

# Volatile Chemicals Identified in Extracts from Leaves of Japanese Mugwort (*Artemisia princeps* Pamp.)

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Extracts from leaves of Japanese mugwort (*Artemisia princeps* Pamp.) were obtained using two methods: steam distillation under reduced pressure followed by dichloromethane extraction (DRP) and simultaneous purging and extraction (SPSE). A total of 192 volatile chemicals were identified in the extracts obtained by both methods using gas chromatography (GC) and gas chromatography–mass spectrometry (GC-MS). They included 47 monoterpenoids (oxygenated monoterpenes), 26 aromatic compounds, 19 aliphatic esters, 18 aliphatic alcohols, 17 monoterpenes (hydrocarbon monoterpenes), 17 sesquiterpenes (hydrocarbon sesquiterpenes), 13 sesquiterpenoids (oxygenated sesquiterpenes), 12 aliphatic aldehydes, 8 aliphatic hydrocarbons, 7 aliphatic ketones, and 9 miscellaneous compounds. The major volatile constituents of the extract by DRP were borneol (10.27 ppm),  $\alpha$ -thujone (3.49 ppm), artemisia alcohol (2.17 ppm), verbenone (1.85 ppm), yomogi alcohol (1.50 ppm), and germacren-4-ol (1.43 ppm). The major volatile constituents of the extract by SPSE were 1,8-cineole (8.12 ppm), artemisia acetate (4.22 ppm),  $\alpha$ -thujone (3.20 ppm),  $\beta$ -caryophyllene (2.39 ppm), bornyl acetate (2.05 ppm), borneol (1.80 ppm), and *trans*- $\beta$ -farnesene (1.78 ppm).

**Keywords:** Volatile chemicals; gas chromatography; Japanese mugwort; yomogi

## INTRODUCTION

Japanese mugwort (yomogi; *Artemisia princeps* Pamp.) is a plant native to China, Japan, and Korea. It generally grows in mountainous areas. The plant—including stem (1 cm), branches, and leaves—grows to ~60–120 cm. Young leaves of yomogi have a characteristic greenish aroma. In the spring in Japan, yomogi leaves are mixed with rice cakes to give them a fresh aroma and a greenish color. The green juice of yomogi leaves is also used in traditional Japanese folk medicine to treat skin injuries. In Korea, the juice of yomogi leaves is used to treat gastrointestinal disorders (Kim et al., 1994). The extracts from yomogi leaves have received attention from researchers in Japan and Korea since the mid-1960s. Before appropriate gas chromatography–mass spectrometry (GC-MS) was developed, 22 constituents of extracts from yomogi leaves were identified using fractional distillation and packed column GC (Tsubaki et al., 1966). Later, nearly 100 components of yomogi extracts were identified using an advanced GC-MS with a capillary column (Fujita and Nogami, 1994, 1995).

In the present study, volatile chemicals in extracts obtained from young yomogi leaves were identified by GC and GC-MS.

## EXPERIMENTAL PROCEDURES

**Materials.** Japanese mugwort leaves or yomogi leaves (*A. princeps* Pamp.) were bought from a local market. Authentic compounds were purchased from Aldrich Chemical Co. (Milwaukee, WI), Tokyo Kasei Organic Chemicals (Tokyo, Japan),

Wako Pure Chemical Industries, Ltd. (Osaka, Japan), and Fluka Chemical Co. (Ronkonkoma, NY) or obtained from Takata Koryo Co., Ltd. (Osaka, Japan) as a gift. Yomogi alcohol, artemisia alcohol, and caryophylla-2(12),6(13)-dien-5-one were synthesized according to the methods of Thomas and Pawlak (1971), Wilson and Guazzaroni (1989), and Kaiser and Lamparsky (1983), respectively.

**Isolation of Volatile Chemicals by Steam Distillation under Reduced Pressure (DRP).** Yomogi leaves (250 g) were washed with cold water three times and once with hot water and then cut into small pieces (1 cm) using a knife. The pieces of yomogi leaves were homogenized in a blender with 1800 mL of distilled water and 200 mL of saturated sodium chloride solution. The homogenized sample was placed in a 3 L round-bottom flask. The solution was steam distilled at 32 °C for 30 min under reduced pressure (32 mmHg). The distillate (900 mL) was extracted with 130 mL of dichloromethane using a liquid–liquid continuous extractor for 6 h. After the extract was dried over anhydrous sodium sulfate, the solvent was removed by distillation with a Vigreux column. The distillation was stopped when the volume of extract was reduced to 1 mL, and then the solvent was further reduced under a purified nitrogen stream until the extract weight was 100 mg. The sample was stored at 5 °C until analysis.

**Headspace Isolation by Simultaneous Purging and Solvent Extraction (SPSE).** Yomogi leaves (350 g) were washed with cold water three times and once with hot water and then cut into small pieces (1 cm) using a knife. The pieces of yomogi leaves were homogenized in a blender with 2000 mL of distilled water and 200 mL of saturated sodium chloride solution. The homogenized sample was placed in a 5 L round-bottom flask. The flask was connected to an SPSE apparatus previously prepared (Umamo and Shibamoto, 1987, 1988). The flask was kept at 40 °C with a water bath. Headspace volatile chemicals were purged into 200 mL of distilled water, which was extracted with 30 mL of dichloromethane simultaneously and continuously for 2 h. After the extract was dried over anhydrous sodium sulfate, the solvent was removed by distillation with a Vigreux column. Distillation was stopped when the volume of extract was reduced to 1 mL. The excess solvent was further reduced under a purified nitrogen stream until

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**Table 1. Aroma Chemicals Identified in Yomogi Leaf Extracts**

compound	GC peak <sup>a</sup>	<i>I</i> <sup>b</sup>	concentration (ppm)	
			DRP <sup>c</sup>	SPSE <sup>d</sup>
<b>monoterpenes</b>				
$\alpha$ -pinene	9	1021	nd <sup>e</sup>	1.10
$\alpha$ -thujene	10	1024	nd	0.34
camphene	15	1064	0.28	1.88
$\beta$ -pinene	18	1107	nd	0.66
sabinene	19	1119	tr <sup>f</sup>	0.47
$\alpha$ -phellandrene	24	1161	0.11	nd
myrcene	25	1161	nd	1.06
$\alpha$ -terpinene	27	1176	0.24	0.15
D-limonene	32	1197	0.09	1.29
$\beta$ -phellandrene	33	1206	0.13	tr
<i>cis</i> - $\beta$ -ocimene	37	1230	tr	0.47
$\gamma$ -terpinene	39	1243	0.26	0.21
<i>trans</i> - $\beta$ -ocimene	41	1249	nd	0.22
1-(1-methylethyl)-4-methylbenzene ( <i>p</i> -cymene)	46	1266	tr	tr
terpinolene	50	1279	tr	tr
1-(1-methylethyl)-2-methylbenzene ( <i>o</i> -cymene)	55	1298	tr	nd
1-(1-methylethenyl)-4-methylbenzene (dehydro- <i>p</i> -cymene)	83	1432	tr	nd
<b>monoterpenoids</b>				
2,3-dehydro-1,8-cineol	31	1190	tr	nd
1,8-cineol	34	1208	0.13	8.12
5,5-trimethyl-2,6-heptadien-4-one (artemisia ketone)	64	1346	nd	tr
2,5,5-trimethylhepta-3,6-dien-2-ol (yomogi alcohol)	78	1404	1.50	0.96
$\alpha$ -thujone	80	1417	3.49	3.20
2,5,5-trimethylhepta-2,6-dien-4-yl acetate (artemisia acetate)	81	1417	tr	4.22
$\beta$ -thujone	84	1436	0.20	0.22
<i>trans</i> -sabinene hydrate	88	1467	0.40	0.25
chrysanthenone	93	1501	0.16	0.45
2,5,5-trimethylhepta-2,6-dien-4-ol (artemisia alcohol)	94	1509	2.17	0.67
camphor	95	1510	1.06	0.14
thujyl acetate	99	1542	tr	tr
<i>cis</i> -sabinene hydrate	100	1550	0.45	tr
pinocarvone	102	1561	tr	tr
<i>p</i> -menth-2-en-1-ol <sup>g</sup>	103	1563	0.20	0.02
bornyl acetate	104	1578	0.43	2.05
4-terpineol	107	1601	0.34	0.07
lavandulyl acetate	108	1606	0.07	0.15
myrtenal	111	1621	tr	0.01
bornyl isobutanoate	113	1638	0.18	0.35
bornyl propanoate	114	1641	0.16	0.34
pinocarveol	115	1654	0.12	0.02
thujyl alcohol (first)	117	1664	0.09	nd
thujyl alcohol (second)	121	1679	1.37	nd
<i>trans</i> -verbenol	122	1679	nd	0.06
$\alpha$ -terpinyl acetate	123	1694	nd	nd
$\alpha$ -terpineol	124	1697	nd	0.01
borneol	125	1701	10.27	1.79
verbenone	126	1701	1.85	nd
$\alpha$ -citral	130	1726	0.04	nd
L-carvone	132	1729	0.05	nd
L-carvenyl acetate	133	1731	nd	tr
piperitol	134	1741	0.36	nd
chrysanthenol	136	1751	0.04	0.03
citronellol	138	1769	0.13	nd
L-perillaldehyde	140	1777	0.13	nd
myrtenol	141	1793	0.07	nd
<i>p</i> -mentha-1(7),8-dien-2-ol	142	1797	0.03	nd
isopiperitenone	144	1832	0.01	nd
<i>trans</i> -carveol	145	1833	0.28	nd
<i>p</i> -cymen-8-ol	146	1847	0.02	nd
geraniol	147	1850	0.10	nd
<i>trans</i> -myrtenol	148	1856	tr	nd
<i>cis</i> -myrtenol	149	1861	0.03	nd
<i>cis</i> -carveol	150	1866	0.34	nd
piperityl acetate	154	1900	0.02	nd
L-perillyl alcohol	161	2004	0.31	nd
<b>sesquiterpenes</b>				
$\alpha$ -copaene	91	1487	nd	0.05
$\alpha$ -bourbonene	96	1513	nd	tr
$\beta$ -cubebene	98	1524	nd	tr
<i>trans</i> - $\alpha$ -bergamotene	105	1583	nd	tr
$\beta$ -caryophyllene	106	1591	0.07	2.39
aromadendrene	109	1610	nd	tr
$\alpha$ -humulene	116	1664	nd	0.77
<i>trans</i> - $\beta$ -ndarnesene	118	1668	0.09	1.78

Table 1 (Continued)

compound	GC peak <sup>a</sup>	<i>I</i> <sup>b</sup>	concentration (ppm)	
			DRP <sup>c</sup>	SPSE <sup>d</sup>
<b>sesquiterpenes</b>				
<i>β</i> -guaiene <sup>g</sup>	119	1671	nd	tr
<i>γ</i> -muurolene	120	1679	nd	0.04
germacrene D	127	1705	nd	1.23
zingiberene	128	1718	nd	0.21
<i>α</i> -muurolene	129	1722	0.15	tr
<i>cis,trans</i> - <i>α</i> -farnesene	131	1726	0.04	0.71
<i>trans,trans</i> - <i>α</i> -farnesene	135	1747	nd	0.21
<i>δ</i> -cadinene	137	1755	1.03	0.21
<i>ar</i> -curcumene	139	1770	nd	0.02
<b>sesquiterpenoids</b>				
caryophyllene oxide	159	1977	0.30	0.01
<i>α</i> -humulene oxide (first)	162	2010	0.02	nd
elemyl acetate	164	2026	0.01	nd
<i>α</i> -humulene oxide (second)	165	2033	0.12	tr
caryophylla-2(12),6(13)-dien-5-one	166	2037	0.20	0.01
<i>trans</i> -nerolidol	167	2041	0.27	tr
germacren-4-ol <sup>g</sup>	168	2050	1.43	nd
globulol	169	2073	nd	tr
caryophylla-2(12),6-dien-5-one	170	2079	0.07	nd
<i>δ</i> -cadinol <sup>g</sup>	174	2169	0.64	0.06
<i>α</i> -bisabolol	177	2214	0.06	nd
<i>α</i> -cadinol <sup>g</sup>	178	2232	1.36	nd
caryophylla-2(12),6(13)-dien-5-ol	180	2294	0.41	tr
<b>aliphatic aldehydes</b>				
2-methylpropanal	2	818	0.02	0.99
2-methyl-2-propenal	5	893	nd	0.05
( <i>E</i> )-2-butenal	13	1037	tr	nd
4-methylpentanal	14	1038	nd	tr
hexanal	16	1080	tr	0.04
heptanal	29	1183	nd	0.01
( <i>E</i> )-2-hexenal	35	1215	0.05	0.14
octanal	53	1286	tr	0.02
( <i>E</i> )-2-heptenal	57	1321	nd	tr
nonanal	76	1391	tr	0.02
( <i>E</i> )-2-octenal	82	1426	tr	nd
( <i>E,Z</i> )-2,4-heptadienal	85	1460	tr	nd
<b>aliphatic esters</b>				
ethyl butanoate	11	1033	tra	nd
2-methylpropyl 2-methylpropanoate	17	1092	nd	tr
3-methylbutyl propanoate	30	1188	nd	tr
butyl 2-methylbutanoate	38	1232	nd	tr
hexyl acetate	47	1271	nd	tr
3-methylbutyl 2-methylbutanoate	48	1276	nd	tr
2-methylbutyl 2-methylbutanoate	51	1279	nd	0.06
1-hepten-3-yl acetate	52	1284	nd	tr
2-methylbutyl 3-methylbutanoate	54	1295	nd	0.02
( <i>Z</i> )-3-hexenyl acetate	56	1316	0.04	0.27
pentyl 2-methylbutanoate	62	1327	nd	0.01
1-octen-3-yl acetate	71	1379	0.01	0.48
4-methylpentyl 2-methylbutanoate	72	1381	nd	tr
( <i>Z</i> )-3-hexenyl 2-methylpropanoate	73	1385	nd	0.02
( <i>Z</i> )-3-hexenyl 2-methylbutanoate	89	1472	nd	tr
1-nonen-3-yl acetate	90	1477	nd	0.01
ethyl hexadecanoate	179	2255	0.08	nd
ethyl oleate	186	2476	0.03	nd
ethyl linoleate	188	2521	0.02	nd
<b>aliphatic hydrocarbons</b>				
1-octene	4	892	nd	0.01
tricyclene	8	1009	nd	0.06
docosane	175	2200	nd	tr
tricosane	181	2300	nd	tr
tetracosane	184	2400	tr	tr
pentacosane	187	2500	tr	tr
hexacosane	190	2600	tr	tr
heptacosane	192	2700	0.03	tr
<b>aliphatic ketones</b>				
acetone	3	846	0.03	nd
3-buten-2-one	6	943	tr	nd
butane-2,3-dione	7	972	nd	nd
octan-3-one	43	1252	nd	tr
6-methyl-5-hepten-2-one	63	1335	tr	trace
2-cyclopentenone	66	1349	tr	nd
2-hydroxy-2-methyl-4-pentanone	68	1359	0.01	nd

**Table 1 (Continued)**

compound	GC peak <sup>a</sup>	<i>I</i> <sup>b</sup>	concentration (ppm)	
			DRP <sup>c</sup>	SPSE <sup>d</sup>
<b>aliphatic alcohols</b>				
butanol	22	1143	tr	nd
1-penten-3-ol	23	1158	tr	nd
2-methyl-1-buten-3-ol	26	1169	tr	tr
3-methyl-3-buten-1-ol	40	1248	0.01	nd
pentanol	42	1250	tr	nd
2-methyl-( <i>E</i> )-2-butenol	59	1322	0.05	nd
hexanol	67	1355	tr	nd
( <i>E</i> )-3-hexenol	70	1365	tr	nd
( <i>Z</i> )-3-hexenol	74	1386	0.96	0.03
octan-3-ol	77	1397	0.03	nd
( <i>E</i> )-2-hexenol	79	1408	0.01	nd
1-octen-3-ol	86	1453	0.62	0.25
2-ethylhexanol	92	1492	0.02	0.02
1-nonen-3-ol	101	1554	0.06	0.02
( <i>E</i> )-2-octenol	110	1615	tr	nd
dodecanol	158	1969	nd	tr
hexadecanol	183	2377	tr	nd
octadecanol	189	2581	0.02	nd
<b>aromatic compounds</b>				
toluene	12	1037	tr	0.02
1,4-dimethylbenzene	20	1131	nd	tr
1,3-dimethylbenzene	21	1137	nd	tr
1,2-dimethylbenzene	28	1180	nd	tr
3-ethyl-1-methylbenzene	36	1222	nd	tr
2-ethyl-1-methylbenzene	44	1257	nd	tr
1,2,4-trimethylbenzene	49	1276	nd	tr
5-ethyl-1,3-dimethylbenzene	58	1321	nd	tr
1,2,3-trimethylbenzene	60	1327	nd	tr
2-methyl-1-vinylbenzene	61	1327	tr	nd
4-ethyl-1,3-dimethylbenzene	65	1348	nd	tr
4-ethyl-1,2-dimethylbenzene	69	1362	nd	tr
3-ethyl-1,2-dimethylbenzene	75	1390	0.01	nd
benzaldehyde	97	1514	tr	nd
phenylacetaldehyde	112	1633	0.24	nd
phenylethyl acetate	143	1811	0.10	tr
benzyl alcohol	151	1874	0.05	nd
phenylethyl 2-methylpropanoate	152	1877	0.13	0.02
phenylethyl propanoate	153	1880	0.08	nd
phenylethyl alcohol	155	1908	0.15	nd
phenylethyl 2-methylbutanoate	157	1968	0.11	tr
phenylethyl 3-methylbutanoate	160	1986	0.07	0.02
methyl anisate	171	2085	0.03	nd
cinnamyl alcohol	172	2098	0.08	nd
eugenol	173	2162	0.88	nd
6-methyl-3-isopropylphenol	176	2210	0.03	nd
<b>miscellaneous</b>				
dimethyl sulfide	1	748	nd	tr
2-methylpyrazine	45	1264	tr	nd
3-(methylthio)propanal	85	1449	0.03	nd
2,6-di- <i>tert</i> -butyl-4-methylphenol (BHT)	156	1909	nd	tr
12-hydroxy- <i>cis</i> -9-dodecenoic acid lactone <sup>g</sup>	163	2018	0.04	nd
diethyl phthalate	182	2361	nd	tr
$\delta$ -dodecalactone	185	2416	0.03	nd
dibutyl phthalate	191	2680	0.27	0.11

<sup>a</sup> Refer to Figures 1 and 2. <sup>b</sup> Kovats index on DB-Wax column. <sup>c</sup> Volatiles obtained by steam distillation under reduced pressure. <sup>d</sup> Volatiles obtained by simultaneous purging and solvent extraction. <sup>e</sup> Not detected. <sup>f</sup> Concentration <0.01 ppm. <sup>g</sup> Tentatively identified.

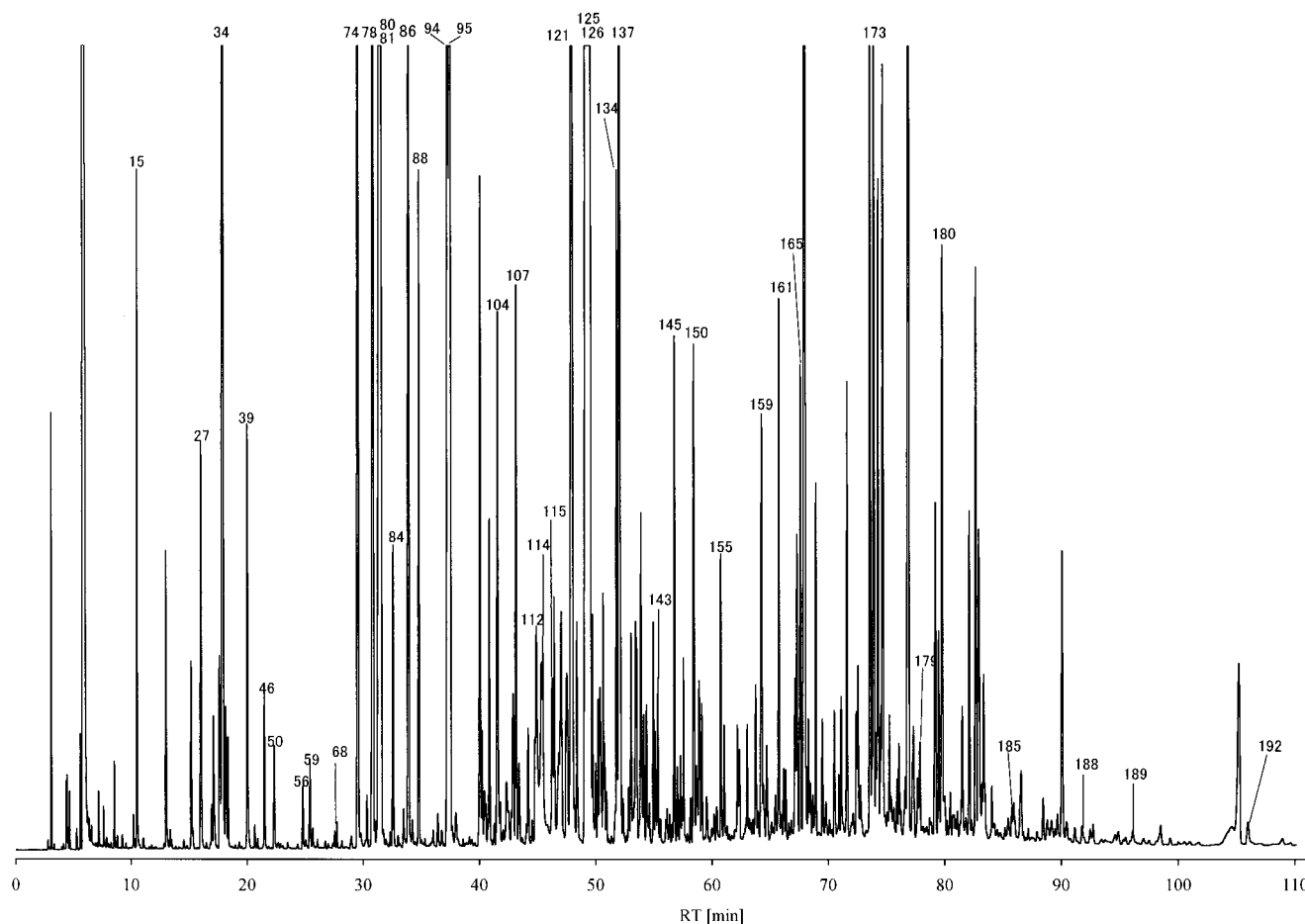
the extract weight was 100 mg. The sample was stored at 5 °C until analysis.

**Instrumental Analyses of Components.** All samples were analyzed using the Kovats GC retention index *I* (Kovats, 1965) and GC-MS. The GC retention index and MS fragmentation pattern of each component were compared with those of the authentic compound for qualitative analysis. A Hewlett-Packard (HP) 6890 GC equipped with a 60 m × 0.25 mm ( $d_f = 0.25 \mu\text{m}$ ) DB-Wax bonded-phase fused silica capillary column (J&W Scientific, Folsom, CA) and a flame ionization detector (FID) was used for routine quantitative analysis. The oven temperature was held at 40 °C for 2 min and then programmed to 200 °C at 2 °C/min. Detector and injector temperatures were 250 °C. The linear velocity of the helium carrier gas flow rate was 30 cm/s at a split ratio of 30/1.

A Varian 3500 GC interfaced to a Finnigan MAT model 800 ion trap detector was used for MS identification of the GC components. The column and oven conditions for GC-MS analysis were identical to those used for the GC analysis.

## RESULTS AND DISCUSSION

The total yields of volatile chemicals (relative to the fresh yomogi leaves used) were 0.0049% (w/w) and 0.0042% (w/w) from DRP and SPSE, respectively. Table 1 shows the compounds identified in extracts obtained from yomogi leaves, along with their calculated concentration and Kovats index on a DB-Wax column. The



**Figure 1.** Typical gas chromatogram of the extract obtained by DRP. Refer to Experimental Procedures for GC conditions.

concentration of each chemical was calculated using the following equation:

$$\text{concn (ppm)} = \frac{\text{wt of extract (without solvent)} \times \text{GC peak area \%}/100 (\mu\text{g})}{\text{wt of yomogi leaves (231.7 g)}}$$

Typical gas chromatograms of extracts by DRP and SPSE are shown in Figures 1 and 2, respectively.

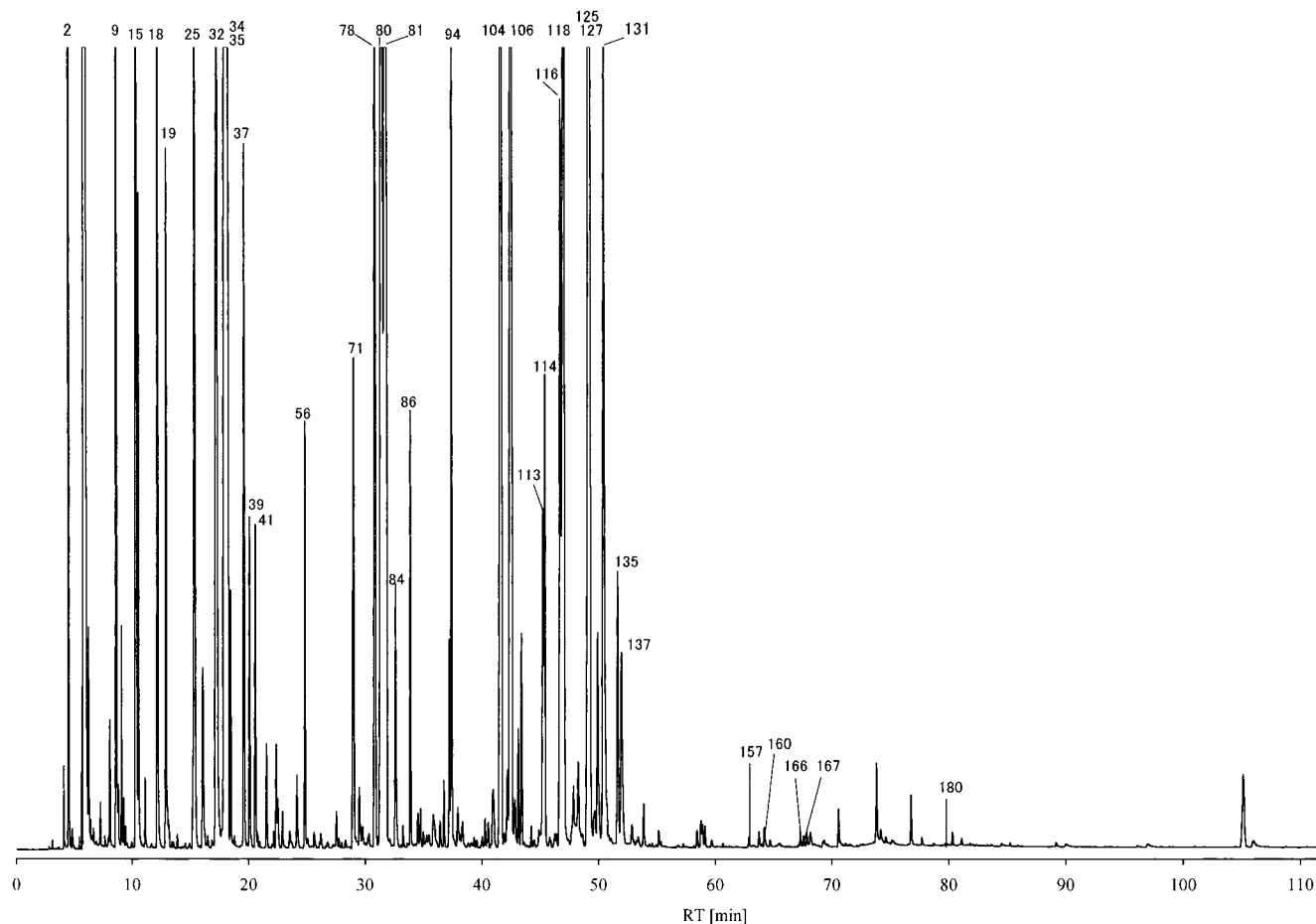
A total of 192 components were identified in the present study. The composition of extracts recovered by the two different methods showed some differences. Among the 132 chemicals identified in the extract obtained by DRP, 42 were monoterpenoids (oxygenated monoterpenes), which composed 69.51% of the total GC peak area. The major volatile constituents of monoterpenoids in this extract were borneol (10.27 ppm)—which is the greatest amount in the extract, verbenone (1.85 ppm), piperitol (0.36 ppm), *cis*-carveol (0.34 ppm), and *L*-perillyl alcohol (0.31 ppm). Among the 125 chemicals identified in the extract obtained by SPSE, 26 were monoterpenoids, which composed 56.09% of the total GC peak area. The major volatile constituents of monoterpenoids in this extract were 1,8-cineole (8.12 ppm), 2,5,5-trimethylhepta-2,6-dien-4-yl acetate (artemisia acetate, 4.22 ppm),  $\alpha$ -thujone (3.20 ppm), bornyl acetate (2.05 ppm), and borneol (1.79 ppm).

The extract by DRP contained 17 aliphatic alcohols that composed 4.58% of the total GC peak area, whereas the extract by SPSE contained only 6 aliphatic alcohols, which composed 0.79% of the total GC peak area.

Alcohols may be difficult to recover from aqueous solution by SPSE due to their high polarity. On the other hand, 2,5,5-trimethylhepta-3,6-dien-2-ol (yomogi alcohol) and 2,5,5-trimethylhepta-2,6-dien-4-ol (artemisia alcohol) were recovered in rather large quantities by SPSE (0.96 and 0.67 ppm, respectively) as compared with DRP (1.50 and 2.17 ppm, respectively). Yomogi alcohol was isolated and identified at first from the essential oil of *Artemisia feddei* Lev. et Van (Hayashi et al., 1968). Later, it was synthesized and the structure was confirmed (Willhalm and Thomas, 1969). Artemisia alcohol was first reported in the extract of *Artemisia ageratum*, which grows in the central region of Italy (Grandi et al., 1976). The other artemisyl derivatives, such as artemisia ketone and artemisia acetate, were also reported in the extract. Later, artemisia alcohol was also found in the extract of *A. princeps* Pampan (yomogi) (Fujita and Nogami, 1994).

It is interesting that artemisia acetate was recovered as a major constituent by SPSE but was recovered in only trace amounts by DRP. 1,8-Cineole was also recovered by SPSE in large quantities but not by DRP. The essential oil prepared from *Artemisia asiatica* Nakai by hydrodistillation reportedly contained the greatest amount of 1,8-cineole: 39.7% of the total GC peak area (Kalemba, 1999). On the other hand, an oil prepared from *A. princeps* Pampan by steam distillation under normal pressure contained 1,8-cineole only as one of the minor constituents (5.55–0.40%) (Fujita and Nogami, 1994).

The percentage of monoterpenes (hydrocarbon monoterpenes) was much higher in extracts obtained by



**Figure 2.** Typical gas chromatogram of the extract obtained by SPSE. Refer to Experimental Procedures for GC conditions.

SPSE (19.76% of the total GC peak area) than in extracts obtained by DRP (3.19% of the total GC peak area). The major monoterpenes in extracts obtained by SPSE were camphene (1.88 ppm), D-limonene (1.29 ppm),  $\alpha$ -pinene (1.10 ppm), and myrcene (1.06 ppm). In contrast, no monoterpenes were present at levels  $>1$  ppm in extracts obtained by DRP. Sesquiterpenes (hydrocarbon sesquiterpenes) were also recovered by SPSE (18.97% of the total GC peak area) with greater efficiency than by DRP (3.48% of the total GC peak area).

Extracts obtained from yomogi leaves consisted of many terpenoids (oxygenated terpenes). These extracts also contained many oxygenated aliphatic compounds including 12 aldehydes, 19 esters, 7 ketones, and 18 alcohols. Some of these compounds play an important role in the aroma of this extract. For example, aliphatic aldehydes, such as (*E*)-2-hexenal, (*E*)-2-heptenal, and (*E*)-2-octenal, possess a strong green note (Arctander, 1969). It follows that the characteristic strong green aroma of this extract may be due to the presence of these oxygenated aliphatic compounds in addition to the presence of terpenoids.

A total of 26 aromatic compounds were identified in the present study: 16 by DPC and 15 by SPSE. *p*- and *o*-cymenes are aromatic compounds, but they are listed as monoterpenes in Table 1. Alkyl aromatic hydrocarbons such as toluene, dimethylbenzenes, and methyl ethylbenzenes are not generally present in extracts isolated from plants. Therefore, these may be formed from monoterpenes via disproportionation reaction during experiments. Two phthalate compounds found in the

extracts by DRP are probably contaminants from unknown sources.

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