

# Volatile Constituents of Green Mate and Roasted Mate

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Volatile components of green mate and roasted mate produced in South America were analyzed by gas chromatography and gas chromatography/mass spectrometry. The aroma concentrates prepared by a simultaneous steam distillation and extraction method (SDE) consisted of more than 250 components. A total of 196 compounds were newly identified as mate volatiles in the present study. The volatile components of mate were similar to those of *Camellia sinensis* tea, including 144 of the common components such as terpene alcohol, linalool,  $\alpha$ -terpineol, geraniol, and nerolidol and ionone-related compounds  $\alpha$ -ionone,  $\beta$ -ionone, and 2,6,6-trimethyl-2-hydroxycyclohexanone. High levels of 2-butoxyethanol were characteristic, and 3,3,5-trimethylcyclohexanone-related compounds, although present at low levels, were specific to mate flavor. Roasted mate contained more furans, pyrazines, and pyrroles as formed by Maillard reaction during the roasting process.

Mate is a world-famous tea consumed in Paraguay, Brazil, and Argentina. Three hundred thousand tons of mate are produced each year on average. Mate contains 1–1.5% caffeine and 7–11% tannin (Torres, 1981), like other beverages such as tea or coffee. Usually, infusions with hot water or with cold water are called mate or terere, respectively. The material plant *Ilex paraguayensis*, a perennial tree growing in the jungle of the Parana basin, is processed as shown in Figure 1. The initial parching process is performed to inactivate leaf enzymes, similar to green tea manufacturing. Mate has a characteristic mature flavor which is somewhat sweet, sour, withered leaf like, and cigarette-like. This flavor is similar to that obtained from *Camellia sinensis* tea. Flavor constituents of mate have not been previously reported in the literature.

In the present study, the volatile components of Argentinean green mate and Brazilian roasted mate were investigated.

## EXPERIMENTAL PROCEDURES

**Sample Preparations.** Green mate, Taragui, was a product of Las Marias Co. Ltd., Argentina, and roasted mate, Mate Real, was a product of Leon Junior Co. Ltd., Brazil. One hundred grams of each sample was placed in 1000-mL flasks with 500 mL of deionized water. The steam distillate was simultaneously extracted with 50 mL of ethyl ether for 1 h by using a modified Likens-Nickerson apparatus (Schultz et al., 1977). The extracts were dried over anhydrous sodium sulfate for 12 h. After sodium sulfate and solvent were removed, approximately 40 mg of aroma concentrates was obtained for each sample. Both aroma concentrates were analyzed by gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS).

**Instrumental Methods.** A Hitachi Model G-3000 gas chromatograph equipped with an FID and a 60 m  $\times$  0.25 mm HS wax fused silica capillary column was used. The peak area was integrated by using a Hitachi D-2500 integrator. The oven temperature was held at 60 °C for 4 min and then programmed to 180 °C at 2 °C/min. The helium carrier gas flow rate was 30.1 cm/s. The injector and detector temperatures were 200 and 210 °C, respectively. A JEOL JMS-DS 300 mass spectrometer interfaced to a Hewlett-Packard 5790 gas chromatograph was used for MS identification under the following conditions: column, 50 m  $\times$  0.25 mm Carbowax 20M fused silica capillary column; column and injector temperature, same as above; ion

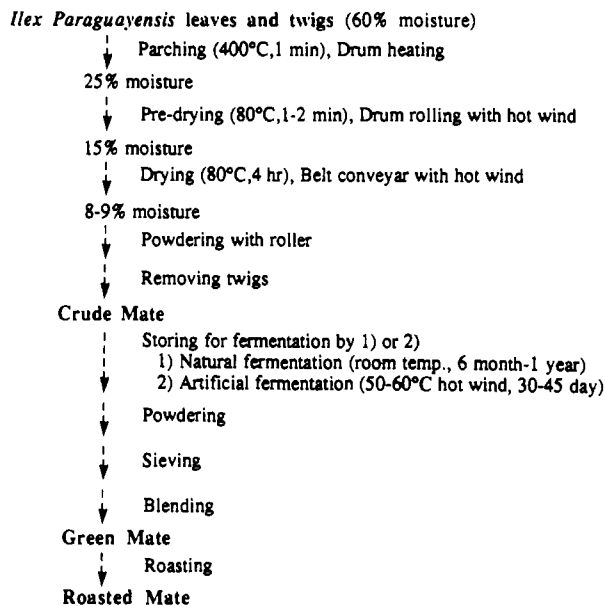


Figure 1. Manufacture of mate.

source temperature, 200 °C; carrier gas flow rate, 30 cm/s; electron energy, 70 eV. The MS data were analyzed by a JEOL DA-5000 data processing system.

The GC Kovats index (KI) and the MS fragmentation patterns of each component were compared to those of the authentic compound as reported in the literature.

## RESULTS AND DISCUSSION

Gas chromatograms of the aroma concentrates from each mate tea are shown in Figure 2. The identified compounds and relative quantities of each compound, as calculated by the peak area, are listed in Table I. A total of 196 compounds were identified as mate volatile, including 23 aliphatic alcohols, 24 aldehydes, 29 ketones, 15 acids, 8 lactones, 9 terpenes, 11 terpene alcohols, 25 alicyclics, 11 phenols, 7 aromatics, 13 furan(ones), 6 pyrazines, and 2 pyrroles. Of these, 144 are shared with tea manufactured from *Camellia sinensis*. The aroma concentrate of green mate contained high levels of 2-butoxyethanol and linalool. Other major components were geranylacetone, 6-methyl-(E)-3,5-heptadien-2-one, 6-methyl-5-hepten-2-one,  $\alpha$ - and  $\beta$ -ionone,  $\alpha$ -terpineol, geraniol, C<sub>2</sub>-C<sub>12</sub> monocarboxylic acids, and 1-penten-3-ol. These compounds are important

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Table I. Composition of the Aroma Concentrates of Green Mate and Roasted Mate

KI <sup>a</sup>	compound	GC peak area		KI <sup>a</sup>	compound	GC peak area			
		green	roast			green	roast		
788	propanal	b	0.3	d	1415	linalool oxide I (cis, furanoid)	0.8	2.2	d
864	butanal	b	c	d	1418	1-octen-3-ol	0.1	c	d
888	2-butanone	b	c	d	1420	3,5,5-trimethylcyclohex-3-en-1-one	0.2	c	
912	3-methylbutanal	0.1	b	d	1425	heptanol	1.3	1.5	d
925	ethanol	0.1	0.2	d	1427	furfural	0.6	3.2	d
932	3-buten-2-one	b	c	d	1430	(E)-2,(Z)-4-heptadienal	0.4	0.3	d
936	2-ethylfuran	0.5	c	d	1440	linalool oxide II (trans, furanoid)	0.5	1.3	d
948	2,3-butanedione	0.1	b	d	1453	2-ethylhexan-1-ol	0.4	0.4	d
960	pentanal	0.8	0.2	d	1456	(E)-2,(E)-4-heptadienal	1.3	1.0	d
972	2-methyl-3-pentanone	b	c		1463	2-decanone	0.3	0.5	d
991	1-penten-3-one	0.4	0.3		1463	2-acetylfuran	0.3	0.5	d
1005	2-methyl-3-buten-2-ol	0.5	0.3	d	1467	decanal	0.2	c	
1012	(E)-2-butenal	0.1	c		1482	benzaldehyde	0.4	0.9	d
1012	$\alpha$ -pinene	b	0.1	d	1482	(E)-3,(Z)-5-octadien-2-one	0.8	0.4	d
1017	toluene	b	c	d	1486	1-acetoxy-2-propionyloxyethane	c	0.4	
1026	2,3-pentanedione	0.2	0.1	d	1491	propionic acid	0.1	0.7	d
1039	1,4-dioxane	0.2	b		1509	(E)-2-nonenal	0.3	0.2	d
1064	hexanal	1.2	0.4	d	1515	2,10,10-trimethyl-6-methylidene-1-oxaspiro[4.5]dec-7-ene	c	1.0	
1073	2-methyl-2-butenal	0.1	b		1520	(isomer of 1515)	c	1.5	
1100	$\beta$ -pinene	0.3	0.2	d	1522	linalool	7.5	0.9	d
1104	(E)-2-pentenal	0.8	0.3	d	1534	octanol	1.4	1.5	d
1110	4-methyl-3-penten-2-one	b	0.1	d	1539	5-methylfurfural	0.6	4.3	d
1118	butanol	0.2	0.3	d	1539	(E)-3,(E)-5-octadien-2-one	0.4	0.8	d
1126	ethylbenzene	b	0.1	d	1548	cyclopent-2-ene-1,4-dione	0.1	0.1	
1139	1-penten-3-ol	2.5	0.9	d	1548	6-methyl-(Z)-3,5-heptadien-2-one	c	b	d
1142	2-methyl-2-pentenal	0.5	b		1555	(E)-2,(Z)-6-nonadienal	0.1	0.1	d
1149	$\beta$ -myrcene	0.2	c	d	1557	(E)-2,(E)-4-octadienal	b	c	d
1154	1-phellandrene	b	c		1561	6-methyl-(E)-3,5-heptadien-2-one	1.6	1.0	d
1158	2-heptanone	0.2	0.3	d	1570	2,6,6-trimethyl-2-hydroxycyclohexanone	1.5	1.1	d
1160	heptanal	0.4	0.3	d	1572	2-undecanone	c	0.2	d
1170	4-methyl-2,3-dihydrofuran	0.3	0.3	d	1573	3,7-dimethyl-1,5,7-octatrien-3-ol	0.1	c	d
1177	3-methylbutanol	b	0.3	d	1577	2-methyl-5-acetylfuran	0.1	0.4	
1184	limonene	0.5	0.5	d	1583	undecanal	b	c	
1188	(E)-3-hexen-2-one	b	b		1583	1-methylformylpyrrole	c	0.2	d
1192	(E)-2-hexenal	1.1	0.5	d	1585	butyric acid	0.2	1.0	d
1198	1,8-cineole	b	b		1590	$\alpha$ ,4-dimethyl-3-cyclohexene-1-acetaldehyde	b	0.1	
1208	ethylmethylbenzene	b	0.1	d	1594	$\beta$ -cyclocitral	0.4	0.3	d
1215	2-pentylfuran	0.4	0.2	d	1596	safranal	0.2	0.2	d
1221	6-methyl-2-heptanone	0.3	0.4	d	1596	(E)-2-decenal	0.6	0.3	d
1231	pentanol	0.7	0.7	d	1609	phenylacetaldehyde	0.1	b	d
1242	$\gamma$ -terpinene	0.2	c	d	1626	furfuryl alcohol	0.2	0.5	d
1242	3-octanone	c	b	d	1631	nonanol	b	c	d
1245	2-methyl-3-oxotetrahydrofuran	b	0.2		1631	3-methylbutanoic acid	0.1	c	d
1258	methylpyrazine	0.1	0.3	d	1632	2-methylbutanoic acid	0.1	1.0	d
1261	p-cymene	0.2	0.4	d	1635	4-methyl-5-hexen-4-olide	0.4	0.4	d
1266	acetoin	0.3	b	d	1649	neral	0.4	0.3	d
1273	2-octanone	0.2	0.2	d	1655	2,6,6-trimethylcyclohex-2-ene-1,4-dione	0.4	0.7	d
1278	octanal	0.4	0.3	d	1660	6,10-dimethylundecanone	0.5	0.6	d
1280	$\alpha$ -terpinolene	0.1	c	d	1662	$\alpha$ -terpineol	1.9	0.4	d
1296	(Z)-2-pentenol	0.2	0.1	d	1674	2-dodecanone	b	b	
1298	4-methylpentanol	c	0.1		1682	1-phenylpropanone	0.3	0.7	d
1302	(E)-2-pentenol	1.1	0.8	d	1682	dodecanal	b	c	
1308	2,6,6-trimethylcyclohexanone	0.2	0.3	d	1686	benzyl acetate	c	0.2	d
1308	2,5-dimethylpyrazine	0.1	0.1	d	1689	valeric acid	0.3	0.8	d
1313	2,6-dimethylpyrazine	b	0.2	d	1693	geranial	0.5	0.6	d
1317	ethylpyrazine	b	0.1	d	1698	naphthalene	0.2	0.3	d
1320	6-methyl-5-hepten-2-one	1.5	1.3	d	1698	linalool oxide III (cis, pyranoid)	c	0.7	d
1328	2,3-dimethylpyrazine	c	0.1	d	1714	1,3,5-trimethyl-2-(1,3-butadienyl)benzene	0.1	0.5	
1332	hexanol	0.3	0.4	d	1720	(E)-2-undecenal	0.5	0.2	d
1342	3,3,5-trimethylcyclohexanone	0.2	0.1		1727	linalool oxide IV (trans, pyranoid)	0.1	0.7	d
1352	6-methyl-2-heptanol	b	0.1		1730	decanol	0.4	0.2	d
1355	2-acetoxypropanal	c	0.1		1734	1-(2-furyl)-1,2-propanedione	b	0.2	
1361	(Z)-3-hexenol	0.2	0.4	d	1739	methyl salicylate	0.2	0.8	d
1364	2-ethyl-5-methylpyrazine	c	0.1	d	1753	3-methyl-2-butenic acid	0.1	0.2	
1366	2-nonanone	0.4	0.4	d	1766	nerol	0.7	0.1	d
1368	(E)-2,(E)-4-hexadienal	0.2	0.2	d	1766	4-heptanolide	c	0.1	d
1368	nonanal	0.4	b	d	1777	(E)-2,(E)-4-decadienal	0.3	0.2	d
1371	2-butoxyethanol	9.5	1.2		1787	2-tridecanone	0.1	b	
1376	2,6,6-trimethylcyclohex-2-en-1-one	0.4	0.4	d	1807	hexanoic acid	2.8	3.2	d
1389	3-formylfuran	c	b		1812	geraniol	1.7	0.3	d
1394	2,3-dihydro-2,5-dimethylfuran	0.2	0.2	d	1815	guaiacol	0.2	0.6	d
1405	acetic acid	0.2	2.2	d	1818	$\alpha$ -ionone	1.5	0.7	d
1408	1,2-dichlorobenzene	c	0.2						

Table I. (Continued)

KI <sup>a</sup>	compound	GC peak area		KI <sup>a</sup>	compound	GC peak area		
		green	roast			green	roast	
1820	geranylacetone	3.4	1.8	d	2041	tridecanol	0.4	0.1
1827	undecanol	0.2	0.1		2046	4-propylguaiaicol	0.1	0.2
1833	benzyl alcohol	0.3	0.9	d	2069	6,10,14-trimethylpentadecanone	1.3	1.7
1863	2-phenylethanol	c	0.2	d	2074	4-decanolide	0.1	0.1
1867	4-octanolide	0.2	0.2	d	2087	bovolide	0.3	0.4
1871	benzyl cyanide	0.1	0.1	d	2096	nonanoic acid	1.7	2.0
1874	2-tetradecanone	0.1	c		2099	eugenol	c	2.5
1887	heptanoic acid	0.7	1.2	d	2105	3-ethylphenol		0.3
1889	$\beta$ -ionone	1.4	1.0	d	2115	4-ethylphenol	0.1	0.1
1892	4-methylguaiaicol	b	c	d	2122	1,6,7-trimethylnaphthalene	b	0.1
1920	dodecanol	0.3	0.1		2131	dihydrobovolide	0.4	0.2
1943	2-ethylnaphthalene	b	0.2		2134	tetradecanol	0.2	c
1953	phenol	0.6	0.9	d	2144	2,4-dihydroxyacetophenone	c	0.2
1957	5,6-epoxy- $\beta$ -ionone	1.4	1.3	d	2149	methyl palmitate	0.2	c
1959	1,2-dimethylnaphthalene	c	0.2		2151	cadinol T	b	c
1973	1-indanone	c	0.1		2163	decanoic acid	0.8	0.6
1978	2-formylpyrrole	b	0.3	d	2177	phytol	0.2	0.1
1985	4-ethylguaiaicol	c	0.3	d	2180	1-(2,3,6-trimethylphenyl)-3-buten-2-one	c	0.2
1989	4-nonanolide	0.2	0.2	d	2294	trans-geranic acid	0.1	0.1
1995	2,3-dihydro-2-methylbenzofuran	0.1	0.6		2304	isoeugenol	c	0.3
1995	2-pentadecanone	0.1	c		2308	dihydroactinidiolide	0.5	0.4
2005	nerolidol	0.3	b	d	2319	undecanoic acid	0.1	0.1
2008	6,10-dimethyl-3,5,9-undecatrien-2-one	0.3	0.1		2325	4-vinylphenol	0.1	c
2013	octanoic acid	2.8	3.5	d	2365	indole	0.2	c
2025	<i>o</i> -cresol	0.6	0.5	d	2500	dodecanoic acid	0.1	0.1
2031	<i>m,p</i> -cresol	0.1	0.3	d				

<sup>a</sup>Kovats index on Carbowax 20M. <sup>b</sup>Value less than 0.05. <sup>c</sup>Not detected. <sup>d</sup>Components of *Camellia sinensis* tea.

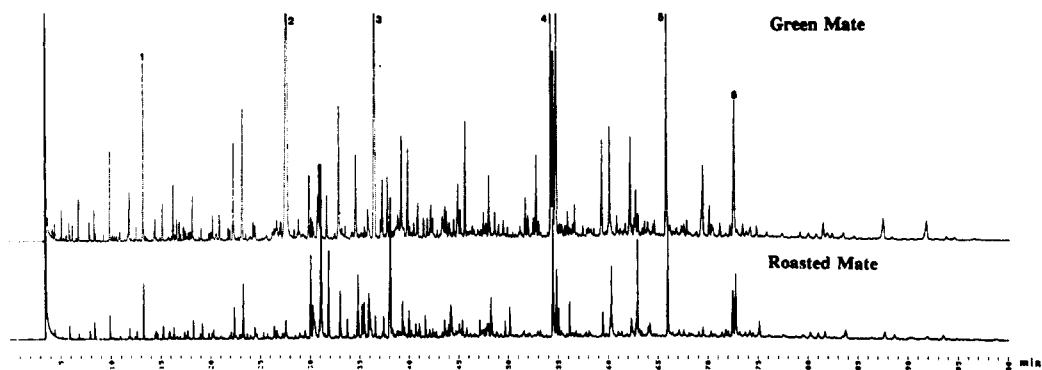


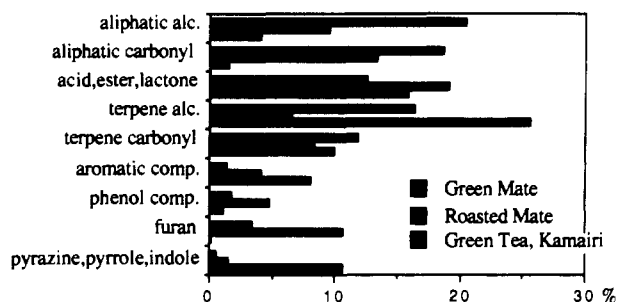
Figure 2. Gas chromatograms of the aroma concentrates from green and roasted mate teas. Peaks: (1) 1-penten-3-ol; (2) 2-butoxyethanol; (3) linalool; (4) hexanoic acid; (5) octanoic acid; (6) nonanoic acid.

major components of *C. sinensis* tea with the exception of 2-butoxyethanol. The presence of high levels of 2-butoxyethanol may suggest that this compound either is a contaminant from some agricultural chemicals or is produced during the manufacturing process. Although the ethylene glycol monoalkyl ether structure is uncommon among the natural plant products, it is found in both green and roasted mates produced in different countries. Moreover, the acetate derivative of the same compound, 1-acetoxy-2-propionyloxyethane, was identified in both volatiles. These results lead us to conclude that ethylene glycol type compounds might be specific products of the mate plant. On the basis of such a conclusion, the presence of dioxane might also be explained.

The skeleton structure of 3,3,5-trimethylcyclohexanone is also specific to mate. The ratios of terpene alcohols such as linalool,  $\alpha$ -terpineol, geraniol, nerol, and nerolidol were similar to those found in *C. sinensis* (Yamanishi et al., 1970; Kawakami et al., 1971; Kawakami and Yamanishi, 1983), and it seems that terpene alcohols were present as glycoside and were formed by hydrolytic degradation (Takeo, 1981; Yano et al., 1990). 6-Methyl-5-hepten-2-one was reported as a hydrolytic degradation product of neral and geraniol by heating (Chen and Ho, 1989). Ionone-related compounds such as  $\alpha$ -ionone,  $\beta$ -ionone, 5,6-

epoxy- $\beta$ -ionone, 2,6,6-trimethyl-2-hydroxycyclohexanone,  $\beta$ -cyclocitral, and dihydroactinidiolide are observed in mate tea as thermal degradation products from carotenoids (Kawashima and Yamanishi, 1973; Kawakami, 1982; Onyewu et al., 1989). Total carotenoids of green mate decreased from 0.66 to 0.08 mg/100 g by roasting (Japan Food Analysis Center, Tokyo, 1986). Most aliphatic alcohols, aldehydes, and acids with a straight chain such as 1-penten-3-ol, hexanal, 2,4-heptadienal, and hexanoic acid are degradation or secondary degradation products from fatty acid subjected to a heating treatment (Frankel et al., 1981). Aliphatic ketones such as 3,5-octadienone, (*E*)-3-penten-2-one, and 1-penten-3-one are easily formed from linolenic acid by photooxidation (Kawakami, 1990). Most of the other minor components in mate tea seem to be thermal degradation products resulting from the heating-drying process.

The components in roasted mate are degraded to a significant extent. Linalool, the major component of green mate, decreased and oxidized into linalool oxides. Other terpenoids also decreased in roasted mate. Instead of the decrease in alcohols and carbonyls, acids such as octanoic acid and nonanoic acid increased as shown in Figure 3 and Table I. The amounts of pyrazines, pyrroles, and furans increased considerably. These compounds are reported



**Figure 3.** Components of green mate (top bar in each grouping), roasted mate (middle bar in each grouping), and green tea (Kamairi) (bottom bar in each grouping).

to be formed by Maillard reaction during the roasting process as observed in roasted foods such as coffee (Tressl, 1989), Japanese Kamairi tea (Yamanishi et al., 1989), Mugicha (roasted barley), and cocoa (Yamanishi, 1981). Pyrazines are formed by Strecker degradation of amino acids with  $\alpha$ -dicarbonyls such as 2,3-butanedione or 2,3-pentanedione, cyclic enols, and furanaldehydes (Tressl, 1989). Their low aroma threshold level contributes significantly to the roasted mate flavor. Furans and furanones are formed from aldehydes such as carbohydrates or with amino acids via deoxyosones. Furfural, 5-methylfurfural, 2-acetylfuran, and 2-methyl-3-oxotetrahydrofuran were produced from glucose with serine by heating at 120 °C in a model system (Baltes et al., 1989). Phenols, characteristic components in roasted mate, increased by roasting, especially eugenol, which possesses a sweet cigarette aroma. 1,4-Substituted and 1,2,4-substituted phenolic compounds are formed from *p*-coumaric acid and ferulic acid precursors, respectively, by heating. The presence of these compounds may explain why the mate flavor partially resembles that of cigarette smoke.

The aroma concentrates of mate tea consisted of many degradation compounds from the heating-drying manufacturing process. They possessed complex flavors: smoky, earthy, sour, sweet, flowery, woody, and roasty, some of which are called off-flavors. The composition of the aroma concentrates of mate tea was slightly different from that of *C. sinensis* tea, but both teas contained similar components as shown in Table I and Figure 3. The complex pattern of mate volatiles could be a contributing factor in mate as a widely accepted beverage in many parts of the world.

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**Registry No.** Propanal, 123-38-6; butanal, 123-72-8; 2-butanone, 78-93-3; 3-methylbutanal, 590-86-3; ethanol, 64-17-5; 3-buten-2-one, 78-94-4; 2-ethylfuran, 3208-16-0; 2,3-butanedione, 431-03-8; pentanal, 110-62-3; 2-methyl-3-pentanone, 565-69-5; 1-penten-3-one, 1629-58-9; 2-methyl-3-buten-2-ol, 115-18-4; (*E*)-2-butenal, 123-73-9;  $\alpha$ -pinene, 80-56-8; toluene, 108-88-3; 2,3-pentanedione, 600-14-6; 1,4-dioxane, 123-91-1; hexanal, 66-25-1; 2-methyl-2-butenal, 1115-11-3;  $\beta$ -pinene, 127-91-3; (*E*)-2-pentenal, 1576-87-0; 4-methyl-3-penten-2-one, 141-79-7; butanol, 71-36-3; ethylbenzene, 100-41-4; 1-penten-3-ol, 616-25-1; 2-methyl-2-pentenal, 623-36-9;  $\beta$ -myrcene, 123-35-3; 1-phellandrene, 4221-98-1; 2-heptanone, 110-43-0; heptanal, 111-71-7; 4-methyl-2,3-dihydrofuran, 34314-83-5; 3-methylbutanol, 123-51-3; limonene, 138-86-3; (*E*)-3-hexen-2-one, 4376-23-2; (*E*)-2-hexenal, 6728-26-3; 1,8-cineole, 470-82-6; ethylmethylbenzene, 25550-14-5; 2-pentylfuran, 3777-69-3; 6-methyl-2-heptanone, 928-68-7; pentanol, 71-41-0;  $\gamma$ -terpinene, 99-85-4; 3-octanone, 106-88-3; 2-methyl-3-oxotetrahydrofuran, 3188-00-9; methylpyrazine, 109-08-0; *p*-cymene, 99-87-6; acetoin, 513-86-0; 2-octanone, 111-13-7; octanal, 124-13-0;  $\alpha$ -terpinolene, 586-62-9; (*Z*)-2-pentenol, 1576-95-0; 4-methylpentanol, 1320-98-5; (*E*)-2-pentenol, 1576-96-1; 2,6,6-trimethylcyclohexanone, 2408-37-9; 2,5-dimethylpyrazine, 123-32-0; 2,6-dimethylpyrazine, 108-50-9; ethylpyrazine, 13925-00-3; 6-methyl-5-hepten-2-one, 110-93-0; 2,3-dimethylpyrazine,

5910-89-4; hexanol, 111-27-3; 3,3,5-trimethylcyclohexanone, 873-94-9; 6-methyl-2-heptanol, 4730-22-7; 2-acetoxypromal, 22094-23-1; (Z)-3-hexenol, 928-96-1; 2-ethyl-5-methylpyrazine, 13360-64-0; 2-nonanone, 821-55-6; (E)-2,(E)-4-hexadienal, 142-83-6; nonanal, 124-19-6; 2-butoxyethanol, 111-76-2; 2,6,6-trimethylcyclohex-2-en-1-one, 20013-73-4; 3-formylfuran, 498-60-2; 2,3-dihydro-2,5-dimethylfuran, 17108-52-0; acetic acid, 64-19-7; 1,2-dichlorobenzene, 95-50-1; linalool oxide B, 5989-33-3; 1-octen-3-ol, 3391-86-4; 3,5,5-trimethylcyclohex-3-en-1-one, 471-01-2; heptanol, 111-70-6; furfural, 98-01-1; (E)-2,(Z)-4-heptadienal, 4313-02-4; linalool oxide A, 34995-77-2; 2-ethylhexan-1-ol, 104-76-7; (E)-2,(E)-4-heptadienal, 4313-03-5; 2-decanone, 693-54-9; 2-acetylfuran, 1192-62-7; decanal, 112-31-2; benzaldehyde, 100-52-7; (E)-3,(Z)-5-octadien-2-one, 4173-41-5; 1-acetoxy-2-propionyloxyethane, 98962-89-1; propionic acid, 79-09-4; (E)-2-nonenal, 18829-56-6; 2,10,10-trimethyl-6-methylidene-1-oxaspiro[4.5]dec-7-ene, 133965-59-0; linalool, 78-70-6; octanol, 111-87-5; 5-methylfurfural, 620-02-0; (E)-3,(E)-5-octadien-2-one, 30086-02-3; cyclopent-2-ene-1,4-dione, 930-60-9; 6-methyl-(Z)-3,5-heptadien-2-one, 29178-96-9; (E)-2,(Z)-6-nonadienal, 557-48-2; (E)-2,(E)-4-octadienal, 30361-28-5; 6-methyl-(E)-3,5-heptadien-2-one, 16647-04-4; 2,6,6-trimethyl-2-hydroxycyclohexanone, 7500-42-7; 2-undecanone, 112-12-9; 3,7-dimethyl-1,5,7-octatrien-3-ol, 29957-43-5; 2-methyl-5-acetylfuran, 1193-79-9; undecanal, 112-44-7; 1-methylformylpyrrole, 1192-58-1; butyric acid, 107-92-6;  $\alpha$ ,4-dimethyl-3-cyclohexene-1-acetaldehyde, 29548-14-9;  $\beta$ -cyclocitral, 432-25-7; safranal, 116-26-7; (E)-2-decenal, 3913-81-3; phenylacetaldehyde, 122-78-1; furfuryl alcohol, 98-00-0; nonanol, 28473-21-4; 3-methylbutanoic acid, 503-74-2; 2-methylbutanoic acid, 116-53-0; 4-methyl-5-hexen-4-olide, 1073-11-6; neral, 106-26-3; 2,6,6-trimethylcyclohex-2-ene-1,4-dione, 1125-21-9; 6,10-dimethylundecanone, 128724-26-5;  $\alpha$ -terpineol, 98-55-5; 2-dode-

canone, 6175-49-1; 1-phenylpropanone, 93-55-0; dodecanal, 112-54-9; benzyl acetate, 140-11-4; valeric acid, 109-52-4; geranial, 141-27-5; naphthalene, 91-20-3; linalool oxide D, 14009-71-3; 1,3,5-trimethyl-2-(1,3-butadienyl)benzene, 5732-00-3; (E)-2-undecenal, 53448-07-0; linalool oxide C, 39028-58-5; decanol, 112-30-1; 1-(2-furyl)-1,2-propanedione, 1438-92-2; methyl salicylate, 119-36-8; 3-methyl-2-butenic acid, 541-47-9; nerol, 106-25-2; 4-heptanolide, 105-21-5; (E)-2,(E)-4-decadienal, 25152-84-5; 2-tridecanone, 593-08-8; hexanoic acid, 142-62-1; geraniol, 106-24-1; guaiacol, 90-05-1;  $\alpha$ -ionone, 127-41-3; geranylacetone, 3796-70-1; undecanol, 112-42-5; benzyl alcohol, 100-51-6; 2-phenylethanol, 60-12-8; 4-octanolide, 104-50-7; benzyl cyanide, 140-29-4; 2-tetradecanone, 2345-27-9; heptanoic acid, 111-14-8;  $\beta$ -ionone, 79-77-6; 4-methylguaiacol, 93-51-6; dodecanol, 112-53-8; 2-ethenyl-naphthalene, 827-54-3; phenol, 108-95-2; 5,6-epoxy- $\beta$ -ionone, 23267-57-4; 1,2-dimethylnaphthalene, 573-98-8; 1-indanone, 83-33-0; 2-formylpyrrole, 1003-29-8; 4-ethylguaiacol, 2785-89-9; 4-nonanolide, 104-61-0; 2,3-dihydro-2-methylbenzofuran, 1746-11-8; 2-pentadecanone, 2345-28-0; nerolidol, 142-50-7; 6,10-dimethyl-3,5,9-undecatrien-2-one, 141-10-6; octanoic acid, 124-07-2; *o*-cresol, 95-48-7; *m,p*-cresol, 1319-77-3; tridecanol, 26248-42-0; 4-propylguaiacol, 2785-87-7; 6,10,14-trimethylpentadecanone, 87531-87-1; 4-decanolide, 706-14-9; boviolide, 774-64-1; nonanoic acid, 112-05-0; eugenol, 97-53-0; 3-ethylphenol, 620-17-7; 4-ethylphenol, 123-07-9; 1,6,7-trimethylnaphthalene, 2245-38-7; dihydroboviolide, 51352-68-2; tetradecanol, 112-72-1; 1,1'-biphenylene, 92-52-4; 2,4-dihydroxyacetophenone, 89-84-9; methyl palmitate, 112-39-0; cadinol T, 5937-11-1; decanoic acid, 334-48-5; phytol, 150-86-7; 1-(2,3,6-trimethylphenyl)-3-buten-2-one, 54789-45-6; *trans*-geranic acid, 4698-08-2; isoeugenol, 97-54-1; dihydroactinidiolide, 17092-92-1; undecanoic acid, 112-37-8; 4-vinylphenol, 2628-17-3; indole, 120-72-9; dodecanoic acid, 143-07-7.