the peaks.

GC. The quantification of the components of the sage liquid smoke was accomplished with a Hewlett-Packard gas chromatograph model 5890 series II, equipped with an FID, and a Hewlett-Packard 3395 integrator. A fused-silica capillary column (30 m long, 0.32 mm i.d., 0.25 μ m thickness), coated with a nonpolar stationary phase (Hewlett-Packard-5, cross-linked 5% phenyl methyl silicone) was used. The chromatographic conditions relative to the heating program were the same as these used in the GC/MS study. Nitrogen was used as the gas carrier. Injector and detector temperatures were 250 and 300 °C, respectively. The injection technique used was splitless, and the injection volume was 1 μ L. The quantification was carried out using external standards. For quantification of the smoke components in sage liquid smoke, response factors of a large number of standard compounds, asterisked in Table 2, were determined as before (Blanco et al., 1992; Guillén et al., 1995; Guillén and Manzanos, 1996a,b, 1997). For the quantification of compounds not available commercially, response factors of compounds of similar natures and retention times were used. All standard compounds used were available from Aldrich, Fluka, and Sigma. The identification of components was based on retention times. The average concentration of the detected compounds in the volatile fraction of the extract in dichloromethane of the sage liquid smoke is given in Table 2 with two replicates.

RESULTS AND DISCUSSION

Study of the Components Extracted from the Aerial Parts of the Plant. The extraction yield of the aerial parts of *S. lavandulifolia* was 2.5% in dried weight. Figure 1 shows the total ion chromatogram of the dichloromethane extract SE, and in Table 1 are given the identified and unidentified compounds, grouped in families by their nature, together with their proportion in the sample; the relative proportions of those compounds whose separation was not good enough were not determined ("nd" in Table 1). In this extract there are compounds of very different molecular weights and natures, many of them difficult to identify and not available commercially. For unidentified compounds, the main mass fragments of their mass spectra are also given; in some cases the nature of some compounds can be deduced from their mass spectra, although their assignment to specific compounds is very difficult with the available data.

The high number of detected compounds in the SE extract shows that this plant contains a great diversity of compounds. In Figure 1 it can be observed that the more volatile fraction of the SE extract elutes from 5 to 30 min approximately; this is basically formed of terpene and sesquiterpene hydrocarbons as well as their oxygenated derivatives and constitutes ~24% of the chromatographable fraction of the SE extract (see Table 1). Therefore, terpene and sesquiterpene hydrocarbons are present in low proportion, and among the latter, *trans*-caryophyllene (0.8%) (spicy, woody flavor) is in the highest proportion. In more significant proportions there are oxygenated terpene and sesquiterpene derivatives (9.3 and 9.1%, respectively); the main oxygenated ter-

Table 1. Identified and Unidentified Compounds in the Extract in Dichloromethane of the Sage Aerial Parts (SE), Together with Their Relative Proportions

peak	compound ^a	SE (%)
terpene hydrocarbons		
1	tricyclene*	1.7
2	α -thujene	tr ^b
3	α -pinene*	tr
4	camphene*	0.5
5	4-methylene-1-(1-methylethyl)bicyclo[3.1.0]hex-2-ene	0.4
6	sabinene	tr
7	β -pinene*	tr
8	β -myrcene*	0.1
9	α -phellandrene*	0.2
10	α -terpinene*	tr
11	<i>p</i> -cymene*	0.1
12	limonene*	0.3
13	γ -terpinene*	tr
14	α -terpinolene*	tr
15	<i>p</i> -mentha-1,5,8-triene	tr
oxygen terpene derivatives		
16	1,8-cineole*	9.3
17	<i>cis</i> -sabinene hydrate	2.8
18	linalool*	tr
19	<i>endo</i> -fenchol	0.1
20	campholene aldehyde	tr
21	<i>trans</i> -pinocarveol	tr
22	camphor*	2.9
23	<i>exo</i> -borneol*	tr
24	<i>endo</i> -borneol*	1.5
25	terpinen-4-ol*	0.1
26	<i>p</i> -cymol	tr
27	α -terpineol*	0.8
28	myrtenol	tr
29	estragole*	tr
30	bornyl formate	tr
31	<i>trans</i> -carveol	tr
32	5-hydroxy-1,8-cineole	tr
33	<i>trans</i> -geraniol*	0.1
34	methylisopropylphenol	nd ^c
35	<i>endo</i> -bornyl acetate	0.7
36	thymol*	tr
37	methylisopropylphenol	tr
38	carvacrol*	tr
39	2,5-bornanedione	tr
40	unidentified [168 (4), 153 (100), 135 (15), 111 (23), 109 (35), 108 (83), 107 (77), 93 (64)] ^d	0.3
41	unidentified [168 (8), 153 (100), 136 (7), 121 (14), 109 (13), 93 (17), 79 (9), 70 (80)]	nd
42	eugenol*	tr
43	geranyl acetate*	tr
44	<i>cis</i> -jasmone	tr
45	oxobornyl acetate	nd
46	geranyl propionate	tr
47	geranyl butanoate	tr
sesquiterpene hydrocarbons		
48	α -cubebene	3.7
49	α -copaene	0.1
50	unidentified [204 (25), 161 (100), 133 (13), 119 (27), 105 (33), 91 (33)]	0.2
51	unidentified [204 (4), 189 (5), 168 (14), 153 (54), 126 (30), 111 (48), 108 (100), 93 (48), 71 (38), 57 (41)]	tr
52	<i>cis</i> -caryophyllene	nd
53	α -gurjunene	0.1
54	unidentified [204 (10), 154 (9), 136 (11), 119 (100), 93 (92), 69 (34), 43 (25)]	tr
55	<i>trans</i> -caryophyllene*	0.8
56	β -cadinene	tr
57	calarene	tr
58	unidentified [204 (22), 189 (10), 161 (100), 133 (14), 122 (56), 107 (59), 93 (43)]	tr
59	aromadendrene	0.1
60	α -humulene	0.6
61	alloaromadendrene	0.1
62	unidentified [204 (19), 161 (100), 133 (14), 119 (42), 105 (37), 93 (30), 79 (20)]	0.1
63	<i>ar</i> -curcumene	0.1
64	<i>epi</i> -bicyclosesquiphellandrene	nd
65	β -selinene	0.2
66	α -selinene	0.1
67	α -muurolene	0.1
68	γ -cadinene	0.4
69	δ -cadinene	0.6
70	cadina-1,4-diene	0.1
71	α -cadinene	tr
72	cadalene	tr

Table 1. Continued

peak	compound ^a	SE (%)
oxygen sesquiterpene derivatives and others		
73	unidentified [220 (1), 169 (100), 123 (7), 109 (9), 86 (30), 70 (33), 55 (14)]	9.1
74	unidentified [206 (12), 168 (38), 153 (100), 57 (25)]	0.1
75	5,6,7,7a-tetrahydro-4,4,7a-trimethyl-2(4 <i>H</i>)-benzofuranone (dihydroactinidiolide)	nd
76	unidentified [200 (19), 157 (100), 142 (44), 141 (24), 115 (7)]	nd
77	unidentified [200 (22), 157 (100), 142 (38), 141 (22)]	0.1
78	palustrol	tr
79	spathulenol	tr
80	caryophyllenol II	0.1
81	unidentified [220 (4), 205 (27), 187 (35), 161 (100), 145 (11), 131 (12), 119 (22)]	0.6
82	viridiflorol	nd
83	unidentified [220 (3), 138 (22), 107 (27), 93 (100), 80 (34)]	3.3
84	viridiflorol (or isomer)	0.1
85	calarene epoxide	nd
86	unidentified [222 (2), 204 (29), 189 (9), 161 (20), 109 (100), 95 (21), 81 (20)]	0.4
87	caryophyllenol II (or isomer)	0.6
88	unidentified [222 (4), 204 (43), 189 (38), 161 (74), 109 (100), 93 (38)]	0.1
89	unidentified [222 (3), 204 (24), 189 (15), 179 (13), 161 (24), 149 (28), 137 (15), 121 (15), 109 (100), 93 (25), 81 (23), 67 (16), 59 (24)]	0.8
90	unidentified [220 (2), 205 (15), 187 (56), 161 (50), 159 (41), 149 (51), 131 (67), 123 (68), 107 (100), 91 (98), 79 (84)]	0.2
91	unidentified [220 (5), 205 (14), 187 (35), 159 (40), 149 (48), 131 (63), 121 (60), 107 (83), 91 (100), 79 (80)]	0.3
92	unidentified [220 (22), 202 (16), 187 (22), 159 (31), 133 (38), 119 (38), 109 (100), 107 (74), 95 (53)]	0.1
93	unidentified [220 (17), 159 (40), 149 (51), 121 (39), 109 (50), 107 (71), 97 (44), 93 (39), 81 (74), 79 (42), 71 (30), 69 (29), 43 (100)]	nd
94	unidentified [220 (35), 202 (9), 177 (100), 159 (71), 131 (22), 117 (23), 105 (19)]	0.4
95	unidentified [220 (84), 187 (89), 159 (100), 131 (71), 91 (56)]	tr
96	7-acetyl-2-hydroxy-2-methyl-5-isopropylbicyclo[4.3.0]nonane	tr
97	5,6,7,7a-tetrahydro-6-hydroxy-4,4,7a-trimethyl-2(4 <i>H</i>)-benzofuranone (loliolide)	tr
98	aristololol (or isomer)	0.3
99	unidentified [222 (8), 207 (100), 189 (11), 161 (14), 153 (35), 137 (23), 121 (15), 109 (28), 95 (18), 81 (27), 71 (15), 55 (13), 43 (31)]	0.1
100	oxo-neoisolongifolene (or isomer)	nd
101	unidentified [234 (1), 220 (13), 202 (17), 177 (16), 162 (76), 159 (100), 147 (33), 131 (25), 119 (88), 105 (37), 93 (41), 79 (37)]	0.6
102	aristololol (or isomer)	tr
103	unidentified [222 (17), 207 (61), 189 (18), 179 (9), 161 (25), 137 (100), 121 (29), 109 (56), 95 (37), 81 (50), 55 (25), 43 (49)]	0.1
104	unidentified [220 (68), 205 (29), 164 (98), 159 (53), 135 (52), 121 (77), 107 (100), 93 (63), 81 (57)]	0.1
105	unidentified [220 (26), 202 (17), 177 (30), 159 (62), 123 (47), 107 (100), 97 (58), 81 (47)]	0.2
106	unidentified [220 (48), 202 (22), 189 (27), 177 (43), 159 (65), 134 (35), 121 (87), 107 (100), 93 (69), 81 (62)]	0.1
107	unidentified [220 (25), 205 (15), 177 (41), 159 (39), 121 (60), 107 (100), 81 (38), 69 (26)]	0.1
diterpenoids, triterpenoids, and other derivatives		
108	neophytadiene* [278 (5), 137 (13), 123 (73), 109 (40), 95 (100), 82 (85), 68 (95), 57 (58), 43 (45)]	52.2
109	6,10,14-trimethyl-2-pentadecanone (1,2-dinor-3-phytanone) [278 (2), 215 (13), 165 (11), 137 (16), 124 (22), 109 (38), 95 (34), 85 (41), 71 (72), 58 (100), 43 (90)]	0.1
110	8(9),15-pimaradiene [272 (31), 257 (100), 230 (10), 187 (30), 175 (17), 161 (28), 149 (26), 133 (16), 119 (20), 105 (29), 91 (25)]	0.1
111	manoyl oxide (or isomer) [290 (1), 275 (94), 257 (100), 245 (11), 192 (56), 177 (45), 147 (21), 137 (43), 123 (29), 109 (26), 95 (48), 81 (48)]	tr
112	8,11,13-abietatriene [270 (31), 255 (100), 213 (8), 199 (10), 185 (35), 173 (53), 159 (52)]	0.1
113	3,7,11,15-tetramethyl-2-hexadecen-1-ol (phytol)* [296 (3), 123 (36), 109 (11), 95 (19), 81 (27), 71 (100), 57 (27), 43 (26)]	nd
114	unidentified [272 (46), 257 (44), 239 (100), 199 (18), 187 (67), 157 (62), 141 (19), 129 (21), 117 (16)]	0.1
115	unidentified [342 (100), 271 (66), 260 (26), 243 (22), 217 (15)]	0.1
116	unidentified [342 (74), 329 (8), 301 (11), 271 (100), 255 (17), 229 (8), 205 (6)]	0.5
117	unidentified [344 (100), 329 (32), 301 (41), 231 (6), 219 (7), 205 (5)]	nd
118	8,11,13-abietatrien-19-al [284 (73), 269 (100), 251 (25), 241 (49), 225 (24), 209 (36), 185 (51), 173 (79), 159 (65)]	0.2
119	unidentified [290 (8), 257 (13), 204 (7), 189 (100), 175 (18), 159 (22), 133 (27), 120 (75), 107 (66), 95 (86)]	0.4
120	unidentified [272 (84), 257 (100), 229 (17), 202 (5), 187 (9), 173 (11), 159 (8), 147 (19), 135 (13)]	0.3
121	unidentified [302 (100), 287 (7), 259 (21)]	nd
122	unidentified [342 (22), 328 (27), 327 (100)]	0.2
123	6,8,11,13-abietatetraene-12-ol (or isomer) [284 (62), 269 (16), 255 (5), 241 (6), 227 (19), 213 (46), 202 (100), 199 (59), 185 (37), 171 (20), 159 (41), 157 (30)]	0.1
124	unidentified [342 (100), 327 (11), 271 (64), 260 (23), 243 (23), 229 (16), 217 (15)]	nd
125	8,11,13-abietatrien-12-ol (ferruginol) [286 (87), 271 (100), 243 (12), 229 (18), 215 (14), 201 (40), 189 (60), 175 (56), 163 (12), 149 (23)]	0.8
126	8,11,13-abietatrien-19-oic acid methyl ester [314 (8), 299 (4), 239 (100), 197 (9)]	tr
127	unidentified [284 (73), 269 (100), 256 (11), 241 (19), 227 (38), 209 (33), 181 (9)]	tr
128	unidentified [342 (100), 327 (54), 299 (23), 286 (34), 274 (32), 271 (33), 259 (11), 257 (10), 243 (33), 229 (12)]	0.4
129	unidentified [286 (100), 271 (44), 243 (37), 230 (87), 215 (51), 204 (35), 187 (16)]	0.1
130	8,11,13-abietatrien-19-ol (4-epidehydroabietol) (or isomer) [286 (35), 271 (84), 253 (100), 239 (8), 225 (8), 211 (21), 197 (11), 185 (28), 173 (65), 159 (52)]	0.8
131	unidentified [282 (100), 267 (86), 249 (26), 239 (27), 223 (15), 183 (32), 171 (52), 157 (45)]	nd
132	unidentified [284 (49), 269 (59), 228 (100), 213 (43), 204 (29)]	0.2
133	unidentified [300 (48), 286 (100), 271 (11), 257 (11), 244 (21), 229 (19), 215 (51), 204 (39), 187 (23)]	0.2
134	unidentified [286 (100), 271 (39), 243 (43), 230 (77), 215 (52), 204 (29), 189 (14)]	4.2
135	unidentified [340 (100), 325 (72), 296 (7), 282 (23), 267 (13), 253 (18)]	0.5
136	unidentified [286 (10), 271 (100)]	nd

Table 1. Continued

peak	compound ^a	SE (%)
137	8,11,13-abietatrien-19-oic acid [300 (29), 285 (100), 239 (97), 197 (30), 141 (18), 129 (12)]	6.5
138	unidentified [374 (33), 342 (100), 327 (45), 299 (20), 286 (20), 274 (19)]	nd
139	unidentified [302 (6), 176 (100), 161 (25), 147 (7)]	tr
140	unidentified [286 (100), 271 (20), 243 (5), 229 (3), 215 (48), 204 (25), 187 (16)]	0.6
141	9(10→20)-abeo-1(10),8,11,13-abietatetraene-11,12-diol (barbatusol) (or isomer) [300 (100), 285 (18), 257 (22), 244 (27), 231 (39), 218 (12), 204 (19), 191 (12), 179 (11), 165 (30)]	0.6
142	unidentified [316 (45), 287 (100), 245 (10), 231 (19), 217 (70), 205 (85), 191 (98)]	1.7
143	8,11,13-abietatrien-12-ol-20-al (or isomer) [300 (13), 271 (100), 229 (14), 215 (12), 201 (36), 189 (48), 175 (49)]	0.7
144	unidentified [298 (41), 283 (69), 237 (100), 197 (7), 181 (19)]	3.4
145	rosmadial (or isomer) [344 (17), 316 (16), 301 (6), 287 (100), 273 (20), 255 (10), 231 (18), 217 (9)]	1.5
146	unidentified [284 (88), 269 (100), 254 (29), 239 (55), 224 (12), 209 (21), 195 (7), 181 (10), 165 (15)]	2.1
147	9(10→20)-abeo-8,11,13-abietatriene-10,11,12-triol (demethylsalvicanol) [318 (5), 300 (57), 285 (12), 231 (19), 218 (10), 204 (20), 192 (100), 177 (30)]	13.9
148	20-nor-5(10),8,11,13-abietatetraene-11,12-diol-1-one (sagenone) (or isomer) [300 (100), 285 (25), 272 (35), 257 (68), 243 (11), 229 (19), 215 (9), 115 (15), 69 (20)]	nd
149	unidentified [298 (100), 283 (8), 195 (10)]	1.8
150	8,11,13-abietatriene-11,12-diol-20-oic acid (carnosic acid) [332 (5), 286 (100), 271 (19), 243 (25), 230 (50), 218 (22), 204 (18), 187 (6)]	2.7
151	8,11,13-abietatriene-11,12,20-triol (or isomer) [318 (32), 300 (7), 287 (100), 269 (5), 231 (19), 217 (71), 205 (70), 191 (80), 69 (15)]	tr
152	unidentified [344 (28), 316 (10), 287 (100), 273 (15), 255 (10), 222 (7), 195 (7)]	nd
153	squalene* [410 (1), 136 (17), 121 (15), 95 (18), 81 (59), 69 (100), 41 (15)]	0.2
154	α-tocopherol (vitamin E)* [430 (79), 205 (11), 165 (100)]	nd
155	unidentified [328 (100), 313 (95), 299 (25), 285 (27), 268 (8)]	3.0
156	4',5-dihydroxy-6,7-dimethoxyflavone (circsimaritin) [314 (100), 299 (97), 285 (33), 271 (36), 239 (7), 204 (6), 181 (21), 153 (40)]	0.3
157	stigmast-5-en-3β-ol (β-sitosterol)* [414 (100), 399 (42), 396 (52), 381 (39), 329 (64), 303 (56), 273 (32), 255 (35), 231 (28), 213 (47)]	1.2
158	β-amyrin [426 (8), 218 (100), 203 (45), 189 (21)]	0.8
159	3,5-dihydroxy-6,7,8-trimethoxyflavone [344 (100), 329 (91), 315 (26), 301 (25), 298 (26), 204 (33), 181 (15), 153 (33)]	1.8
160	α-amyrin (viminalol) [426 (8), 218 (100), 203 (19), 189 (20), 161 (9), 135 (15)]	nd
acids		0.4
161	hexadecanoic acid (palmitic acid)*	0.3
162	9,12-octadecadienoic acid (linoleic acid)	tr
163	9-octadecenoic acid (oleic acid)*	0.1
164	octadecanoic acid (stearic acid)	tr
saturated hydrocarbons		17.8
165	pentacosane*	0.7
166	heptacosane*	0.3
167	octacosane*	0.3
168	ethyl hexacosane	0.1
169	nonacosane*	2.3
170	methyl octacosane	0.1
171	triacontane*	0.2
172	ethyl octacosane	0.3
173	methyl nonacosane	0.1
174	hentriacontane	2.7
175	ethyl nonacosane	0.1
176	methyl triacontane	0.5
177	dotriacontane	1.0
178	ethyl triacontane	0.8
179	methyl hentriacontane	0.2
180	trtriacontane	5.3
181	tetratriacontane	1.9
182	ethyl dotriacontane	0.3
183	pentatriacontane	0.6

^a Asterisked compounds were identified by using standards. ^b tr, traces. ^c nd, not determined. ^d Numbers in brackets are *m/z* values of the fragments of the mass spectra together with their relative intensities.

pene derivatives are camphor (2.9%) (camphoraceous, fresh flavor) and 1,8-cineole (2.8%) (fresh, eucalyptus flavor), in agreement with the chemotype of another *S. lavandulifolia* previously studied from northeastern of Spain (Marcos et al., 1988); also, the contribution of *endo*-borneol is noticeable (1.5%) (camphoraceous, earthy, pine flavor) as in other *S. lavandulifolia* subspecies (Cabo et al., 1987; Marcos et al., 1988; Fournier, 1993). α-Terpineol (0.8%) (sweet, floral, lilac flavor) and *endo*-bornyl acetate (0.7%) are also in significant proportions; however, thujone is not present in this sage plant. Among the identified oxygenated sesquiterpene derivatives the main component is viridiflorol (3.3%). Finally, two lactones are also present in the more volatile

fraction of the SE extract, 5,6,7,7a-tetrahydro-4,4,7a-trimethyl-2(4*H*)-benzofuranone or dihydroactinidiolide, a norisoprenoid breakdown product of carotene, detected also in coffee and in black tea flavors (Flament, 1989), and 5,6,7,7a-tetrahydro-6-hydroxy-4,4,7a-trimethyl-2(4*H*)-benzofuranone (loliolide).

Terpenes, sesquiterpenes, and their oxygenated derivatives play an important role in foods due to their known organoleptic properties and in some cases for their antimicrobial and antioxidant activity; compounds responsible for this latter activity are eugenol, thymol, carvacrol, and other methylisopropylphenols, as well as compounds with an ethylidene side chain able to form

Table 2. Compounds Identified in the Volatile Fraction of the Extract in Dichloromethane of the Liquid Sage Smoke (LSS), Together with Their Concentration in the Preparation and Their Yield, Obtained from 100 g of Sage Sawdust

peak	compound ^a	concn (mg/L)	yield (mg)
aldehydes			
1	acetaldehyde*	83.4	18.4
2	3-methylbutanal*	29.9	6.6
3	2-methylbutanal*	2.5	0.5
4	2-methylbutanal*	9.1	2.0
5	valeraldehyde*	4.9	1.1
6	2-ethylbutanal*	35.8	7.9
7	benzaldehyde*	1.2	0.3
ketones			
8	2-propanone*	703.1	154.5
9	2-butanone*	nq ^b	nq
10	3-methyl-2-butanone*	nq	nq
11	2-pentanone*	57.9	12.7
12	4-methyl-2-pentanone*	14.8	3.2
13	2-methyl-3-pentanone*	13.1	2.9
14	2-methyl-3-pentanone*	5.1	1.1
15	3-hexanone*	24.6	5.4
16	2-hexanone*	3.3	0.7
17	cyclopentanone*	106.7	23.5
18	2-cyclopenten-1-one	nq	nq
19	2-methylcyclopentanone	27.5	6.0
20	3-methylcyclopentanone	5.2	1.2
21	1-acetoxy-propan-2-one	114.2	25.1
22	cyclohexanone*	3.6	0.8
23	2-methyl-2-cyclopenten-1-one*	86.7	19.1
24	2-cyclohexen-1-one	nq	nq
25	dimethyl-2-cyclopenten-1-one	32.1	7.1
26	2,5-dimethyl-2-cyclopenten-1-one	12.9	2.8
27	1-acetoxy-butan-2-one	nq	nq
28	3-methyl-2-cyclopenten-1-one*	84.9	18.7
29	dimethyl-2-cyclopenten-1-one	3.7	0.8
30	2,3-dimethyl-2-cyclopenten-1-one	23.3	5.1
31	trimethyl-2-cyclopenten-1-one	nq	nq
32	dimethyl-2-cyclopenten-1-one	10.4	2.3
33	trimethyl-2-cyclopenten-1-one	nq	nq
34	trimethyl-2-cyclopenten-1-one	3.3	0.7
35	3-ethyl-2-cyclopenten-1-one	51.8	11.4
36	trimethyl-2-cyclopenten-1-one	13.4	2.9
37	1-phenylethanone (acetophenone)*	2.0	0.4
38	1-phenyl-2-propanone	nq	nq
39	1-(2-hydroxyphenyl)-ethanone	1.7	0.4
40	1-(2,4-dihydroxyphenyl)-ethanone	0.9	0.2
41	2,3-dihydro-1 <i>H</i> -inden-1-one	nq	nq
42	methylindanone	nq	nq
diketones			
43	2,5-hexanedione	133.6	29.4
44	3-methyl-1,2-cyclopentanedione (cyclotene)*	5.3	1.2
45	3,5-dimethyl-1,2-cyclopentanedione	87.2	19.2
46	3,5-dimethyl-1,2-cyclopentanedione	nq	nq
47	3-ethyl-1,2-cyclopentanedione (3-ethylcyclopentenolone)*	41.1	9.0
furan and pyran derivatives			
48	2,5-hexanedione	1129.8	248.6
49	3,4-dihydropyran*	3.0	0.7
50	2-furancarboxaldehyde (furfural)*	376.2	82.8
51	2-furanmethanol (furfuryl alcohol)*	163.3	35.9
52	2-ethylfuran	35.0	7.7
53	1-(2-furanyl)-ethanone (acetylfuran)*	159.6	35.1
54	2(3 <i>H</i>)-dihydrofuranone	nq	nq
55	2(5 <i>H</i>)-furanone (γ -crotonolactone)*	305.3	67.2
56	5-methyl-2(5 <i>H</i>)-furanone (β -angelicalactone)	nq	nq
57	propenylfuran	nq	nq
58	5-methyl-2-furancarboxaldehyde (5-methylfurfural)*	27.4	6.0
59	2-methyl-2-furancarboxylate	tr ^c	tr
60	3-methyl-2(5 <i>H</i>)-furanone*	23.3	5.1
61	1-(2-furanyl)-propanone	nq	nq
62	3-hydroxy-2-methyl-4 <i>H</i> -pyran-4-one (maltol)*	36.7	8.1
esters			
63	ethyl acetate*	46.3	10.1
64	methyl propionate*	nq	nq
65	ethyl butyrate*	nq	nq
66	butyl acetate*	5.6	1.2
67	ethyleneglycol monoacetate*	7.4	1.6
68	4-oxopentanoic acid methyl ester (methyl levulinate)*	33.3	7.3
69	2,2-dimethylbutenoic acid methyl ester	nq	nq
70	acetic acid phenyl ester*	nq	nq
phenol derivatives			
71	phenol*	471.0	103.6
72	2-methylphenol*	175.3	38.6
73	2-methylphenol*	73.4	16.1

Table 2. Continued

peak	compound ^a	concn (mg/L)	yield (mg)
69	3-methylphenol*	111.4	24.5
70	2,6-dimethylphenol*	17.2	3.8
71	2-ethylphenol*	14.5	3.2
72	2,4-dimethylphenol* and 2,5-dimethylphenol*	3.8	0.8
73	3-ethylphenol*	75.4	16.6
74	2,3-dimethylphenol*	nq	nq
75	3,4-dimethylphenol*	nq	nq
76	2,4,6-trimethylphenol*	tr	tr
77	2,3,6-trimethylphenol*	nq	nq
78	2,3,5-trimethylphenol*	tr	tr
79	(methylethyl)methylphenol	nq	nq
guaiacol derivatives		312.7	68.8
80	2-methoxyphenol (guaiacol)*	176.7	38.9
81	4-methyl-2-methoxyphenol (4-methylguaiacol)*	44.0	9.7
82	4-ethyl-2-methoxyphenol (4-ethylguaiacol)*	21.2	4.7
83	4-vinyl-2-methoxyphenol (4-vinylguaiacol)*	19.4	4.3
84	4-(2-propenyl)-2-methoxyphenol (eugenol)*	6.1	1.3
85	4-propyl-2-methoxyphenol (4-propylguaiacol)*	1.5	0.3
86	4-hydroxy-3-methoxybenzaldehyde (vanillin)*	5.6	1.2
87	4-(1-propenyl)-2-methoxyphenol (<i>trans</i> -isoeugenol)*	2.3	0.5
88	4-(1-propenyl)-2-methoxyphenol (<i>cis</i> -isoeugenol)*	6.4	1.4
89	1-(4-hydroxy-3-methoxyphenyl)ethanone (acetovanillone)*	8.0	1.8
90	4-hydroxy-3-methoxybenzoic acid methyl ester (methyl vanillate)*	3.7	0.8
91	1-(4-hydroxy-3-methoxyphenyl)-2-propanone (2-propiovanillone)	16.1	3.5
92	1-(4-hydroxy-3-methoxyphenyl)-1-propanone (1-propiovanillone)	1.7	0.4
syringol derivatives		71.4	15.8
93	2,6-dimethoxyphenol (syringol)*	43.1	9.5
94	4-methyl-2,6-dimethoxyphenol (4-methylsyringol)*	5.5	1.2
95	4-ethyl-2,6-dimethoxyphenol (4-ethylsyringol)	3.0	0.7
96	4-(2-propenyl)-2,6-dimethoxyphenol (4-allylsyringol)*	2.2	0.5
97	4-propyl-2,6-dimethoxyphenol (4-propylsyringol)	1.0	0.2
98	4-(1-propenyl)-2,6-dimethoxyphenol (<i>trans</i> -propenylsyringol)	1.6	0.4
99	4-hydroxy-3,5-dimethoxybenzaldehyde (syringaldehyde)*	1.8	0.4
100	4-(1-propenyl)-2,6-dimethoxyphenol (<i>cis</i> -propenylsyringol)	1.7	0.4
101	1-(4-hydroxy-3,5-dimethoxyphenyl)ethanone (acetosyringone)*	5.9	1.3
102	1-(4-hydroxy-3,5-dimethoxyphenyl)-2-propanone (2-propiosyringone)	5.6	1.2
pyrocatechol and alkyl aryl ethers		90.5	19.9
103	1,4-dimethoxybenzene*	4.0	0.9
104	1,2-benzenediol (pyrocatechol)*	nq	nq
105	2,6-dimethoxytoluene	nq	nq
106	3-methoxy-1,2-benzenediol (3-methoxypyrocatechol)*	53.7	11.8
107	3-methyl-1,2-benzenediol (3-methylcatechol)*	4.6	1.0
108	4-methyl-1,2-benzenediol (4-methylcatechol)*	nq	nq
109	4-ethylbenzenediol	28.2	6.2
nitrogenated compounds		nq	nq
110	methylpyrazine	nq	nq
111	3-methylpyridine*	nq	nq
112	2,6-dimethylpyridine*	nq	nq
113	dimethylpyrazine	nq	nq
114	2-ethylpyridine*	nq	nq
115	2,5-dimethylpyrazine*	nq	nq
116	ethylpyrazine	nq	nq
117	2,3-dimethylpyrazine (or isomer)	nq	nq
118	2,4-dimethylpyridine*	nq	nq
119	2,5-dimethylpyridine*	nq	nq
120	2,3-dimethylpyridine*	nq	nq
121	3-ethyl-5-methylpyridine (or isomer)	nq	nq
122	6-methyl-4(1 <i>H</i>)-pyrimidinone (or isomer)	nq	nq
123	3-ethylpyridine*	nq	nq
124	methylethylpyrazine	nq	nq
125	3-methoxypyridine*	nq	nq
126	trimethylpyridine	nq	nq
127	2-ethyl-6-methylpyridine*	nq	nq
128	trimethylpyridine	nq	nq
129	1-(2-pyridinyl)-ethanone	nq	nq
130	5-ethyl-2-methylpyridine*	nq	nq
131	diethylpyridine	nq	nq
132	2-butylpyridine (or isomer)	nq	nq
133	2-methyl-6-propylpyridine (or isomer)	nq	nq
134	2-methyl-3-propylpyrazine (or isomer)	nq	nq
135	2-ethyl-4,6-dimethylpyridine (or isomer)	nq	nq
136	methylpropylpyridine	nq	nq
137	2,6-diethylpyrazine (or isomer)	nq	nq
138	5,6-dimethyl-2-pyrimidinone (or isomer)	nq	nq
139	methylpropylpyridine	nq	nq

Table 2. Continued

peak	compound ^a	concn (mg/L)	yield (mg)
acids and alcohols			
140	acetic acid*	56.3	12.3
141	propionic acid*	nq	nq
142	acetic anhydride*	30.1	6.6
143	3-methyl-3-buten-1-ol*	6.9	1.5
144	3-methyl-1-butanol*	3.8	0.8
145	butyric acid*	5.0	1.1
146	pentanoic acid*	10.5	2.3
147	hexanoic acid*	nq	nq
148	benzenemethanol*	nq	nq
149	3-octen-1-ol	tr	tr
terpenic compounds and others			
150	1,8-cineole*	29.0	6.4
151	<i>cis</i> -linalool oxide	1.6	0.4
152	camphor*	nq	nq
153	<i>endo</i> -borneol*	15.0	3.3
154	terpinen-4-ol*	nq	nq
155	α -terpineol*	9.2	2.0
156	2,5-bornanedione	nq	nq
157	2 <i>H</i> -1-benzopyran-2-one (coumarin)	3.2	0.7
158	jasmine ketolactone	tr	tr

^a Asterisked compounds were identified and quantified by using standards. ^b nq, not quantified. ^c tr, traces.

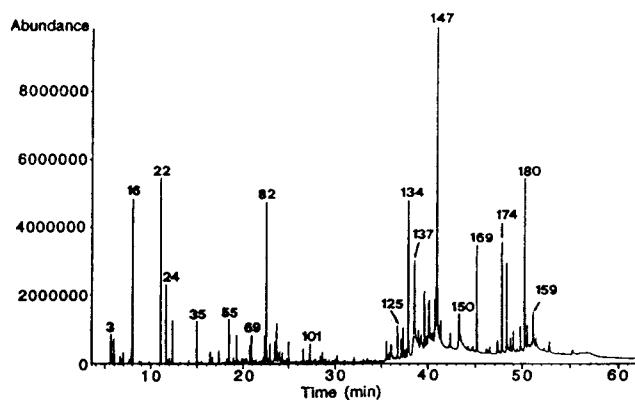


Figure 1. Total ion chromatogram of the extract in dichloromethane of the sage aerial parts.

stable allylic tertiary free radicals (Yan and White, 1990; Tsimidou and Boskou, 1994), such as geranyl esters.

In addition to the compounds above-mentioned, another large group of substances of high molecular weight and very varied structures, which elute from 28 to 55 min, is also present in the SE extract. Their mass spectral data, which may be very useful in recognizing compounds of this nature in other food studies, are given in Table 1. Three phytene derivatives (compounds **108**, **109**, and **113**) are present together with a large group of compounds showing a polyhydrophenanthrene skeleton; in this latter group there are hydrocarbons such as compound **110**, or 8(9),15-pimaradiene (MW = 272), and compound **112**, or 8,11,13-abietatriene (MW = 270), the structures of which are given in Figure 2, as well as aldehydes, such as compound **118** [8,11,13-abietatrien-19-al (MW = 284)], esters, such as compound **126** [8,11,13-abietatrien-19-oic acid methyl ester (MW = 314)], and acids, such as compound **137** [8,11,13-abietatrien-19-oic acid (MW = 300)], derived presumably from compound **112**. From mass spectral fragmentations it could also be inferred that compounds **114** and **120** could be isomers of compound **110**.

The skeleton of compound **112** in Figure 2b is the basic structure of other oxygenated compounds present in the SE sample such as compound **123** [6,8,11,13-abietatetraene-12-ol (MW = 284)] (Figure 2c), compound

125 [ferruginol, also named 8,11,13-abietatrien-12-ol (MW = 286)] (Figure 2d), compound **130** [4-epidehydroabietol, also named 8,11,13-abietatrien-19-ol (MW = 286)] (Figure 2e), compound **143** [8,11,13-abietatrien-12-ol-20-al (MW = 300)] (Figure 2f), compound **148** [probably 20-*nor*-5(10),8,11,13-abietatetraene-11,12-diol-1-one, also named sagenone, MW = 300)] (Figure 2g) (González et al., 1992; Tada et al., 1994) or isomer, compound **150** [carnosic acid, also named 8,11,13-abietatriene-11,12-diol-20-oic acid (MW = 332)] (Figure 2h) (Cuvelier et al., 1994a), and compound **151** [8,11,13-abietatriene-11,12,20-triol or isomer (MW = 318)] (Figure 2i) (González et al., 1991). Taking into account their mass spectra, compounds **127**, **132**, and **146** could be isomers of compound **123** [6,8,11,13-abietatetraene-12-ol], and compounds **129**, **134**, **136**, and **140** could be isomers of compound **125** [ferruginol]; in the same way compounds **133** and **142** have mass spectra similar to those of carnosol (Cuvelier et al., 1994a) and 8,11,13-abietatriene-11,12,20-triol (González et al., 1991), respectively, except in the molecular ion.

In the SE sample there have also been detected other diterpenoids such as compound **111** [manoyl oxide (MW = 290)] (Figure 2j), the skeleton of which is related to compound **110** [8(9),15-pimaradiene], compound **141** [barbatusol, also named 9(10→20)-abeo-1(10),8,11,13-abietatetraene-11,12-diol (MW = 300)] (Figure 2k), and compound **147** [demethylsalvicanol, also named 9(10→20)-abeo-8,11,13-abietatriene-10,11,12-triol (MW = 318)] (Figure 2l) (González et al., 1991), the structures of which are similar to that of rosmaridiphenol (Houlihan et al., 1984), compound **145** or rosmadial (MW = 344) (Figure 2m) (Cuvelier et al., 1994a), and compound **152** (MW = 344), the mass spectrum of which is very similar to those of rosmadial and saffcinolide (Tada et al., 1994).

Phenolic functional groups in a position *ortho* to an isopropyl group are one of the chemical structural characteristics considered to be responsible for the antioxidant activity of many compounds (Brieskorn and Dömling, 1969; Inatani et al., 1983; Nakatani and Inatani, 1981, 1983, 1984; Cuvelier et al., 1994a) such as carnosol, isocarnosol, rosmanol, epirosmanol, rosmaridiphenol, and methyl carnosate, not detected in the SE sample, as well as 6,8,11,13-abietatetraene-12-ol

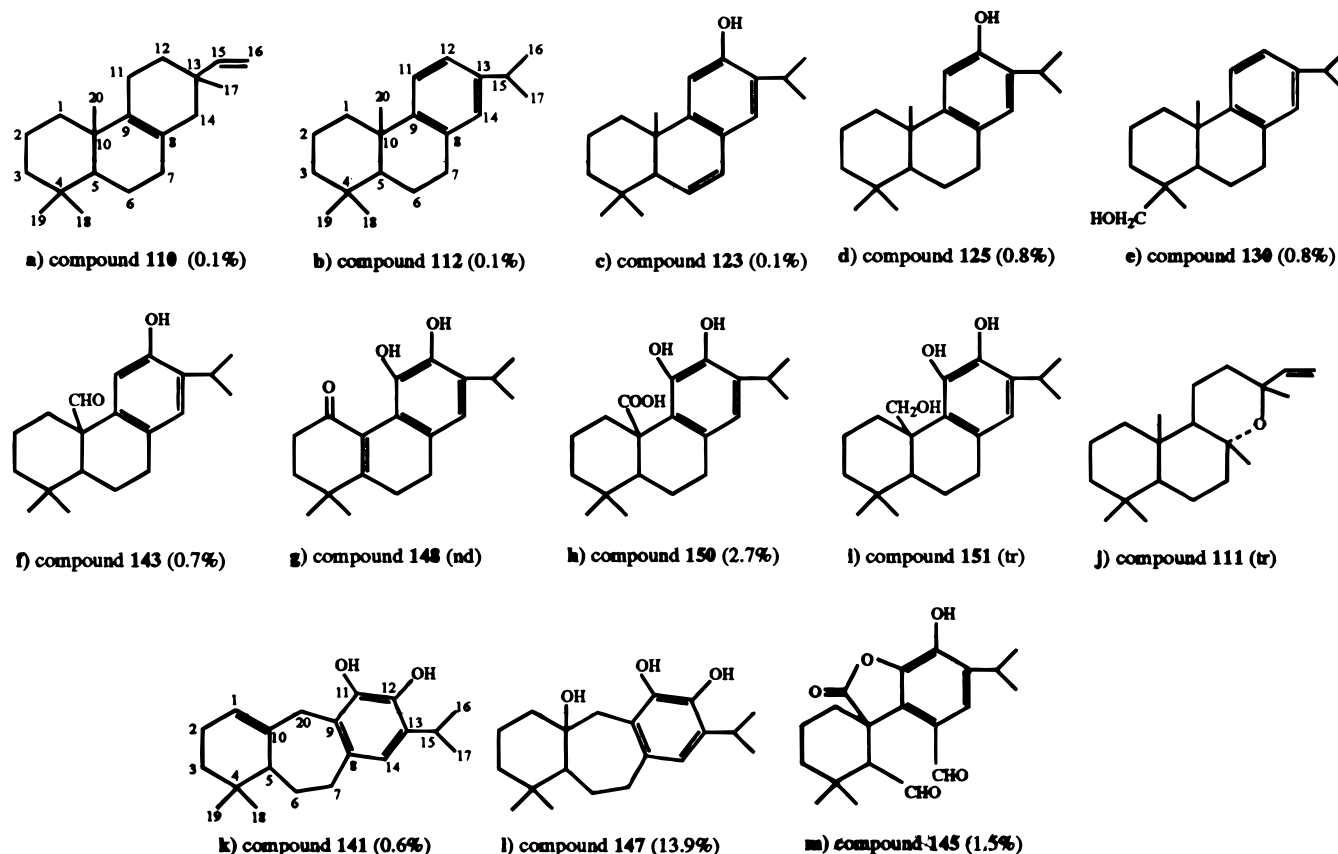


Figure 2. Chemical structures of significant compounds detected in the extract of the sage aerial parts and their relative proportions: (a) 8(9),15-pimaradiene; (b) 8,11,13-abietatriene; (c) 6,8,11,13-abietatetraen-12-ol; (d) 8,11,13-abietatrien-12-ol (ferruginol); (e) 8,11,13-abietatrien-19-ol (4-epidehydroabietol); (f) 8,11,13-abietatrien-12-ol-20-al; (g) 20-nor-5(10),8,11,13-abietatetraene-11,12-diol-1-one (sagenone); (h) 8,11,13-abietatriene-11,12-diol-20-oic acid (carnosic acid); (i) 8,11,13-abietatriene-11,12,20-triol; (j) manoyl oxide; (k) 9(10→20)-abeo-1(10),8,11,13-abietatetraene-11,12-diol (barbatusol); (l) 9(10→20)-abeo-8,11,13-abietatriene-10,11,12-triol (demethylsalvicanol); (m) rosmadial.

(0.1%), ferruginol (0.8%), 8,11,13-abietatrien-12-ol-20-al (0.7%), 20-nor-abieta-5(10),8,11,13-tetraene-11,12-diol-1-one (nd), carnosic acid (2.7%), abieta-8,11,13-triene-11,12,20-triol (tr), demethylsalvicanol (13.9%), rosmadial (1.5%), barbatusol (0.6%), and/or isomers detected in the SE sample, some of them in high proportions. Some of these latter compounds have also been detected in other sage species such as *Salvia sclarea* and *Salvia limbata* (Ulubelen et al., 1994, 1996), *Salvia officinalis* (Schwarz and Ternes, 1992a,b; Cuvelier et al., 1994a; Tada et al., 1994), *Salvia canariensis*, *Salvia apiana*, *Salvia carnosa*, and *Salvia triloba* (Chapman and Hall, 1994), and *Salvia mellifera* (González et al., 1991, 1992), and some of them have shown not only antioxidant but also antiviral and antibacterial activities (Tada et al., 1994).

Some flavonoids can also contribute to the antioxidant activity of this plant; two flavones have been identified in the SE extract (2.1%), although other researchers have found more (Tomás-Lorente et al., 1988; Cañigual et al., 1989).

In addition, the presence of some triterpenoids and other related compounds such as squalene, stigmast-5-en-3 β -ol (β -sitosterol) (1.2%), β -amyrin (0.8%), and α -tocopherol (vitamin E), which also has antioxidant activity, is noteworthy. Finally, a high proportion (17.8%) of saturated hydrocarbons of a large number of carbon atoms and a small proportion of fatty acids (0.4%) have also been found in the SE extract. These C₂₅–C₃₅ *n*-paraffins are present on plant surfaces and are easily coextracted with the dichloromethane.

In conclusion, the aerial parts of this plant are a rich source of compounds not only with organoleptic but also with antioxidant, antiviral, and antibacterial properties. If these compounds cross to form part of the smoke generated, it will have very interesting properties, not only from the organoleptic but also from the preservative point of view.

Study of the Liquid Sage Smoke (LSS). The LSS obtained was bright yellow in color and its odor was described as very aromatic, smoky, and pungent, with significant floral and herbaceous notes. Its acidity was 0.062 equiv of acid L⁻¹, lower than that of other liquid smokes obtained from several wood sources under the same external pyrolytic conditions (Guillén and Ibargoitia, 1996; Guillén and Manzanos, 1999).

To characterize the composition of the LSS sample, 25 mL was extracted with 25 mL of dichloromethane and the extract obtained was studied by GC/MS and GC with FID detector. Figure 3 shows the chromatogram obtained with this latter technique; it can be observed that LSS components elute in the first 30 min, that is to say, only components with low molecular weights are present in the sample. Table 2 gives the components identified together with their concentrations in milligrams per liter in the LSS sample and their yields in milligrams from 100 g of sage. Those compounds that did not have separation not good enough were not quantified ("nq" in Table 2).

The first observation in Table 2 is the low yield obtained in all components in relation to those obtained from other plant sources under the same external

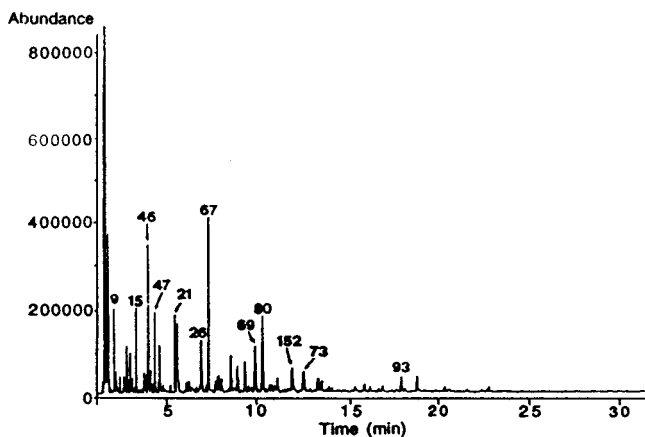


Figure 3. Chromatogram of the extract in dichloromethane of the liquid sage smoke.

pyrolytic conditions (Guillén and Ibargoitia, 1996; Guillén and Manzanos, 1999). Among the compounds found are the typical smoke components such as carbonylic derivatives, including aldehydes, ketones, diketones, and pyran and furan derivatives, acids, esters, and some alcohols and phenolic derivatives, including phenol, guaiacol, syringol, pyrocatechol, and their derivatives, as well as alkyl aryl ethers. In addition, a high number of nitrogenated derivatives, in small proportions, were detected, which may be responsible for the lower acidity of this liquid smoke compared with that of liquid smokes obtained from other plant sources (Guillén and Ibargoitia, 1996; Guillén and Manzanos, 1999). A small number of other aromatic compounds, some of them previously found in the aerial parts of the plant, were also found.

Although the typical smoke components are present in the LSS sample with a higher proportion of carbonylic derivatives (67%) than of phenolic derivatives (~30%), within these two categories the proportions of compounds found are very different from those found in other smoke flavorings obtained from other plant sources (Guillén and Ibargoitia, 1996; Guillén and Manzanos, 1999).

The most significant fact is the high proportion of ketones (23%) in relation to the other carbonyl derivatives, even though the group with the highest proportion corresponds to furan and pyran derivatives (36%). In the group of ketones, 1-acetoxy-propan-2-one (114 mg L⁻¹) and cyclopentanone (107 mg L⁻¹) are the main components, and in the group of diketones, as is usual in smoke, 3-methyl-1,2-cyclopentanedione is the main component (87 mg L⁻¹) (brandy or caramel, an odor and taste such as hydrolyzed vegetable protein, smoked ham, cloves) (Tóth and Potthast, 1984; Potthast et al., 1988; Potthast and Eigner, 1988). In the group of furan and pyran derivatives, 2-furancarboxaldehyde (sweet, bread-like, caramel-like) (376 mg L⁻¹), 2(5*H*)-furanone (305 mg L⁻¹), 2-furanmethanol (163 mg L⁻¹), and 1-(2-furanyl)ethanone (sweet, balsamic, cocoa, slightly coffee) (160 mg L⁻¹) are the main derivatives. In addition to their organoleptic function, the carbonylic derivatives contribute to modifying the texture and color of the smoked foods (Guillén et al., 1998).

Within the phenolic derivatives, which in general contribute with typical smoky notes, the scarce presence of syringol and its derivatives is noteworthy, as well as the lower proportion of guaiacol and its derivatives compared to phenol and its derivatives; that is to say,

phenol and its derivatives are the main group. The proportion of phenol is remarkable (175 mg L⁻¹), as are the significant proportions of several alkylphenol derivatives such as 3-methylphenol (111 mg L⁻¹), 3-ethylphenol (75 mg L⁻¹), and 2-methylphenol (73 mg L⁻¹) with pungent and cresolic notes in general, together with guaiacol (177 mg L⁻¹) (sweet, smoky, somewhat pungent) (Kim et al., 1974). However, the proportion of syringol (43 mg L⁻¹) (smoky) is even lower than that of 3-methoxyprocatechol (54 mg L⁻¹) (heavy, sweet, and burnt) (Kim et al., 1974). The great difference in concentrations within the phenolic derivatives between the LSS sample and smoke obtained from soft- or hardwoods can be observed from the ratios between the concentrations of the most significant compounds; therefore, in the LSS sample phenol/guaiacol = 1.0 and phenol/syringol = 4.1, whereas in smoke from softwoods these ratios are 0.4 and 1.3 and from hardwoods these ratios are 0.5 and 0.3, respectively (Baltes et al., 1981). Besides their organoleptic properties, phenols also show antioxidant and antimicrobial functions in foods (Guillén et al., 1998).

In addition to the common smoke components the LSS sample has a large group of nitrogenated derivatives in small proportions. Among these, there are eight alkylpyrazine derivatives. Pyrazines are aromatic compounds that can be caused by the Maillard reaction in several foods (Maga, 1982; Flament, 1989), through extrusion cooking (Ames et al., 1997; Bredie et al., 1998), roasting (Flament, 1989; Beal and Mottram, 1994), or by other thermic processes, as well as in some cases by fermentation (Owens et al., 1997). Some pyrazines (nine) have also been previously detected in smoke flavorings (Maga and Chen, 1985; Chen and Maga, 1995); however, most of these do not coincide with those found in the LSS sample. The main properties of this kind of compound are organoleptic, described in general as pungent, nutty, burnt, roasted, grassy, and, in some cases, butterscotch.

Among nitrogenated compounds, a large group of pyridine derivatives (19 compounds) has also been detected in the LSS sample. Even though only pyridine has been detected in smoke (Maga, 1988) and a small group of these derivatives has been found in the basic fraction of fire charred white oak (Maga, 1988), some authors have described that compounds of this nature are formed in the pyrolysis of alkaloids such as trigonelline (Viani and Horman, 1974). This group of nitrogenated derivatives plays an important role in coffee, cocoa, and tea flavors, and some of their organoleptic properties have been described as green, bitter, roasted, or burnt (Flament, 1989). Besides the compounds above-mentioned, other nitrogenated compounds also having a ketonic group have been tentatively detected, such as methyl- and dimethylpyrimidinone as well as pyridinylethanone; to the best of our knowledge, these kinds of compounds have not also been detected in smoke before.

Finally, some characteristic sage aromatic compounds have been found, such as camphor (15 mg L⁻¹) (camphoraceous, fresh flavor), terpinen-4-ol (9 mg L⁻¹) (peppery, woody, earthy, musty), 2,5-bornanedione (3 mg L⁻¹), 1,8-cineole (2 mg L⁻¹) (camphoraceous), and *endo*-borneol (camphoraceous, earthy, pine flavor), α -terpineol (sweet, floral, lilac flavor), as well as other components not common in smoke and not previously detected in the SE sample, such as *cis*-linalool oxide,

2H-1-benzopyran-2-one (pleasant and fragrant odor resembling that of vanilla beans, burning taste) (Windholz, 1983), and jasmine ketolactone. All of these compounds, not generally present in wood smoke, contribute to enriching the common organoleptic properties of this smoke flavoring with specific pleasant sage notes.

In conclusion, this smoke flavoring has low acidity and contains both common compounds found in many liquid smokes and others characteristic of the plant. Among the common carbonylic smoke components, furan and pyran derivatives constitute the main group, although ketones are in high proportion. Among phenolic compounds, phenol and its derivatives are the main components. In addition, a large group of nitrogenated derivatives, in small proportions, such as pyrazines and pyridines, as well as some pyrimidinones, are present in this liquid smoke; many of these have not been detected in smoke before. Some aromatic compound constituents of the plant, basically terpene and sesquiterpene derivatives, also form part of this liquid smoke; there are also other aromatic compounds not detected before, neither in the plant nor in smoke, such as *cis*-linalool oxide, 2H-1-benzopyran-2-one, and jasmine ketolactone. However, the diterpenoic derivatives of the plant, many of them with very interesting properties for food technology, are not present in the liquid smoke; that is to say, in the pyrolysis of the sage these latter compounds are lost and only some of the more volatile plant components "cross" to form part of the smoke.

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