

Aroma Compounds from Aqueous Solution of Haze (*Rhus succedanea*) Honey Determined by Adsorptive Column Chromatography

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Aroma concentrate separated from an aqueous solution of Haze honey by adsorptive column chromatography had a stronger aroma intensity than that separated by a combination of a preliminary extraction with acetone and separation of volatile compounds from acetone extract by steam distillation extraction. A total of 130 compounds were identified, including 27 alcohols, 19 aldehydes, 9 ketones, 12 esters, 8 acids, 35 hydrocarbons, 10 furanoids or pyranoids, and 10 miscellaneous compounds. The sensory importance of the volatile compounds was investigated by sniffing the fractions separated by preparative gas chromatography. As a result, benzeneacetaldehyde, linalool, phenethyl alcohol, *p*-cresol, *p*-anisaldehyde, methyl-*p*-anisaldehydes, trimethoxybenzene, 5-hydroxy-2-methyl-4*H*-pyran-4-one, and lilac aldehydes seemed to contribute to Haze honey aroma.

Keywords: *Aroma compounds; flavor components; honey; column concentration*

Honey is a nutritious product with organoleptic importance and a distinctive aroma. Several studies on the volatile compounds of honey have been carried out since the work of Dorrscheidt and Friedrich (1962). For example, Merz (1963) dealt with the ether extract from honey and tried to correlate the quality of honey with amounts of 5-(hydroxymethyl)furfural (HMF) and of the higher boiling volatile components. Cremer and Reidmann (1964) extracted honey volatiles in a stream of hydrogen at 70–90 °C, and identified 80 volatiles. Graddon et al. (1979) extracted honey volatiles with dichloromethane from unifloral Austrian honeys and identified almost 100 components with varying degrees of certainty, including phenylacetaldehyde, benzyl alcohol, 2-phenylethanol, linalool oxide, and hexenyl butyrate. Aroma compounds and methylated compounds in extracts from many types of New Zealand unifloral honeys have been analyzed (Tan et al., 1988, 1989, 1990; Wilkins et al., 1993). Recently, organic extractives from Leatherwood honey were analyzed to investigate the effect of maturation of Leatherwood flowers and leaves on the volatile components (Rowland et al., 1995).

There are several approaches to evaluate the potent aroma compounds of honey. The concentrations of aromatic acid, aldehydes, hydrocarbons, phenols, and N- or S-containing compounds in honey were compared with their odor threshold values (Stegg and Montag, 1987, 1988; Hausler and Montag, 1990a,b, 1991). Twenty-one compounds with high factors of dilution (FD) were designated as contributors to the aroma of linden honey (Blank et al., 1989) by aroma extract dilution analysis.

It was reported that the aroma concentrate prepared by the SDE method coupled with acetone extraction had a stronger honey-like odor than those prepared by direct steam distillation extraction (SDE), by continuous extraction with Soxhlet apparatus, and by direct extraction with ethyl acetate (Bicchi et al., 1983). Recently,

Bouseta et al. (1995) optimized the method of Bicchi et al. (1983); that is, pre-extraction with dichloromethane under an inert atmosphere was followed by optimized SDE operation.

We have applied a column extraction method to the separation of volatile compounds from infusions of green tea (Shimoda et al., 1995) and black tea (Shigematsu et al., 1994), wherein their aromas degrade during distillation even under reduced pressure, and from sake (Sakamoto et al., 1993), wherein ethyl alcohol (~15 v/v%) disturbs a quantitative separation of volatile compounds. Separation of volatile compounds from the sugar matrix of honey is the most important procedure because it greatly influences the quality of the aroma concentrate. The aim of present paper was to use the column extraction method to separate the volatile compounds from honey and determine the contributors to the aroma of Haze (*Rhus succedanea*) honey, which are volatiles that have not yet been investigated.

MATERIALS AND METHODS

Materials. The Haze honey sample (1994 season) was purchased directly from a beekeeper in Nagasaki prefecture. Cyclohexanol, diethyl ether, and anhydrous sodium sulfate were from Nacalai Tesque, Inc. (Kyoto, Japan). Methanol was purchased from Wako Pure Chemical Industries Company, Ltd. (Osaka, Japan) and was purified by passing it twice through a column (50 × 3 cm i.d.) packed with activated charcoal (analytical grade). Porapak type Q (50–80 mesh) was from Millipore Corp. (Milford, MA). 1-Phenyl-2-butanol and trimethoxybenzenes were from Aldrich Chemical Corp. (Milwaukee, WI).

Isolation of Volatile Flavor Compounds. *Column Extraction Method.* The 100-g honey sample was dissolved in 500 mL of deionized water, and 10 μL of 1.0% cyclohexanol solution was added to the sample solution as an internal standard. The sample solution was passed through a column (2 cm i.d. × 10 cm) packed with porous polymer beads (Porapak Q), and then the column was washed with 50 mL of deionized water to remove water-soluble constituents. Adsorbed volatiles were eluted with 80 mL of diethyl ether, and the eluate was dried over anhydrous sodium sulfate and concentrated to ~200 μL.

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Table 1. Volatile Compounds Separated by Column Extraction Method from Haze Honey

peak	KI ^a	compound	concentration (ppb)	threshold value	
				in air ^b (ppb,v/v)	in water (ppb)
1	882	ethyl acetat	269		
2	889	?-methyloctane	21		
3	921	2-propanol	253		
4	975	2-pentanone	28	1500	
5	985	methyl butyrate	61	4.68	43 ^m
6	992	1,2-dimethoxyethane ^{c,d}	tr ^f		
7	1000	<i>n</i> -decane	11		
8	1007	methyl 2-methylbutyrate	74	32	
9	1020	trichloromethane	35		
10	1022	2-butanol	34	1700	
11	1036	<i>n</i> -decene	84		
13	1040	toluene	54	1550	
14	1048	3-methyldecane	44		
15	1072	butyl acetate	27	195	66 ⁿ
16	1081	<i>n</i> -hexanal	28	13.8	4.5 ^o
17	1089	unknown	55		
18	1100	<i>n</i> -undecane	72		
19	1106	3,7-octadien-2-one ^{c,d}	37		
20	1136	1,4-dimethylbenzene	19	490	
21	1140	3-methyl-2(3 <i>H</i>)-furanone	30		
22	1142	1,3-dimethylbenzene	15	324	
23	1147	4-methylundecane ^c	6		
24	1160	2-methylcyclopentyl acetate ^{c,d}	61		
25	1176	1,2,3-trimethylbenzene	11		
26	1183	2-heptanone	22		140 ^p
27	1186	<i>n</i> -heptanal	10	4.79	2 ^q
28	1187	1,2-dimethylbenzene	8	851	
29	1200	<i>n</i> -dodecane	48	229	
30	1207	2-methylbutanol	55	115	
31	1212	<i>n</i> -propylbenzene	12		
32	1226	1-ethyl-4-methylbenzene	7		
33	1228	1-ethyl-3-methylbenzene	17		
34	1234	ethyl 2-oxopropanoate	5		
35	1246	3,4-dimethyl-1-decene ^c	6		
36	1259	ethenylbenzene	3		
37	1265	1-methylethylbenzene	7		
38	1272	4-penten-2-ol ^d	6		
39	1285	1,2,4-trimethylbenzene	21	155	
40	1289	3-hydroxy-2-butanone	19		
41	1291	<i>n</i> -octanal	tr	1.35	0.7 ^r
42	1300	<i>n</i> -tridecane	281		
43	1322	2-octanol	3	5.62	
44	1341	1-ethyl-2-methylbenzene	9		
45	1345	2,3-butanediol	9		
46	1356	tetrahydro-3,7-dimethyl-2 <i>H</i> -pyran-2-one ^{c,d}	21		
47	1361	1,3-bis(1-methylethyl)benzene ^{c,d}	8		
48	1366	3-methyltridecane	6		
49	1371	4-ethyl-1,2-dimethylbenzene	2		
50	1388	(<i>Z</i>)-3-hexenol ^d	21		70 ^o
51	1397	<i>n</i> -nonanal	95	2.24	1 ^s
52	1400	<i>n</i> -tetradecane	71		
53	1404	1,4-bis(1-methylethyl)benzene ^{c,d}	4		
54	1410	cyclohexanol (internal standard)	1000		
55	1448	linalool oxide (<i>trans</i> -furanoid)	2461		7000 ^t
56	1451	acetic acid	358	145	
57	1461	octyl acetate	tr		12 ^u
58	1467	furfural	18	776	3000 ^p
59	1477	linalool oxide (<i>cis</i> -furanoid)	1967		6000 ^t
60	1495	2-ethylhexanol ^{c,d}	10	245	
61	1500	<i>n</i> -pentadecane	71		
62	1514	acetylfuran	9		10000 ^p
63	1522	<i>trans</i> -decahydronaphthalene	8		
64	1534	benzaldehyde	136	41.7	3 ^r
65	1541	2,3-butanediol	633		
66	1547	linalool	113	53.7	6 ^v
67	1556	lilac aldehyde ^c	31		
68	1560	unknown	10		
69	1564	lilac aldehyde ^c	28		
70	1571	2-methylpropanoic acid	76	19.5	
71	1573	5-methyl-2-furfural	tr		
72	1576	1,3-butanediol	29		
73	1588	lilac aldehyde ^c	30		
74	1600	<i>n</i> -hexadecane	37		
75	1613	2,6-dimethyl-1,3,7-octatrien-6-ol	113		

Table 1 (Continued)

peak	KI ^a	compound	concentration (ppb)	threshold value	
				in air ^b (ppb,v/v)	in water (ppb)
76	1620	1- <i>p</i> -menthen-9-al	2		
77	1623	borneol	tr		
78	1631	butanoic acid	40	38.9	200 ^w
79	1646	benzeneacetaldehyde	49		4 ^l
80	1662	furfuryl alcohol	98		1900 ^p
81	1669	5-ethenyl-5-methyl-2(3 <i>H</i>)-furanone ^{c,d}	140		
82	1673	3-methylbutanoic acid	210	2.45	750 ^w
83	1694	(<i>Z</i>)-2-hexenyl acetate	tr		
84	1797	γ -octalactone ^d	79	7	
85	1700	<i>n</i> -heptadecane	35		
86	1705	α -terpineol	tr	46	
87	1706	azulene ^d	23		
88	1711	4-ethylbenzaldehyde ^d	31		
89	1721	isomer of linalool oxide	25		
90	1724	1,2,3,4-tetrahydro-2,7-dimethylnaphthalene	5		
91	1731	4-(1-methylethyl)benzaldehyde ^c	21		
92	1734	unknown ^g	tr		
93	1745	linalool oxide (<i>trans</i> -pyranoid)	3407		3600 ^t
94	1769	linalool oxide (<i>cis</i> -pyranoid)	3665		5400 ^t
95	1779	methyl salicylate	65	43.7	
96	1782	2,2,6-trimethyl-1,4-cyclohexanedione ^d	tr		
97	1786	unknown ^g	62		
98	1796	2,3-butanedione monooxime ^{c,d}	6		
99	1800	<i>n</i> -octadecane	29		
100	1808	<i>N,N</i> -dibutylacetamide ^{c,d}	47		
101	1821	methyl 2,4-dimethylbenzoate ^{c,d}	tr		
102	1823	tetrahydro-2-furanmethyl acetate ^d	72		
103	1836	1-(3,4-dimethylphenyl)ethanone ^d	326		
104	1843	2-methyl-1-propenylbenzene ^{c,d}	24		
105	1853	2,5-hexanediol ^{c,d}	5		
106	1856	hexanoic acid	39	12.6	
107	1866	<i>p</i> -guaiacol	17	1	3 ^v
108	1870	<i>exo</i> -2-hydroxycineole ^{c,d}	18		
109	1876	1-(2,4-dimethylphenyl)ethanone ^d	174		
110	1886	benzenemethanol	3932		20000 ^v
111	1894	unknown	484		
112	1903	unknown	83		
113	1920	2,6-bis(1,1-dimethylethyl)-4-methylphenol ^e	4077		
114	1923	phenethyl alcohol	820	17	1000 ^o
115	1942	a sesquiterpene	11		
116	1951	(<i>E</i>)-3-hexenyl hexanoate ^d	804		
117	1955	unknown	57		
118	1960	unknown ^h	790		
119	1976	unknown ⁱ	257		
120	1982	unknown	116		
121	1989	unknown ⁱ	58		
122	1993	unknown ^h	481		
123	1998	unknown ⁱ	61		
124	2001	furyl hydroxymethyl ketone ^{c,d}	208		
125	2016	<i>p</i> -anisaldehyde	560	33.1	
126	2020	unknown ⁱ	642		
127	2030	5-hydroxy-2-methyl-4 <i>H</i> -pyran-4-one ^d	42		
128	2037	unknown ^k	203		
129	2044	unknown ^k	273		
130	2048	octanoic acid	127	3.98	
131	2060	trimethoxybenzene	25		
132	2073	1,5-bis(1,1-dimethylethyl)-3,3-dimethyl-bicyclo[3.1.0]hexan-2-one ^{c,d}	201		
133	2076	2-hydroxybenzaldehyde	18	7.41	
134	2082	unknown ^h	615		
135	2090	2,6-dimethyl-?,?-octadiene-?,?-diol	611		
136	2099	unknown ^h	1964		
137	2128	nonanoic acid	396		
138	2139	unknown	240		
139	2179	unknown	3561		
140	2184	2,6-dimethyl-?,?-octadiene-?,?-diol	796		
141	2191	4-methoxybenzenemethanol ^d	961		
142	2200	<i>n</i> -docosane	592		
143	2206	3,5-dihydroxy-2-methyl-4 <i>H</i> -pyran-4-one ^d	404		
144	2216	2,6-dimethyl-?,?-octadiene-?,?-diol	1834		
145	2226	<i>trans-p</i> -menth-8-ene-1,2-diol ^c	49		
146	2318	3-hydroxybenzeneethanol ^{c,d}	40898		
147	2347	unknown ^l	3928		
148	2354	unknown ^l	656		
149	2380	1-phenyl-2-butanol ^d	9667		

Table 1 (Continued)

peak	KI ^a	compound	concentration (ppb)	threshold value	
				in air ^b (ppb,v/v)	in water (ppb)
150	2410	5-(hydroxymethyl)-2-furfural	2769		
151	2436	1-phenyl-1-pentanol ^{c,d}	19754		
152	2442	<i>cis-p</i> -menth-8-ene-1,2-diol ^c	563		
153	2490	benzeneacetic acid	2717		

^a Modified Kovats indices calculated for DB-wax capillary column on the GC system. ^b Devos et al., 1990. ^c Tentatively identified by mass spectrum. ^d Reported as honey constituents for the first time. ^e Antioxidant/stabilizer in ethyl ether. ^f tr represents concentration of <1 ppb. ^g EIMS at 70 eV, *m/z* 43(100), 59(51), 84(43), 41(39), 81(35), 83(22), 55(18), 71(16). ^h EIMS at 70 eV, *m/z* 43(100), 111(67), 55(52), 93(49), 75(40), 41(40), 57(35), 68(27). ⁱ EIMS at 70 eV, *m/z* 79(100), 43(89), 135(57), 92(43), 150(28), 107(22), 65(17), 121(10). ^j EIMS at 70 eV, *m/z* 43(100), 71(71), 41(44), 108(17), 57(17), 55(17), 93(10), 69(9). ^k EIMS at 70 eV, *m/z* 43(100), 55(77), 59(61), 84(60), 71(46), 41(34), 110(34), 81(34). ^l EIMS at 70 eV, *m/z* 43(100), 59(89), 68(50), 72(44), 41(37), 94(35), 71(35), 55(31). ^m Hansen et al., 1992. ⁿ Ahmed et al., 1978. ^o Flath et al., 1967. ^p Buttery et al., 1987. ^q Buttery et al., 1994. ^r Moshonas and Shaw, 1994. ^s Karahadian and Johnson, 1993. ^t Gomez et al., 1993. ^u Beritz and Grosch, 1987a. ^v Takeoka et al., 1992. ^w Vercellotti et al., 1987. ^x Beritz and Grosch, 1987b.

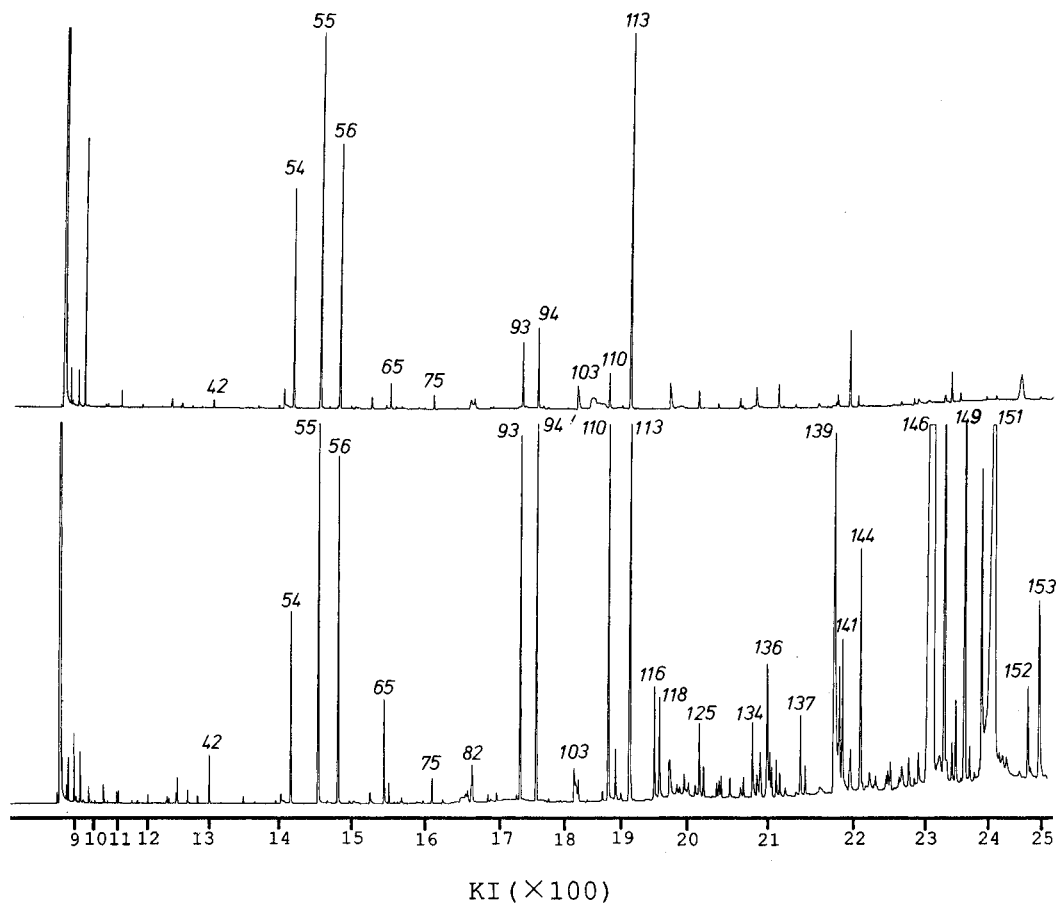


Figure 1. Gas chromatograms of aroma concentrates by a combined method of acetone extraction and SDE separation (top) and adsorptive column method (bottom) from Haze honey. For more information, see Materials and Methods and Results.

SDE Method Coupled with Acetone Extraction. This method was carried out almost according to the method of Bicchi et al. (1983). One hundred grams of honey containing 10 μ L of 1.0% cyclohexanol solution as internal standard were extracted for 2 h by stirring with 100 mL of acetone (repeated two times). The acetone combined phase was concentrated to \sim 10 mL in a rotary evaporator at 25 $^{\circ}$ C, and then diluted with 500 mL of water. Volatiles were separated with 80 mL of diethyl ether from the aqueous solution by a simultaneous SDE method under reduced pressure for 80 min with a modified Likens-Nickerson apparatus (SDE method). The condenser of the SDE apparatus was cooled with a mixture of water and diethylene glycol at -5 $^{\circ}$ C. The ether solution was dried over anhydrous sodium sulfate, and then concentrated to \sim 200 μ L under a stream of nitrogen at 35 $^{\circ}$ C.

Capillary Gas Chromatography (GC). Capillary GC analysis was carried out on a Shimadzu GC 14A gas chromatograph equipped with a flame ionization detector (FID) and connected to a Shimadzu Chromatopak C-R5A integrator. Separation was achieved on a 60 m \times 0.25 mm i.d. fused silica

capillary column, coated with cross-linked poly(ethylene glycol) 20M, with a film thickness of 0.25 μ m (DB-Wax, J&W Science, Folsom, CA). The column temperature was programmed at 3 $^{\circ}$ C/min from 50 up to 230 $^{\circ}$ C. The injector and detector temperatures were both 220 $^{\circ}$ C. Helium was used as a carrier gas at a column flow rate of 28 cm/s (50 $^{\circ}$ C). An injection splitter was used at a split ratio of 20:1. Retention indices were estimated by a modified Kovats method (Van den Dool and Kratz, 1963).

Capillary Gas Chromatography–Mass Spectrometry (GC–MS). Electron-impact mass spectrometric data were collected on a JEOL Auto Mass 50 gas chromatograph–mass spectrometer system. The column and the chromatographic conditions were the same as described for GC analysis. The mass spectrometer was operated at an ionization voltage of 70 V and an ion source temperature of 200 $^{\circ}$ C. The mass spectra of the unknown compounds were compared with those in the Wiley/NBS Registry of Mass Spectral Data with a computer system and other published spectra (*Eight Peak*

Table 2. Odor Characteristics of the GC Effluents Fractionated by Preparative GC

fraction	range ^a	odor characteristics	odor strength
I	882–1265	estery, fruity	medium
II	1272–1547	floral	weak
III	1556–1920	honey-like, poor in sweet odor	medium
IV	1923–2191	honey-like, very sweet	strong
V	2200–2490	fruity	weak

^a Modified Kovats indices.

Index of Mass Spectra, 1983; Wiley/NBS Registry of Mass Spectral Data, 1989).

Preparative GC and Sniffing. To evaluate odor attributes of five fractions in the gas chromatogram, preparative GC and sniffing was done as described in our previous paper (Shiratsuchi et al., 1995). For preparative GC, a Shimadzu GC 8A equipped with a 60 m × 0.75 mm i.d. chemically bonded PEG 20M (film thickness, 1 μm) megabore open tubular column (Supelco-wax 10; Supelco, Bellefonte, PA) and an FID was used. The oven temperature was programmed from 50 to 220 °C at 2 °C/min. The odor concentrate was introduced to the GC with a splitless injection. Short capillaries (25 cm × 0.53 mm i.d.) with a chemically bonded phase of PEG 20M were used for trapping volatiles. The separated volatiles were eluted on a filter paper with a drop of ethyl ether, and the odor was sniffed by co-workers.

RESULTS AND DISCUSSION

Separation and Concentration of Aroma Compounds. A column extraction was conducted to separate volatile compounds from honey. For comparison, an aroma concentrate was prepared by a combination of a preliminary extraction from a sugar matrix with acetone and the separation of volatile compounds from acetone extract by SDE under reduced pressure. Comparative sniffing of the two aroma concentrates showed that the concentrate obtained by the column method had a much stronger honey-like odor than that obtained by the SDE method coupled with acetone extraction.

GC and GC-MS Analysis. Gas chromatograms are compared in Figure 1. The column concentrate was rich in medium and high boiling compounds compared with that obtained by SDE coupled with acetone extraction. The relation of the profile of the gas chromatograms with their odor strength was consistent with the conclusion described by Merz (1963); that is, the contributors to honey odor are in the medium to high boiling fractions. The identified volatile compounds in the column concentrate and their quantitative values on the basis of the peak area ratios to internal standard on the total ion chromatogram (TIC) are listed in Table 1. A total of 130 compounds were definitely or tentatively identified, including 27 alcohols, 19 aldehydes, 9 ketones, 12 esters, 8 acids, 35 hydrocarbons, 10 furanoids or pyranoids, and 10 miscellaneous compounds. The odor threshold values in the vapor and aqueous phases were listed as a measure of sensory importance.

Preparative GC and Sniffing. The column concentrate was separated into five fractions by preparative GC to sniff the GC effluents. The ranges in retention indices and odor characteristics of each fraction are shown in Table 2. Fraction I smelled estery and fruity, and the odors were very light. Fraction II had a weak floral odor. Fractions III and IV had a honey-like odor; especially fraction IV, which had a strong and typical honey-like odor rich in a sweet odor. The odor of fraction V was slightly fruity but very weak. The results suggested that principal contributors to the odor of Haze honey were eluted in the range from 1923 to 2191 in modified Kovats index on DB-Wax column.

In fraction I, ethyl acetate, methyl butyrate, methyl 2-methylbutyrate, butyl acetate, 2-methylcyclopentyl acetate, and ethyl 2-oxopropanoate contributed to the estery and fruity odors. Besides these esters, aliphatic aldehydes such as *n*-hexanal and *n*-heptanal, partly contributed to the fruity odor.

Linalool oxides (both of *trans*-furanoid and *cis*-furanoid) were principal components in amount, but their high threshold values indicated they could not directly contribute to the floral odor of fraction II. *n*-Nonanal, acetic acid, benzaldehyde, and linalool were considered to have a sensory importance because of their low threshold values, and they could be responsible for the floral odor of fraction II.

The large quantities of *cis*- and *trans*-pyranoid of linalool oxides might contribute little to the honey-like odor of fraction III because of their extremely high threshold values. 2,6-Dimethyl-1,3,7-octatrien-6-ol (trienol), with a very sweet and flowery odor (Nakatani et al., 1969); benzeneacetaldehyde, with a honey-like odor (Blank et al., 1989); γ -octalactone, with a sweet odor; 4-ethylbenzaldehyde, with a sweet, bitter almond-like odor with floral greenness (Arctander, 1969); methyl salicylate, with a minty and cool odor (*Atlas of Odor Character Profiles*, 1985); and guaiacol, with a smoky odor (*Atlas of Odor Character Profiles*, 1985) were main contributors to the odor of fraction III. In this fraction, 2-methylpropanoic acid, butanoic acid, 3-methylbutanoic acid, and hexanoic acid, which smell pungent, were found in various concentrations. Three isomers of lilac aldehyde were tentatively identified by comparison with mass spectra reported by Wilkins et al. (1993), and they seemed to contribute to the odor of fraction III. Fraction IV, which had a very sweet and honey-like odor, was the most important fraction. In this fraction, phenethyl alcohol, with an intense floral and fragrant odor (*Atlas of Odor Character Profiles*, 1985); two methyl-*p*-anisaldehydes, one of which was 3-methyl-*p*-anisaldehyde, with a sweet and somewhat spicy odor; and trimethoxybenzene with a sweet, jam-like, and pungent odor, could contribute to the sweet honey-like odor. Blank et al. (1989) reported that *p*-anisaldehyde, which smells minty and sweet, was an important odorant of linden, acacia, and heath honey. A large amount of *p*-anisaldehyde was found and it could be a potent odor contributor. 5-Hydroxy-2-methyl-4*H*-pyran-4-one seemed to contribute to a sweet odor because its isomer, 3-hydroxy-2-methyl-4*H*-pyran-4-one (maltol), has a strong sweet odor (Pittet et al., 1970). Peaks 92 and 97 and peaks 118, 122, 134, and 136 gave similar mass spectra. The latter spectra had high similarity with the spectrum of lilac alcohol, except for 75 mass fragment (Wilkins et al., 1993), which suggested acetal analogues of lilac aldehyde. The mass spectra of peaks 123 and 126 and peaks 128 and 129 were also similar to each other, respectively. None of the four mass spectra shown in the legend of Table 1 could be found in the Wiley/NBS Registry of Mass Spectral Data and other published spectra. Further investigations on their sensory characteristics and the identification should be done.

The constituents of fraction V had only a small sensory importance in spite of their high concentrations. Two isomers of 1-phenyl-2-butanol could contribute to the fruity odor to some extent because the compound (racemic mixture) smelled estery and solvent-like. The compounds of peaks 147 and 148 gave identical mass spectra with furanoid types of linalool oxides, but their retention indices suggested they were unknown oxygenated compounds of linalool.

Blank et al. (1989) reported that (*E*)- β -damascenone, which had the largest FD factor (≥ 1024) and honey-like, fruity, and sweet odors, was found in linden, acacia, and heath honey. However, the compound was not found in Haze honey. Benzeneacetaldehyde, linalool, phenethyl alcohol, *p*-cresol, and *p*-anisaldehyde, which had the next largest FD factors, were also found in Haze honey. Besides these compounds, methyl-*p*-anisaldehydes, trimethoxybenzene, 5-hydroxy-2-methyl-4*H*-pyran-4-one, lilac aldehydes, and some of isomers A, B, C, and D might also contribute to Haze honey aroma.

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