

Identification of Characteristic Aroma-Active Compounds from Water Dropwort (*Oenanthe javanica* DC.)

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Characteristic aroma components of water dropwort (*Oenanthe javanica* DC.) were evaluated by aroma extract dilution analysis and solid-phase microextraction–gas chromatography–olfactometry. α -Terpinolene (plastic/cucumber-like) was the most intense aroma-active compound in water dropwort. Other potent aroma-active compounds included *p*-cymene (kerosene-like), α -terpinene (lemon), (*E*)-caryophyllene (woody), (*Z,E*)- α -farnesene (woody), hexanal (green), (*Z*)-3-hexenol (green), phenylacetaldehyde (honey), (*E*)-2-nonenal (cucumber), bornyl acetate (cooked vegetable), and γ -terpinene (lemon). Of these, *p*-cymene was believed to be primarily responsible for the distinct kerosene-like aroma note of water dropwort. The aroma property of *p*-cymene was dependent on its concentration and was described as kerosene-like at relatively high concentrations but changed to citrus and green aroma notes at low concentrations.

KEYWORDS: Water dropwort (*Oenanthe javanica* DC.); gas chromatography–olfactometry; aroma-active compound; *p*-cymene

INTRODUCTION

Water dropwort (*Oenanthe javanica* DC.) is a perennial herb with distinctive aroma and taste and is cultivated in marshy places of Asia and Australia. It belongs to the Umbelliferae family along with, for example, coriander, caraway, fennel, and cumin (1, 2). The stems and leaves are used as a salad or as a seasoning in soups and stews in Korea. Water dropwort is known to have an antimutagenic effect against aflatoxin B₁ due to flavonoids (3) and the capability to remove heavy metals, such as Cd and Pb, in polluted water (4).

Little research has been performed to characterize the aroma property of water dropwort (5, 6). Limonene, pulegone, germacrene D, and β -pinene were identified as the major volatile compounds of water dropwort (5). It is known that water dropwort has a kerosene-like aroma property; however, the characteristic aroma-active compound responsible for this kerosene-like aroma is still unknown.

Gas chromatography–olfactometry (GC-O) is used for the detection of aroma-active components in a volatile extract. GC-O is a powerful tool for the measurement of odor quality and identification of odorants (7). The relative aroma potency of each component can be determined by aroma extract dilution analysis (AEDA) and Charm analysis (8, 9). AEDA involves the analysis of a serially diluted flavor extract by GC-O to obtain a flavor dilution (FD) factor for each aroma-active compound present in the original extract. An FD factor for a particular component can be defined as the highest dilution at which it is

detected by GC-O (9). Results from AEDA help to provide a better understanding of the role each compound plays in the overall flavor.

Solid-phase microextraction (SPME) is a solvent-free, rapid, and simple sample preparation technique based on absorption, which is useful for the extraction and concentration of analytes either by submersion in liquid phase or by exposure to a gaseous phase (10). Deibler et al. (11) reported the application of SPME to the preparation of samples for GC-O dilution analysis by varying the fiber thickness and length to achieve various absorbent volumes.

The objectives of this study were to isolate volatile flavor components of water dropwort using various extraction techniques, such as water distillation and vacuum simultaneous steam distillation and solvent extraction (V-SDE) as well as SPME, and to evaluate characteristic aroma-active compounds by GC-O.

MATERIALS AND METHODS

Materials. The water dropwort was purchased from a local market in Cheonan, Korea; it was grown and harvested at Bucheon, Kyonggido, Korea. After purchasing, water dropwort was refrigerated at 4 °C until extraction. The stems and leaves of water dropwort were surface-cleaned and ground in a Waring blender at a ratio of 2:1 with deodorized distilled water before extraction. Ground water dropwort was extracted as quickly as possible to inactivate lipoxygenase activity.

Authentic standard compounds, (*Z*)-2-pentenol, hexanal, (*E*)-2-hexenal, (*Z*)-3-hexenol, (*E,E*)-2,4-hexadienal, α -pinene, β -myrcene, α -terpinene, *p*-cymene, limonene, phenylacetaldehyde, γ -terpinene, α -terpinolene, linalool, (*E,E*)- β -farnesene, and (*Z,E*)- β -farnesene, were obtained from Sigma-Aldrich Chemical Co. (Milwaukee, WI); terpinen-4-ol and α -terpineol were from Tokyo Kasei Kogyo Co. (Tokyo, Japan),

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and borneol, (*E*)-caryophyllene, and α -humulene were from Fluka Chemie (Buchs, Switzerland).

Water Distillation. One kilogram of fresh water dropwort was extracted for 1 h in a water distillation apparatus, which consisted of a distillation flask, condenser, and separatory funnel, with 500 mL of deodorized distilled water to obtain essential oil. The essential oil was obtained with yield of 0.06 g/kg.

Vacuum Simultaneous Steam Distillation and Solvent Extraction. A standard SDE apparatus was modified as described by Cadwallader et al. (12) to minimize artifact formation during extraction. One kilogram of ground water dropwort was placed into a 5 L round-bottom flask. 3-Heptanol (38.88 μ g) was added to the flask as an internal standard. The SDE apparatus was equilibrated for 30 min prior to vacuum state. Extraction was carried out for 4 h using 200 mL of dichloromethane as a solvent. Sample boiling point was maintained at 55–60 °C. After extraction, water was removed by freezing, and then the extract was dried over 3 g of anhydrous sodium sulfate. The extract was concentrated to 200 μ L under a gentle stream of nitrogen.

Solid-Phase Microextraction. Two hundred and fifty grams of ground water dropwort was placed into a 500 mL headspace flask. 3-Heptanol (9.72 μ g) was added to the headspace flask as an internal standard. The headspace flask was capped and then preheated at 40 °C for 40 min. The SPME fiber coated with 100 μ m polydimethylsiloxane (PDMS) was exposed to the headspace of the sample for 30 min. The fiber was desorbed in the GC injection port for 1 min.

Direct Gas Chromatography–Olfactometry (D-GC-O). For SPME, D-GC-O was employed to assess the odor representativeness of water dropwort (13). A Varian 3350 GC (Varian Instrument Group, Walnut Creek, CA) equipped with a sniffing port was supplied with a short capillary of untreated silica (160 cm length \times 0.32 mm i.d.). The carrier gas was helium with a constant flow rate of 1.4 mL/min. Injector and oven temperatures were kept at 40 and 250 °C, respectively.

Gas Chromatography–Mass Spectrometry (GC-MS). The GC-MS system consisted of an HP 6890N GC-HP 5973N mass selective detector (MSD) (Hewlett-Packard Co., Palo Alto, CA). One microliter of essential oil diluted at 1:100 or V-SDE extract was injected (splitless mode; 60 s valve delay) onto DB-5ms (60 m length \times 0.25 mm i.d. \times 0.25 μ m film thickness; J&W Scientific, Folsom, CA) and DB-Wax (30 m length \times 0.25 mm i.d. \times 0.25 μ m film thickness; J&W Scientific). The carrier gas was helium with a constant flow rate of 0.8 mL/min. Injector and detector temperatures were 200 and 250 °C, respectively. The oven temperature was held for 5 min at 40 °C, raised at 2 °C/min to 200 °C, and then maintained for 20 min at 200 °C. MSD conditions were as follows: capillary direct interface temperature, 280 °C; ionization energy, 70 eV; mass range, 33–350 amu; electron multiplier voltage, 1242 V; scan rate, 1.4 scans/s. Duplicate analyses were performed.

Gas Chromatography–Olfactometry. The GC-O system consisted of a Varian 3350 GC (Varian Instrument Group) equipped with a flame ionization detector (FID) and a sniffing port. Column effluent was split 1:1 between the FID and sniffing port by using a deactivated capillary column (40 cm length \times 0.25 mm i.d.). AEDA was carried out for the essential oil and V-SDE extract (12). Serial dilutions (1:3) of water dropwort essential oil and V-SDE extract were prepared using dichloromethane as a diluent. For serial dilutions of water dropwort essential oil, 1 μ L was injected (splitless mode; 60 s valve delay) onto DB-5ms (30 m length \times 0.25 mm i.d. \times 0.25 μ m film thickness; J&W Scientific) and DB-Wax columns (30 m length \times 0.25 mm i.d. \times 0.25 μ m film thickness; J&W Scientific). For the V-SDE extract, 1 μ L was injected onto DB-5ms. For SPME, GC-O dilution analysis was performed on DB-5ms (11). The SPME fiber was fully exposed (1 cm), three-fourths exposed (0.75 cm), half exposed (0.5 cm), and a fourth exposed (0.25 cm) to the headspace of water dropwort. The fiber was desorbed in the GC injection port for 1 min (splitless mode; 60 s valve delay). GC conditions were the same as for GC-MS except that the oven temperature was programmed from 40 to 200 °C at 8 °C/min with initial and final hold times of 5 and 20 min, respectively. Two panelists familiar with water dropwort aroma performed GC-O.

Compound Identification. Positive identifications were based on comparison of retention indices (RI), mass spectra, and aroma properties of unknowns with those of authentic standard compounds. RI was

calculated using *n*-paraffins C₇–C₂₂ as external references (14). Tentative identifications were based on matching mass spectra of unknowns with those in the Wiley 7N mass spectral database (Hewlett-Packard Co.) and literature or on matching RI values and aroma properties of unknowns with those of authentic standard compounds.

Quantitation of Compounds. Calibration curves of amount ratios (compound/internal standard) versus peak area ratios (compound/internal standard) were used to quantify positively identified compounds. The concentration of a compound in the sample was calculated as follows:

$$\text{concn (ppm)} = \frac{\text{amount ratio} \times \mu\text{g of 3-heptanol}}{\text{g of sample}}$$

RESULTS AND DISCUSSION

Volatile Components in Water Dropwort. Table 1 lists the volatile compounds identified, their concentrations (or the relative percentages of peak area), and the RIs of the compounds on the DB-5ms column by water distillation, V-SDE, and SPME. A total of 59 compounds were identified, which included 28 hydrocarbons, 16 alcohols, 8 aldehydes, 4 esters, 2 ethers, and 1 ketone. Of the 28 identified hydrocarbons, 14 compounds were monoterpenes and the others, sesquiterpenes.

Thirty-nine volatile compounds were identified by water distillation. γ -Terpinene (11) was the most abundant of these hydrocarbons, followed by limonene (8) and (*E*)-caryophyllene (18). These compounds have been reported as the major flavor constituents in water dropwort (5, 6). Rhee et al. (6) extracted volatile compounds from water dropwort by solvent extraction and identified limonene, γ -terpinene, and α -pinene as the major volatile compounds. Also, limonene, germacrene D, β -pinene, (*E*)-caryophyllene, and α -terpinolene have been identified from water dropwort by a steam distillation method (5). The most abundant monoterpenes identified in this study were similar to those identified in the papers mentioned. Limonene has been reported as the major flavor compounds in various citrus fruits (16, 19, 20). (*E*)-Caryophyllene and (*Z,E*)- β -farnesene (25), which are known as the most common sesquiterpenes found in various essential oils, were present in relatively high amounts in water dropwort. These two volatile compounds have been identified as the most abundant volatiles in, for example, *Mosla calveriei* Level (21). Of the 10 alcohols identified in water dropwort, (*E*)-farnesol (41) was the most relatively abundant, followed by α -cadinol (43) and sphathulenol (42). In addition, several alcohols, such as (*Z*)-3-hexenol (30), borneol (36), terpinen-4-ol (37), and α -terpineol (38), were found in low abundance. (*Z*)-3-Hexenol has been identified as the major volatile compound in, for example, *Chaenomeles japonica* (22). α -Terpineol is considered to be desirable in many fruits, whereas in others it is perceived as an off-flavor described as terpineol-like, camphoraceous, stale, musty, and pungent (23). One aldehyde (50), three esters (53, 54, and 56), and two ethers (57 and 58) were also detected in low abundance.

Forty-two volatile compounds were identified by V-SDE. (*Z*)-3-Hexenol (30) was the most abundant of these volatiles, followed by α -terpinolene (12), β -pinene (3), *p*-cymene (7), and γ -terpinene (11). Also, 28 volatile compounds were identified by SPME. α -Terpinolene (12) was the major volatile compound, followed by β -pinene (3), γ -terpinene (11), and limonene (8).

Aroma-Active Components in Water Dropwort. Of the 39 volatile compounds identified from water dropwort essential oil, 17 aroma-active compounds were detected by AEDA. Aroma-active compounds identified and their aroma properties are listed in Table 2. To better resolve aroma-active compounds, AEDA was conducted on two GC columns of different polarities (DB-5ms and DB-Wax). Most of the aroma-active compounds in

Table 1. Volatile Compounds Identified from Water Dropwort

no. ^a	RI ^b	compound	rel % ^c WD ^e	concn ^d (ppm)		identification method
				V-SDE ^f	SPME ^g	
Hydrocarbons						
1	932	α -pinene	0.7	0.9	1.5	MS, ^h RI, odor ⁱ
2	944	camphene		0.1		MS, RI ^j
3	975	β -pinene	3.4	2.7	4.5	MS, RI ^j
4	995	β -myrcene	1.0	1.2	2.0	MS, RI, odor
5	1003	α -phellandrene	0.3	0.1	0.2	MS, RI ^j
6	1015	α -terpinene	0.1	0.1	0.1	MS, RI, odor
7	1029	<i>p</i> -cymene	3.8	1.9	1.4	MS, RI, odor
8	1031	limonene	8.6	0.9	3.2	MS, RI, odor
9	1043	(<i>Z</i>)- β -ocimene	0.2		0.2	MS, RI ^j
10	1059	(<i>E</i>)- β -ocimene	0.7			MS, RI ^j
11	1093	γ -terpinene	21.7	1.3	3.5	MS, RI, odor
12	1095	α -terpinolene	2.5	4.6	10.7	MS, RI, odor
13	1138	limonene oxide		0.1	0.1	MS, RI ^k
14	1147	epoxyterpene	0.1	0.2	0.1	MS
15	1345	bicycloelemene			0.4	MS
16	1368	α -copaene	0.7	0.1	0.8	MS, RI ^j
17	1388	β -elemene	0.6	0.1		MS, RI ^j
18	1412	(<i>E</i>)-caryophyllene	6.1	0.4	2.8	MS, RI, odor
19	1446	α -humulene	1.4	0.3		MS, RI, odor
20	1456	(<i>E</i>)- β -farnesene	2.3	0.3	1.7	MS, RI, odor
21	1471	α -amorphene	0.2			MS
22	1475	germacrene D		0.3	1.6	MS, RI ^j
23	1481	β -selinene	4.2			MS
24	1489	α -selinene	3.8			MS
25	1494	(<i>Z,E</i>)- α -farnesene	5.9	0.2	0.9	MS, RI, odor
26	1507	(<i>E,E</i>)- α -farnesene	3.9	0.1	0.6	MS, RI ^j
27	1519	δ -cadinene	4.7	0.2	1.2	MS, RI ^j
28	1836	neophytadiene	0.9	0.3	1.0	MS
Alcohols						
29	746	(<i>Z</i>)-2-pentanol		0.1		MS, RI, odor
30	875	(<i>Z</i>)-3-hexanol	0.1	6.1	0.1	MS, RI, odor
31	879	(<i>E</i>)-2-hexanol		0.6	0.1	MS, RI ^j
32	881	(<i>E</i>)-1-hexanol		0.1		MS, RI ^j
33	965	2-heptanol		0.1		MS, RI ^j
34	1010	octanol	0.1	0.1		MS, RI ^j
35	1102	linalool		0.1		MS, RI, odor
36	1160	borneol	0.2			MS, RI, odor
37	1178	terpinen-4-ol	0.8	0.1		MS, RI, odor
38	1198	α -terpineol	0.1			MS, RI, odor
39	1199	<i>p</i> -cymen-8-ol		0.7		MS, RI ^j
40	1568	nerolidol		0.3		MS, RI ^j
41	1571	(<i>E</i>)-farnesol	2.4			MS, RI ^j
42	1581	sphathulenol	1.1			MS
43	1659	α -cadinol	1.5			MS, RI ^j
44	2056	falcarinol	2.1			MS
Aldehydes						
45	802	hexanal		0.1		MS, RI, odor
46	806	(<i>Z</i>)-3-hexenal		0.1		MS, RI ^j
47	867	(<i>E</i>)-2-hexenal		0.2		MS, RI, odor
48	915	(<i>E,E</i>)-2,4-hexadienal		0.1		MS, RI, odor
49	1051	phenylacetaldehyde		0.2		MS, RI, odor
50	1104	nonanal	0.1			MS, RI ^j
51	1157	2,6-nonadienal		0.1	0.1	MS, RI ^j
52	1164	(<i>E</i>)-2-nonenal		0.1	0.1	MS, RI, odor
Esters (Acetates)						
53	1119	1-octen-3-yl		0.1		MS
54	1131	3-octanyl		0.1		MS
55	1148	methyl phenyl		0.1		MS, RI ^j
56	1283	bornyl	0.1	0.1	0.1	MS, RI ^j
Ethers						
57	1229	thymyl methyl		0.7	0.1	MS, RI ^m
58	1233	carvacryl methyl		0.5	0.1	MS, RI ^m
Ketone						
59	1190	1-(4-methylphenyl)-ethanone		0.3		MS

^a Numbers correspond to those in Tables 2, 4, and 5. ^b Retention indices were determined on DB-5ms using C₇–C₂₂ as external references. ^c Average of relative percentage of total peak area. ^d Concentration (ppm). ^e Water distillation. ^f Vacuum simultaneous steam distillation and solvent extraction. ^g Solid-phase microextraction. ^h Mass spectrum was consistent with that of Wiley 7N mass spectrum database. ⁱ Identification was based on GC-O with an authentic compound. ^j From ref 15. ^k From ref 16. ^l From ref 17. ^m From ref 18.

both columns are similar, but α -pinene (**1**), thymyl methyl ether (**57**), and carvacryl methyl ether (**58**) were detected only in DB-5ms. α -Terpinolene (**12**), α -terpinene (**6**), (*E*)-caryophyllene (**18**), and (*Z,E*)- α -farnesene (**25**) were the most intense aroma-active compounds with high log₃ FD factors on both columns. α -Terpinolene, which had a plastic and cucumber-like aroma note, exhibited the highest log₃ FD factor (= 4). α -Terpinene had a lemon-like aroma note. (*E*)-Caryophyllene and (*Z,E*)- α -farnesene are believed to impart the woody note to water dropwort.

p-Cymene (**7**) was detected with the second highest log₃ FD factor (= 3) on the DB-Wax column. Its aroma property (kerosene-like) was the most similar to that of water dropwort. On the basis of its aroma property and relatively high log₃ FD factor, *p*-cymene is believed to be a character-impact aroma-active compound contributing to the aroma of water dropwort. *p*-Cymene has been identified as the most abundant volatile compound from, for example, fresh *Citrus unshiu* blossom (**19**). As shown in Table 3, the aroma property of *p*-cymene was dependent on its concentration. *p*-Cymene was described as kerosene-like at relatively high concentrations, but changed to a citrus and green-like aroma note at low concentrations. It has been reported that this compound has a typical kerosene-like odor at high concentration with a threshold of 13.3 ppb (**24**). Choi et al. (**25**) mentioned that aroma properties of volatile compounds could be changed by dilution.

Seven aroma-active compounds including (*Z*)-3-hexanol (**30**), β -myrcene (**4**), limonene (**8**), γ -terpinene (**11**), borneol (**36**), α -copaene (**16**), and (*E*)- β -farnesene (**20**) were detected on both columns with relatively high log₃ FD factors. (*Z*)-3-Hexanol, which is known as leaf alcohol, was described as having a green odor. This compound is considered to be formed in green leaves via lipoxygenase-mediated lipid oxidation (**26**), which might be formed during sample preparation because no action was taken to inactivate lipoxygenase in this study. β -Myrcene, which was described as pine odor, has been identified as a major volatile compound in, for example, *Piatacia lenticus* (**27**). Limonene and γ -terpinene, having a citrus aroma and being present in high amount, had relatively low log₃ FD factors. Borneol, α -copaene, and (*E*)- β -farnesene were described as having cucumber, woody, and burnt odors, respectively. α -Pinene (pine), terpinen-4-ol (cucumber), thymyl methyl ether (smoky woody), carvacryl methyl ether (woody), and bornyl acetate (cooked vegetable) were identified with relatively low log₃ FD factors.

Twenty aroma-active compounds were detected from V-SDE, and their aroma properties are listed in Table 4. α -Terpinolene (**12**, plastic/cucumber-like) was the most intense aroma-active compound with a high log₃ FD factor. *p*-Cymene (**7**), which was considered to be a character-impact compound of water dropwort, was detected with a relatively high log₃ FD factor (= 3) on the DB-Wax column. GC-O result of V-SDE was similar to that of essential oil. Hexanal (**45**, green), (*Z*)-3-hexanol (**30**, green), phenylacetaldehyde (**49**, honey), and bornyl acetate (**56**, cooked vegetable) were aroma-active compounds with relatively high log₃ FD factors. (*Z*)-2-Pentanol (**29**, plastic), hexanal, (*E*)-2-hexenal (**47**, green), (*E,E*)-2, 4-hexadienal (**48**, green), phenylacetaldehyde, linalool (**35**, lemon), (*E*)-2-nonenal (**52**, cucumber), and *p*-cymen-8-ol (**39**, cucumber) were detected only by V-SDE. (*Z*)-2-Pentanol, hexanal, (*E*)-2-hexenal, (*E,E*)-2,4-hexadienal, and (*E*)-2-nonenal are considered to be biosynthesized in green leaves via lipoxygenase-mediated lipid oxidation (**26**). Linalool and bornyl acetate have been identified

Table 2. Aroma-Active Compounds from Water Dropwort Essential Oil

no. ^a	RI ^b		compound	aroma description	log ₃ FD	
	DB-5ms	DB-Wax			DB-5ms	DB-Wax
30	875	1372	(Z)-3-hexenol	green	2	2
1	932		α-pinene	pine	0	
4	995	1170	β-myrcene	pine	2	2
6	1015	1152	α-terpinene	lemon	3	3
7	1029	1268	p-cymene	kerosene-like	2	3
8	1031	1195	limonene	citrus	2	2
11	1093	1228	γ-terpinene	citrus	2	2
12	1095	1280	α-terpinolene	plastic, cucumber-like	4	4
36	1160	1690	borneol	cucumber	2	2
37	1178	1583	terpinen-4-ol	cucumber	1	1
57	1229		thymyl methyl ether	smoky woody	1	
58	1233		carvacryl methyl ether	woody	1	
56	1283	1559	bornyl acetate	cooked vegetable	0	0
16	1368	1462	α-copaene	woody	2	2
18	1412	1583	(E)-caryophyllene	woody	3	3
20	1456	1657	(E)-β-farnesene	burnt	2	2
25	1494	1732	(Z,E)-α-farnesene	woody	3	3

^a Numbers correspond to those in **Tables 1, 4, and 5**. ^b Retention indices were determined on DB-5ms and DB-Wax using C₇–C₂₂ as external references.

Table 3. Aroma Changes of p-cymene Depending on Concentration

concn ^a (ppm)	aroma description
4000	kerosene
2000	kerosene
1000	kerosene
500	kerosene + citrus
250	citrus + green
125	not detected

^a Authentic p-cymene was dissolved in dichloromethane to make specified concentrations. One microliter of p-cymene solution was injected in the GC-O system to describe aroma property by sniffing.

Table 4. Aroma-Active Compounds from Water Dropwort by V-SDE

no. ^a	RI ^b	compound	aroma description	log ₃ FD
29	746	(Z)-2-pentenol	plastic	1
45	802	hexanal	green	3
47	867	(E)-2-hexenal	green	0
30	875	(Z)-3-hexenol	green	4
48	915	(E,E)-2,4-hexadienal	green	0
1	932	α-pinene	pine	2
4	995	β-myrcene	pine	2
6	1015	α-terpinene	lemon	2
7	1029	p-cymene	kerosene-like	3
49	1051	phenylacetaldehyde	honey	3
11	1093	γ-terpinene	lemon	0
12	1095	α-terpinolene	plastic, cucumber-like	5
35	1102	linalool	lemon	2
52	1164	(E)-2-nonenal	cucumber	4
39	1199	p-cymen-8-ol	cucumber, plastic	0
56	1283	bornyl acetate	cooked vegetable	3
16	1368	α-copaene	woody	0
18	1412	(E)-caryophyllene	woody	1
19	1446	α-humulene	woody	1
25	1494	(Z,E)-β-farnesene	woody	1

^a Numbers correspond to those in **Tables 1, 2, and 5**. ^b Retention indices were determined on DB-5ms using C₇–C₂₂ as external references.

as aroma-active compounds in, for example, citrus Hallabong (28) and *Cnidium officinale* MAKINO (29), respectively.

Four aroma-active compounds were detected by SPME-GC-O, and their aroma properties are listed in **Table 5**. We used a PDMS fiber for SPME-GC-O because of the availability of various film thicknesses, which makes dilution analysis possible. We confirmed by D-GC-O that the odor absorbed on the PDMS fiber was similar to the original odor of water dropwort. The

Table 5. Aroma-Active Compounds from Water Dropwort by SPME

no. ^a	RI ^b	compound	aroma description	OSV ^c
30	875	(Z)-3-hexenol	green	82
7	1028	p-cymene	kerosene-like	82
11	1067	γ-terpinene	lemon	58
12	1094	α-terpinolene	plastic, cucumber	100

^a Numbers correspond to those in **Tables 1, 2, and 4**. ^b Retention indices were determined on DB-5ms using C₇–C₂₂ as external references. ^c Odor spectrum value = (potency/maximum potency)^{0.5} × 100.

odor spectrum value was obtained from SPME-GC-O dilution analysis data by normalization of odor potency as described by Deibler et al. (11). α-Terpinolene (12) was the most intense, followed by p-cymene (7). The GC-O result of SPME was the same as those of essential oil and V-SDE for potent aroma-active compounds. (Z)-3-Hexenol (30, green) and γ-terpinene (11, lemon) were also identified by SPME.

In conclusion, p-cymene, having a kerosene-like aroma note, was identified as a character-impact compound of water dropwort. In addition, α-terpinolene, α-terpinene, (E)-caryophyllene, and (Z,E)-α-farnesene play significant roles in the aroma of water dropwort.

ABBREVIATIONS USED

AEDA, aroma extract dilution analysis; D-GC-O, direct gas chromatography–olfactometry; FD, flavor dilution; FID, flame ionization detector; GC-MS, gas chromatography–mass spectrometry; PDMS, polydimethylsiloxane; SPME, solid-phase microextraction; V-SDE, vacuum simultaneous steam distillation and solvent extraction.

LITERATURE CITED

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Received for review January 21, 2005. Revised manuscript received June 12, 2005. Accepted June 19, 2005. This study was supported by the Technology Development Program for Agriculture and Forestry, Ministry of Agriculture and Forestry, Republic of Korea.

JF050150Z