Water-Soluble Constituents of Caraway: Carvone Derivatives and Their Glucosides

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Nine monoterpenoids related to carvone and seven glucosides were isolated from the water-soluble portion of the methanolic extract of the caraway (fruit of *Carum carvi* L.), and their structures were clarified by spectral investigation. Among them, eight monoterpenoids and six glucosides were new.

Key words caraway; *Carum carvi* fruit; carvone derivative; *p*-menthanediol; *p*-menthanetetrol; *p*-menthane glucoside

In a previous paper, we reported the isolation and characterization of 10 new *p*-menthanetriols, including eight stereoisomers of *p*-menthane-2,8,9-triol and five new glucosides from the methanolic extract of caraway (fruit of *Carum carvi* LINN., Umbelliferae), which has been used as a popular aromatic herb and medicine.[1,2] In continuation of our studies on the water-soluble constituents of spices, and to reveal the relationship between the essential oil and the water-soluble constituents,[1,3] we undertook the isolation and structure elucidation of monoterpenoids related to carvone, and their glucosides.

Commercial caraway was extracted with 70% methanol, and the methanolic extract was worked up as described in the previous paper.[1] From the same aqueous portion, monoterpenoid diol (**1**), monoterpenoid enone-diols (**2**, **3**), monoterpenoid tetrols (**4** to **9**), and monoterpenoid glucosides (**10** to **16**) were isolated by the combination of Sephadex LH-20, silica gel, Lobar RP-8 column chromatography, and HPLC. Among them, eight monoterpenoids (**2** to **9**) and six monoterpenoid glucosides (**10** to **15**) were new. All new glucosides described in this paper were β-D-glucopyranosides as shown by their ^{13}C-NMR data (Table 1), and this was confirmed by hydrolysis to yield D-glucose, or by comparison of the $[\alpha]_D$ or $[M]_D$ values with those of their aglycones.[4] Their molecular formulae were suggested from the accurate mass number of $[M+H]^+$ or $[M+Na]^+$ ion peaks in the high-resolution positive FAB-MS.

Diol **1** ($C_{10}H_{18}O_2$, an amorphous powder, $[\alpha]_D^{21}$ +34°) and glucoside **16** ($C_{16}H_{28}O_7$, an amorphous powder, $[\alpha]_D^{25}$ −50°) were identified as (1*S*,2*S*,4*R*)-*p*-menth-8-ene-1,2-diol[5] and (4*S*)-*p*-menth-1-ene-7,8-diol 8-*O*-β-D-glucopyranoside,[6] respectively.

Glucoside **10** ($C_{16}H_{28}O_7$, mp 154—156 °C, $[\alpha]_D^{25}$ +13°) showed $[M+H]^+$ ion peak at *m*/*z* 333 and $[M-C_6H_{12}O_6+H]^+$ ion peak at *m*/*z* 153 in the positive FAB-MS. Glucoside **10** was hydrolyzed with hesperidinase and, from the hydrolyzed mixtures, **1** and D-glucose were obtained. Consequently, **10** was a monoglucoside of **1**. The position of the β-glucosyl unit of **10** was proved to be C-2 from the cross-peak between the glucosyl H-1/C-2 in the heteronuclear multiple bond connectivity (HMBC) spectrum and the observed nuclear Overhauser effect (NOE) interaction between the glucosyl H-1/H-2 in the NOE spectroscopy (NOESY) spectrum. Thus **10** was characterized as (1*S*,2*S*,4*R*)-*p*-menth-8-ene-1,2-diol 2-*O*-β-D-glucopyranoside.

Enone-diol **2** ($C_{10}H_{16}O_3$, an amorphous powder, $[\alpha]_D^{25}$ −6°) and **3** ($C_{10}H_{16}O_3$, an amorphous powder, $[\alpha]_D^{25}$ −7°) showed an $[M+H]^+$ ion peak at *m*/*z* 185 in the positive FAB-MS. They showed similar ^{1}H- and ^{13}C-NMR spectra (Tables 2, 1), and have two *tert*-methyls, one hydroxymethyl, two methylenes, one methine, one oxygenated quaternary carbon, and one carbonyl group conjugated with a trisubstituted double bond. From analysis of the HMBC correlation data of **3** (H-6/C-4, C-5, C-7; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9), they were suggested to be 8,9-dihydroxy-8,9-dihydro derivatives of carvone. Therefore **2** and **3** were revealed to be stereoisomers of C-8. In a previous paper, we reported that comparison of C-3 and C-5 ^{13}C-chemical shifts was useful to determine the C-8 configuration of 8-epimeric pairs of *p*-menthane-2,8,9-triol.[1] In these pairs, C-3 signals in the (4*R**,8*S**)-forms were found significantly downfield from those in the (4*R**,8*R**)-forms; on the contrary, the C-5 signals in (4*R**,8*S**)-forms appeared significantly upfield from those in the (4*R**,8*R**)-forms. For **2** and **3**, the ^{13}C chemical shift at C-3 of **2** (δ 40.2) was downfield from that of **3** (δ 39.6), whereas the C-5 of **2** (δ 27.2) was upfield from that of **3** (δ 27.8). Therfore the stereochemical relationship between C-4 and C-8 was considered to be 4*R**,8*S** in **2** and 4*R**,8*R** in **3**. Comparison of the ^{1}H-chemical shifts of the H_2-3 and H_2-5 signals of **2** and **3** was also useful to determine the relative configuration at C-8. As in the case of the 8-epimeric pairs of *p*-menthane-2,8,9-triol, the H_2-3 signals of **2** (H-3_{ax} δ 2.58; H-3_{eq} δ 2.98) were shifted upfield from those of **3** (H-3_{ax} δ 2.63; H-3_{eq} δ 3.12), and the H_2-5 signals of the (4*R**,8*S**)-form (**2**; H-5_{ax} δ 2.50; H-5_{eq} δ 2.66) were shifted downfield from those of the (4*R**,8*R**)-form (**3**; H-5_{ax} δ 2.39; H-5_{eq} δ 2.47).[1] The absolute configuration of C-4 was determined to be *S* by the results of circular dichroism (CD) spectra which showed a negative Cotton effect [250 nm for **2** ($\Delta\varepsilon$ −0.48) and 240 nm for **3** ($\Delta\varepsilon$ −0.39)], as observed for (+)-carvone [260 nm ($\Delta\varepsilon$ −0.41)].[7] Furthermore, the NOE interactions observed in the one-dimensional (1D)-NOESY spectrum (**2**; between H-3_{ax}/H-5_{ax}, between H_2-9/H-3_{eq}, H-4, H-5_{eq}, and between H_3-10/H-3_{ax}, H-3_{eq}, H-4, **3**; between H-3_{ax}/H-5_{ax}, between H_2-9/H-3_{ax}, H-3_{eq}, and between H_3-10/H-3_{ax}, H-4, H-5_{eq}; Fig. 1) supported the stereochemical structures. Thus **2** and **3** were characterized as (4*S*,8*R*)-8,9-dihydroxy-8,9-dihydrocarvone and (4*S*,8*S*)-8,9-dihydroxy-8,9-dihydrocarvone, respectively.

Tetrol **4** ($C_{10}H_{20}O_4$, an amorphous powder, $[\alpha]_D^{21}$ +4°) showed an $[M+H]^+$ ion peak at *m*/*z* 205 in the positive FAB-MS, and the ^{1}H- and ^{13}C-NMR spectral data (Tables 2, 1) re-

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Table 1. ^{13}C-NMR Chemical Shifts of **1**—**15**, **14a**, and **15a** (in Pyridine-d_5, 125 MHz)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
C-1	70.70	134.87	134.96	42.90	70.88	70.87	70.89	70.91	73.56
C-2	74.03	199.88	200.23	71.49[a)]	74.38	74.34	75.91	76.02	77.95
C-3	35.39	40.17	39.58	29.37	31.41	30.47	32.97	31.91	33.87
C-4	38.44	42.43	42.28	40.08	38.01	37.87	44.27	44.15	43.91
C-5	27.31	27.24	27.77	30.30	22.35	23.30	22.09	23.13	24.23
C-6	34.69	145.93	145.44	71.51[a)]	34.92	34.88	38.63	38.64	39.74
C-7	28.64	15.88	15.86	5.96	28.89	28.86	28.16	28.12	19.75
C-8	151.30	73.09	73.13	74.01	74.38	74.44	74.12	74.05	73.84
C-9	108.69	68.55	68.58	69.12	69.11	69.21	69.08	69.15	69.07
C-10	21.21	22.23	21.96	21.92	21.96	21.57	21.72	21.53	21.98

	10	**11**	**12**	**13**	**14**	**14a**	**15**	**15a**
C-1	70.45 (−0.3)	70.27 (−0.6)	70.24 (−0.6)	73.52	30.29 (−4.5)	34.75	137.35 (−3.5)	140.89
C-2	83.65 (+9.6)	85.43 (+11.1)	85.32 (+11.0)	77.92	78.01 (+5.9)	72.09	63.91	64.48
C-3	33.53 (−1.9)	29.49 (−1.9)	28.24 (−2.2)	33.87	33.31 (−2.3)	35.58	37.44	37.66
C-4	38.64	38.15	37.24	44.00	40.47	40.59	36.01	36.19
C-5	26.95	22.27	23.10	24.18	25.94	25.88	31.28	31.19
C-6	34.99	35.46	35.16	39.73	30.88	31.27	127.69	124.13
C-7	28.07	28.74	28.66	19.81	11.38	11.37	71.69 (+6.8)	64.86
C-8	150.88	74.56	74.73	73.36 (−0.5)	155.06	155.49	149.93	150.17
C-9	108.73	68.73	69.69	77.65 (+8.6)	107.05	106.95	109.26	109.16
C-10	21.25	22.06	20.77	21.91	64.32	64.50	20.92	20.92
Glc-1	106.25	106.46	106.11	106.09	101.46		103.60	
Glc-2	75.64	75.70	75.63	75.32	75.40		75.22	
Glc-3	78.65	78.72	78.69	78.72	78.69		78.73	
Glc-4	71.74	71.83	72.06	71.69	71.74		71.89	
Glc-5	78.21	78.39	78.46	78.62	78.47		78.52	
Glc-6	62.85	63.12	63.28	62.81	62.81		62.92	

δ in ppm from tetramethylsilane (TMS). $\Delta\delta$ (δ glucoside−δ aglycone) are given in parentheses. *a*) Assignments may be interchanged.

vealed the presence of one *tert*-methyl, one *sec*-methyl, one hydroxymethyl, two methylenes, four methines (two oxygenated), and one oxygenated quaternary carbon. From the analysis of HMBC spectral data (H-4$_{ax}$/C-2, C-3, C-5, C-6, C-8, C-9, C-10; H$_3$-7/C-1, C-2, C-6; H$_2$-9/C-4, C-8, C-10; H$_3$-10/C-4, C-8, C-9), **4** was suggested to be *p*-menthane-2,6,8,9-tetrol. As cross-peaks based on the NOE interactions between H$_3$-7/H-3$_{ax}$, H-5$_{ax}$, between H-3$_{ax}$/H-5$_{ax}$, and between H-4/H-2$_{ax}$, H-6$_{ax}$ were observed in the NOESY spectrum (Fig. 1), the conformation of the cyclohexane ring was indicated to be the chair form with a 7,8-*cis* substituent, and the C-2 and C-6 hydroxyl groups were equatorial. The broad H-2 and H-6 signals (each δ 4.21, ddd J=3.5, 3.5, 12.0 Hz) also suggested the presence of an equatorial hydroxyl group. Therefore **4** was characterized as 4βH-*cis*-*p*-menthane-2α,6α,8,9-tetrol.

Tetrols **5** ($C_{10}H_{20}O_4$, an amorphous powder, $[\alpha]_D^{22}$ +30°) and **6** ($C_{10}H_{20}O_4$, an amorphous powder, $[\alpha]_D^{22}$ +27°) revealed an $[M+H]^+$ ion peak at *m*/*z* 205 in the positive FAB-MS, and showed similar ^{1}H- and ^{13}C-NMR spectral features (Tables 2, 1). They have two *tert*-methyls, one hydroxymethyl, three methylenes, two methines (one oxygenated), and two oxygenated quaternary carbons. From the result of the HMBC experiment on **5** (H-4$_{ax}$/C-5, C-9; H$_3$-7/C-1, C-2, C-6; H$_2$-9/C-4, C-8, C-10; H$_3$-10/C-4, C-8, C-9), they were suggested to be *p*-menthane-1,2,8,9-tetrol. The conformation of **5** and **6** was found to be the 7,8-*trans* form from the observed NOE interactions between H$_3$-7/H-6$_{ax}$, H-6$_{eq}$, and between H-4/H-6$_{ax}$ in their NOESY spectra (Fig. 1), and the configuration of the C-2 hydroxyl was suggested to be axial by the equatorial H-2 signal which found a narrow double doublet with a half-bandwidth of 3 Hz in their ^{1}H-NMR spectra. Therefore **5** and **6** were revealed to be stereoisomers of *trans*-*p*-menthane-1,2$_{ax}$,8,9-tetrol at C-8, respectively. Furthermore, the ^{13}C chemical shift of the C-3 of **5** (δ 31.4) was downfield from that of **6** (δ 30.5), and the C-5 of **5** (δ 22.3) appeared upfield from that of **6** (δ 23.3), with the same relationship as that between **2** and **3**. This conclusion was supported by the results of NOESY spectra of **5** and **6**, which showed the same interactions as the (4*R**,8*S**)-form of *p*-menthane-2,8,9-triols (between H$_3$-10/H$_2$-3, H$_2$-5, and between H$_2$-9/H-3$_{eq}$) and the (4*R**,8*R**)-form of *p*-menthane-2,8,9-triols (between H$_3$-10/H$_2$-3, H$_2$-5, and between H$_2$-9/H-5$_{eq}$).[1)]

Glucoside **11** ($C_{16}H_{30}O_9$, mp 137—138 °C, $[\alpha]_D^{24}$ +22°) and **12** ($C_{16}H_{30}O_9$, an amorphous powder, $[\alpha]_D^{24}$ +17°) showed an $[M+H]^+$ ion peak at *m*/*z* 367 and an $[M-C_6H_{12}O_6+H]^+$ ion peak at *m*/*z* 187 in the positive FAB-MS. They were hydrolyzed with β-glucosidase and **5** from **11**, and **6** from **12**, were obtained from the hydrolyzed mixtures together with D-glucose. Consequently, **11** and **12** were monoglucosides of **5** and **6**, respectively. The position of the β-glucosyl unit of both glucosides was confirmed to be C-2 from the HMBC correlation of glucosyl H-1/C-2 of **11**, and from the observed NOE interaction between the glucosyl H-1/H-2 in their NOESY spectra (Fig. 1). The absolute configurations at C-2 of **11** and **12** were indicated to be *S* by the values of the glycosylation shift of the α- and β-carbons, and

Table 2. ^{1}H-NMR Chemical Shifts of **2**—**15** (in Pyridine-d_5, 500 MHz)

	2	**3**	**4**
H-3$_{ax}$	2.58 dd (14.0, 14.0)	2.63 dd (13.0, 13.0)	H-1$_{eq}$ 2.86 m
H-3$_{eq}$	2.93 ddd (2.0, 2.0, 14.0)	3.12 dd (2.0, 13.0)	H-2$_{ax}$ 4.21 ddd (3.5, 3.5, 12.0)
H-4$_{ax}$	2.63 m	2.65 m	H-3$_{ax}$ 2.05 ddd (12.0, 12.0, 12.0)
H-5$_{ax}$	2.50 m	2.39 m	H-3$_{eq}$ 2.49 ddd (3.5, 3.5, 12.0)
H-5$_{eq}$	2.66 dddd (2.0, 3.0, 5.5, 13.0)	2.47 ddd (3.5, 5.0, 13.5)	H-4$_{ax}$ 2.18 dddd (3.5, 3.5, 12.0, 12.0)
H-6	6.65 br d (5.5)	6.62 br d (5.0)	H-5$_{ax}$ 1.93 ddd (12.0, 12.0, 12.0)
H$_3$-7	1.83 s	1.83 s	H-5$_{eq}$ 2.25 ddd (3.5, 3.5, 12.0)
H$_2$-9	3.89 d (11.0)	3.87 d (11.0)	H-6$_{ax}$ 4.21 ddd (3.5, 3.5, 12.0)
	3.92 d (11.0)	3.92 d (11.0)	H$_3$-7 1.50 d (7.0)
H$_3$-10	1.42 s	1.41 s	H$_2$-9 3.96 d (11.0)
			3.99 d (11.0)
			H$_3$-10 1.47 s

	5	**6**	**7**	**8**
H-2$_{ax}$	—	—	3.71 dd (3.0, 12.0)	3.73 dd (4.0, 12.0)
H-2$_{eq}$	4.24 dd (3.0, 3.0)	4.27 dd (3.0, 3.0)	—	—
H-3$_{ax}$	2.53 ddd (3.0, 13.0, 13.0)	2.62 ddd (3.0, 13.0, 13.0)	2.10 ddd (12.0, 12.0, 12.0)	2.25 ddd (12.0, 12.0, 12.0)
H-3$_{eq}$	2.27 ddd (3.0, 3.0, 13.0)	2.53 dddd (3.0, 3.0, 3.0, 13.0)	2.33 ddd (3.0, 3.0, 12.0)	2.60 dddd (3.0, 3.0, 4.0, 12.0)
H-4$_{ax}$	2.74 dddd (3.0, 3.0, 13.0, 13.0)	2.76 dddd (3.0, 3.0, 13.0, 13.0)	2.15 dddd (3.0, 3.0, 12.0, 12.0)	2.12 dddd (3.0, 3.0, 12.0, 12.0)
H-5$_{ax}$	2.28 dddd (3.0, 13.0, 13.0, 13.0)	2.15 dddd (3.0, 13.0, 13.0, 13.0)	2.10 br ddd (12.0, 12.0, 12.0)	1.97 dddd (3.0, 12.0, 12.0, 12.0)
H-5$_{eq}$	2.19 dddd (3.0, 3.0, 3.0, 13.0)	1.90 dddd (3.0, 3.0, 3.0, 13.0)	2.07 dddd (3.0, 3.0, 3.0, 12.0)	1.77 dddd (3.0, 3.0, 3.0, 12.0)
H-6$_{ax}$	2.31 ddd (3.0, 13.0, 13.0)	2.26 ddd (3.0, 13.0, 13.0)	1.47 ddd (3.0, 12.0, 12.0)	1.47 ddd (3.0, 12.0, 12.0)
H-6$_{eq}$	1.92 ddd (3.0, 3.0, 13.0)	1.91 ddd (3.0, 3.0, 13.0)	2.11 ddd (3.0, 3.0, 12.0)	2.07 ddd (3.0, 3.0, 12.0)
H$_3$-7	1.71 s	1.71 s	1.55 s	1.55 s
H$_2$-9	3.97 d (11.0)	3.94 d (10.5)	3.92 d (10.5)	3.92 d (10.5)
	4.02 d (11.0)	4.02 d (10.5)	3.99 d (10.5)	3.97 d (10.5)
H$_3$-10	1.52 s	1.49 s	1.45 s	1.44 s

	9	**10**	**11**	**12**
H-2$_{ax}$	4.10 dd (4.5, 11.5)	—	—	—
H-2$_{eq}$	—	4.20 dd (3.0, 3.0)	4.17 dd (3.0, 3.0)	4.21 dd (3.0, 3.0)
H-3$_{ax}$	1.81 ddd (11.5, 12.0, 12.0)	2.39 ddd (3.0, 13.0, 13.0)	2.38 ddd (3.0, 13.0, 13.0)	2.48 ddd (3.0, 13.0, 13.0)
H-3$_{eq}$	2.47 ddd (3.5, 4.5, 12.0)	2.32 ddd (3.0, 3.0, 13.0)	2.69 ddd (3.0, 3.0, 13.0)	2.88 ddd (3.0, 3.0, 13.0)
H-4$_{ax}$	2.20 dddd (3.5, 3.5, 12.0, 12.0)	2.67 dddd (3.0, 3.0, 13.0, 13.0)	2.72 dddd (3.0, 3.0, 13.0, 13.0)	2.75 dddd (3.0, 3.0, 13.0, 13.0)
H-5$_{ax}$	1.68 dddd (3.5, 12.0, 12.0, 12.0)	2.01 dddd (3.0, 13.0, 13.0, 13.0)	2.19 dddd (3.0, 13.0, 13.0, 13.0)	2.04 dddd (3.0, 13.0, 13.0, 13.0)
H-5$_{eq}$	2.18 m	1.59 dddd (3.0, 3.0, 3.0, 13.0)	2.05 dddd (3.0, 3.0, 3.0, 13.0)	1.74 dddd (3.0, 3.0, 3.0, 13.0)
H-6$_{ax}$	1.85 ddd (3.5, 12.0, 12.0)	2.05 ddd (3.0, 13.0, 13.0)	2.10 ddd (3.0, 13.0, 13.0)	2.10 ddd (3.0, 13.0, 13.0)
H-6$_{eq}$	2.10 ddd (3.5, 3.5, 12.0)	1.79 ddd (3.0, 3.0, 13.0)	1.86 ddd (3.0, 3.0, 13.0)	1.81 ddd (3.0, 3.0, 13.0)
H$_3$-7	1.60 s	1.82 s	1.83 s	1.81 s
H-9a	3.93 d (11.0)	4.74 br s	3.90 d (11.0)	3.92 d (11.0)
H-9b	3.96 d (11.0)	4.84 br s	4.06 d (11.0)	3.94 d (11.0)
H$_3$-10	1.46 s	1.73 s	1.45 s	1.42 s
Glc-1	—	5.02 d (7.5)	5.01 d (8.0)	5.00 d (8.0)

	13	**14**	**15**
H-1$_{eq}$	—	2.45 m	H-2$_{eq}$ 4.80 dd (4.0, 4.0)
H-2$_{ax}$	4.03 dd (3.5, 11.5)	4.26 dd (4.5, 4.5, 12.0)	H-3$_{ax}$ 1.65 ddd (4.0, 12.0, 12.0)
H-3$_{ax}$	1.71 ddd (11.5, 12.5, 12.5)	1.84 ddd (12.0, 12.0, 12.0)	H-3$_{eq}$ 2.18 ddd (4.0, 4.0, 12.0)
H-3$_{eq}$	2.45 ddd (3.0, 3.5, 12.5)	2.14 ddd (3.0, 4.5, 12.0)	H-4$_{ax}$ 2.81 dddd (4.0, 4.0, 12.0, 12.0)
H-4$_{ax}$	2.16 dddd (3.0, 3.0, 12.5, 12.5)	2.11 dddd (3.0, 3.0, 12.0, 12.0)	H-5$_{ax}$ 1.91 br dd (12.0, 17.5)
H-5$_{ax}$	1.60 dddd (3.0, 12.5, 13.0, 13.0)	1.43 dddd (3.0, 12.0, 12.0, 12.0)	H-5$_{eq}$ 2.15 ddd (3.0, 4.0, 17.5)
H-5$_{eq}$	2.09 dddd (3.0, 3.0, 3.0, 13.0)	1.51 dddd (3.0, 3.0, 3.0, 12.0)	H-6 6.01 br d (3.0)
H-6$_{ax}$	1.79 ddd (3.0, 13.0, 13.0)	1.44 dddd (3.0, 3.0, 12.0, 12.0)	H-7a 4.55 d (12.0)
H-6$_{eq}$	2.05 ddd (3.0, 3.0, 13.0)	1.56 br ddd (3.0, 3.0, 12.0)	H-7b 4.97 d (12.0)
H$_3$-7	1.57 s	1.18 d (7.0)	H-9a 4.78 br s
H-9a	3.84 d (10.5)	5.00 d (2.0)	H-9b 4.80 br s
H-9b	4.29 d (10.5)	5.28 d (2.0)	H$_3$-10 1.68 s
H$_3$-10	1.37 s	—	Glc-1 4.98 d (7.5)
H$_2$-10	—	4.36 br s	
Glc-1	4.96 d (8.0)	5.02 d (7.5)	

δ in ppm from TMS [coupling constants (J) in Hz are given in parentheses].

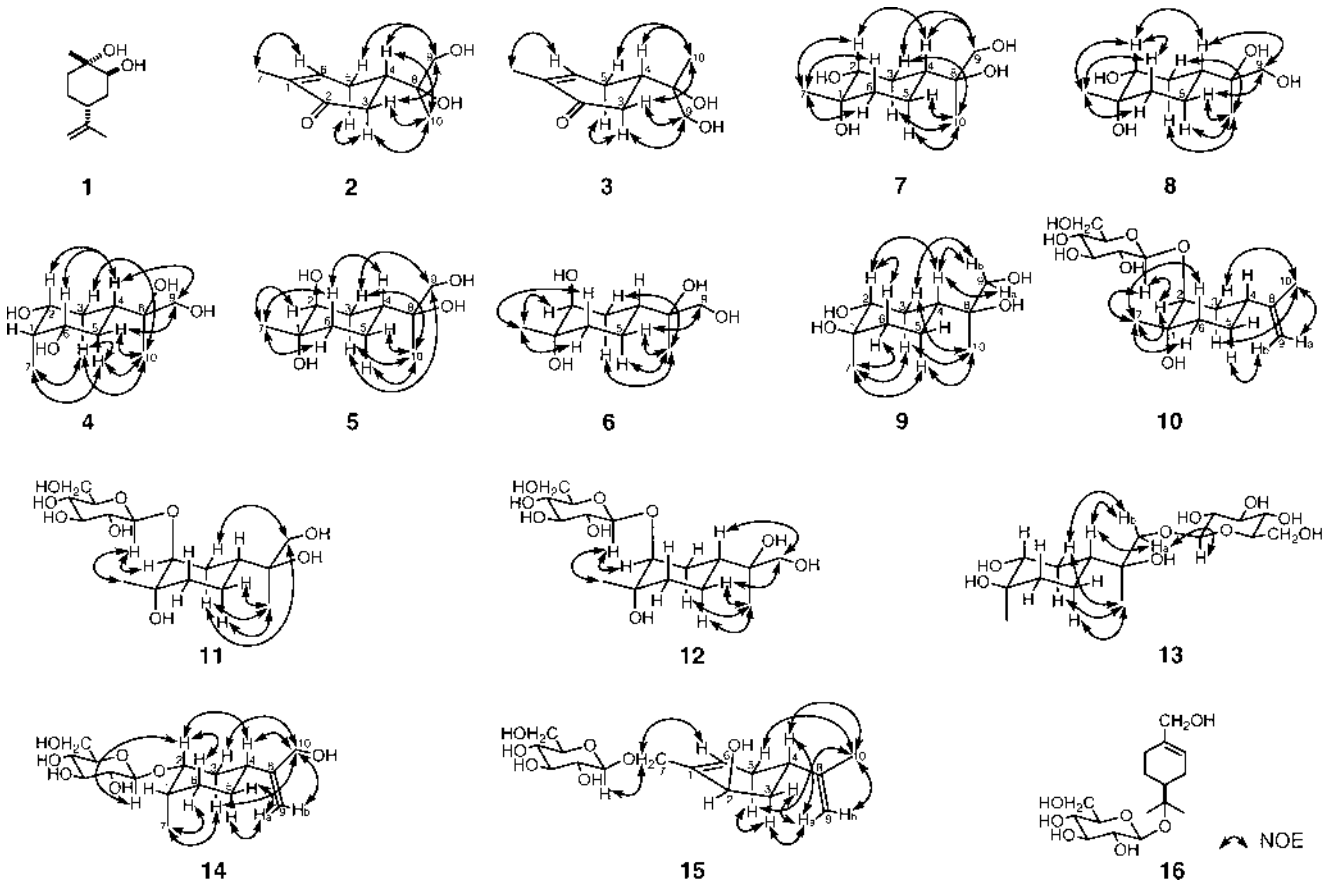

Fig. 1. Structures of **1**—**16**, and NOE Interactions Observed in the NOESY Spectra of **2**—**15**

the chemical shift of the glucosyl anomeric carbon, as shown in Table 1.[1,8] Thus **5**, **6**, **11**, and **12** were characterized as (1*S*,2*S*,4*R*,8*S*)-*p*-menthane-1,2,8,9-tetrol, (1*S*,2*S*,4*R*,8*R*)-*p*-menthane-1,2,8,9-tetrol, (1*S*,2*S*,4*R*,8*S*)-*p*-menthane-1,2,8,9-tetrol 2-*O*-*β*-D-glucopyranoside, and (1*S*,2*S*,4*R*,8*R*)-*p*-menthane-1,2,8,9-tetrol 2-*O*-*β*-D-glucopyranoside, respectively.

Tetrols **7** ($C_{10}H_{20}O_4$, an amorphous powder, $[\alpha]_D^{23}$ +11°) and **8** ($C_{10}H_{20}O_4$, an amorphous powder, $[\alpha]_D^{23}$ +26°) showed similar ^{1}H- and ^{13}C-NMR spectral features (Tables 2, 1) and revealed an $[M+H]^+$ ion peak at *m*/*z* 205 in the positive FAB-MS. From the result of the HMBC experiment on **7** (H-4_{ax}/C-3, C-5, C-6, C-8, C-9; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9), they were also indicated to be *p*-menthane-1,2,8,9-tetrol. The configuration of the C-2 hydroxyl was concluded to be equatorial by the axial H-2 signal pattern of their ^{1}H-NMR spectra (dd, *J*=3.0, 12.0 Hz for **7** and dd, *J*=4.0, 12.0 Hz for **8**; Table 2). The stereochemical relationship between C-7 and C-8 was suggested to be *trans* from the observed NOE interactions in their NOESY spectra (Fig. 1). Therefore **7** and **8** were concluded to be stereoisomers at the C-8 of *trans*-*p*-menthane-1,2_{eq},8,9-tetrol, respectively. The ^{13}C chemical shifts of C-3 (**7**, *δ* 33.0; **8**, *δ* 31.9) and C-5 (**7**, *δ* 22.1; **8**, *δ* 23.1) suggested that the relative configurations at C-4 and C-8 were 4*R**,8*S** for **7** and 4*R**,8*R** for **8**. This suggestion was supported by the NOESY spectrum of **7**, which showed NOE interactions between H_3-10/H-3_{ax}, H_2-5, and between H_2-9/H-3_{eq}, and that of **8** which showed NOE interactions between H_3-10/H_2-3, H_2-5, and between H_2-9/H-5_{eq} (Fig. 1). Therefore **7** and **8** were concluded to be rel-(1*S*,2*R*,4*R*,8*S*)-*p*-menthane-1,2,8,9-tetrol and rel-(1*S*,2*R*,4*R*,8*R*)-*p*-menthane-1,2,8,9-tetrol, respectively.

Tetrol **9** ($C_{10}H_{20}O_4$, an amorphous powder, $[\alpha]_D^{21}$ −3°) was indicated to be *p*-menthane-1,2,8,9-tetrol by the same methods as described in **2** to **8**, and the configuration of the C-2 hydroxyl was concluded to be equatorial by the axial H-2 signal patterns of the ^{1}H-NMR spectrum (Table 1). The stereochemical relationship between C-7 and C-8 was suggested to be *cis* from the observed NOE interactions between H_3-7/H-3_{ax}, H-5_{ax}, and between H-2_{ax}/H-4_{ax}, H-6_{ax} in the NOESY spectra, and comparison of chemical shifts of H-3_{ax} (*δ* 1.81) and H-5_{ax} (*δ* 1.68) with those of **7** and **8**, which were lowfield shifted by the effect of the C-1 axial hydroxyl group (H-3_{ax}, **7**; *δ* 2.10, **8**; *δ* 2.10; H-5_{ax}, **7**; *δ* 2.25, **8**; *δ* 1.97). Therefore **9** was revealed to be *cis*-*p*-menthane-1,2_{eq},8,9-tetrol. In addition, the NOESY spectrum of **9** showed the NOE interactions between H_3-10/H_2-3, H-5_{ax}, and between H-9b/H-3_{eq}, which were also observed in the NOESY spectra of **4** and **7** (Fig. 1). The relative configuration at C-4 and C-8 was assumed to be 4*R**,8*S**. From this evidence, **9** was concluded to be rel-(1*R*,2*R*,4*R*,8*S*)-*p*-menthane-1,2,8,9-tetrol.

Glucoside **13** ($C_{16}H_{30}O_9$, an amorphous powder, $[\alpha]_D^{23}$ −15°) showed an $[M+H]^+$ ion peak at *m*/*z* 367 and an $[M-C_6H_{12}O_6+H]^+$ ion peak at *m*/*z* 187 in the positive FAB-MS. By comparison of ^{1}H- and ^{13}C-NMR data with those of **9** (Tables 2, 1), and from the observed NOE interaction between the glucosyl H-1/H-9b in the NOESY spectrum (Fig.

1), **13** was suggested to be a glucoside of **9**, and the position of attachment of the glucosyl unit was revealed to be C-9. Since the glucose was suggested to be D-form from its $[M]_D$ value $[\Delta[M]_D$ (**13**−**9**) −47°; methyl β-D-glucopyranoside −62°],[4] **13** was concluded to be rel-(1*R*,2*R*,4*R*,8*S*)-*p*-menthane-1,2,8,9-tetrol 9-*O*-β-D-glucopyranoside.

Glucoside **14** ($C_{16}H_{28}O_7$, an amorphous powder, $[\alpha]_D^{25}$ −26°) showed an $[M+H]^+$ ion peak at *m*/*z* 333 and an $[M-C_6H_{12}O_6+H]^+$ ion peak at *m*/*z* 153 in the positive FAB-MS. The ^{1}H-, ^{13}C-, and ^{13}C–^{1}H correlation spectroscopy (COSY) NMR spectral data (Tables 2, 1) showed the presence of one β-glucopyranosyl, one *sec*-methyl, four methylenes (one oxygenated), three methines (one oxygenated), and one terminal-methylene group. From the result of the HMBC experiment on **14** (H-4_{ax}/C-2, C-5, C-6, C-8, C-9, C-10; H_3-7/C-1, C-6; H-9a/C-4, C-8, C-10; H-9b/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9; Glc H-1/C-2), the aglycone was suggested to be *p*-menth-8-ene-2,10-diol and the position of the glucosyl unit was found to be C-2. The configuration of C-2 hydroxyl was concluded to be equatorial by the axial H-2 signal pattern of its ^{1}H-NMR spectrum (ddd, *J*=4.5, 4.5, 12.0 Hz; Table 2). The stereochemical relationship between C-7 and C-8 was indicated to be *cis*, and the conformation of the cyclohexane ring was suggested to be the chair form from the NOE interactions between H_3-7/H-3_{ax}, H-6_{eq} and between H-2_{ax}/H-4_{ax}, H-6_{ax} in the NOESY spectrum (Fig. 1). Enzymatic hydrolysis of **14** gave an aglycone (an amorphous powder, $[\alpha]_D^{22}$ −11°; **14a**) and D-glucose, and the absolute configuration at C-2 was confirmed to be *R* by the values of the glycosylation shift of the α- and β-carbons, and the chemical shift of the glucosyl anomeric carbon, as shown in Table 1.[1,8] From these data, **14** was characterized as (1*S*,2*R*,4*R*)-*p*-menth-8-ene-2,10-diol 2-*O*-β-D-glucopyranoside.

Glucoside **15** ($C_{16}H_{26}O_7$, an amorphous powder, $[\alpha]_D^{24}$ +12°) showed an $[M+H]^+$ ion peaks at *m*/*z* 331 and an $[M-C_6H_{12}O_6+H]^+$ ion peaks at *m*/*z* 151 in the positive FAB-MS. Enzymatic hydrolysis of **15** gave an aglycone (an amorphous powder, $[\alpha]_D^{22}$ +36°; **15a**) and D-glucose. The ^{1}H, ^{13}C-, and ^{13}C–^{1}H COSY NMR spectral data (Tables 2, 1) of **15** showed the presence of one β-glucopyranosyl, one *tert*-methyl, three methylenes (one oxygenated), two methines (one oxygenated), one tri-substituted double bond, and one terminal-methylene group, and the result of the HMBC experiment (H-6/C-2, C-4, C-5, C-7; H_2-7/C-1, C-2, C-6, Glc C-1; H-9a/C-4, C-8, C-10; H-9b/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9; Glc H-1/C-7) suggested that **15** was 7-hydroxycarveol 7-*O*-β-D-glucopyranoside. As the equatorial H-2 signal pattern was shown in the ^{1}H-NMR spectrum (dd, *J*=4.0, 4.0 Hz; Table 2), and the NOE interactions between H-3_{ax}/H-5_{ax}, between H-9a/H-3_{ax}, H-3_{eq}, H-4, and between H_3-10/H-4, H-5_{ax}, H-5_{eq} were observed in the NOESY spectrum (Fig. 1), the configuration of the C-2 hydroxyl was concluded to be axial and the stereochemical relationship between the C-2 hydroxyl and C-4 isopropenyl group was *trans*. It has been reported that the (2*R*,4*S*)- and (2*S*,4*R*)-forms of carveol show positive and negative optical rotations, respectively.[9] Becouse **15a** showed positive optical rotation, **15** was concluded to be (2*R*,4*S*)-7-hydroxycarveol 7-*O*-β-D-glucopyranoside.

Experimental

Melting points were determined on a Yanagimoto micromelting point apparatus and are uncorrected. Optical rotations were measured on a JASCO DIP-370 digital polarimeter. The CD spectra were recorded with a JASCO J-600 spectropolarimeter at 23 °C. FAB-MS were recorded with a JEOL HX-110 spectrometer using glycerol as a matrix. ^{1}H- and ^{13}C-NMR spectra were recorded on JEOL A-500 spectrometers with TMS as an internal standard, and chemical shifts were recorded as δ values. ^{13}C–^{1}H COSY, HMBC, NOESY, and 1D-NOESY spectra were obtained with the usual pulse sequence, and data processing was performed with standard JEOL software. Column chromatography was carried out under TLC monitoring using Kieselgel 60 (70—230 mesh, Merck), Sephadex LH-20 (25—100 μm, Pharmacia), Lobar RP-8 column (Merck), and Amberlite XAD-II (Organo). TLC was performed on silica gel (Merck 5721), and spots were detected with *p*-anisaldehyde–H_2SO_4 reagent. HPLC separation was carried out with Symmetryprep C_{18} 7 μm (Waters; column size, 7.8×300 mm; octadecyl silica (ODS)), Carbohydrate Analysis (Waters; column size, 3.9×300 mm; CHA) columns. Acetylation was done in the usual way using Ac_2O and pyridine. No acetoxyl group had been detected by NMR spectral analysis of the materials prior to acetylation.

Extraction and Separation Commercial caraway (the fruit of *Carum carvi* L.; purchased from Asaoka Spices Ltd., lot no. 93010, 2.0 kg) was extracted with 70% methanol (4 l×2), and the extract was partitioned into ether–water and ethyl acetate–water, respectively. The aqueous portion was chromatographed on Amberlite XAD-II (H_2O→MeOH), and the methanol eluate (27.6 g) was subjected to Sephadex LH-20 (MeOH) column chromatography to give eight fractions (frs. A—H). Fraction B (18.9 g) was chromatographed on silica gel [$CHCl_3$–MeOH–H_2O (17 : 3 : 0.2→4 : 3 : 0.1→7 : 3 : 0.5)→MeOH] to give 14 fractions (frs. B_1—B_{14}). Fraction B_2 (1.32 g) was passed through a Lobar RP-8 column [MeCN–H_2O (1 : 4→1 : 1)] to give seven fractions (frs. $B_{2\text{-}1}$—$B_{2\text{-}7}$), and fr. $B_{2\text{-}2}$ was subjected to HPLC [ODS, MeOH–H_2O (1 : 4)] and silica gel [$CHCl_3$–MeOH (19 : 1)] chromatography to give **2** (7 mg) and **3** (9 mg). Fraction $B_{2\text{-}4}$ was subjected to HPLC [ODS, MeCN–H_2O (3 : 7)] to give **1** (4 mg). Fraction B_5 (0.44 g) was subjected to a Lobar RP-8 column [MeCN–H_2O (3 : 17)] and HPLC [CHA, MeCN–H_2O (19 : 1)] to give **15** (8 mg). Fraction B_6 (0.94 g) was passed through a Lobar RP-8 column [MeCN–H_2O (3 : 17)] to give eight fractions (frs. $B_{6\text{-}1}$—$B_{6\text{-}8}$). Fraction $B_{6\text{-}2}$ was subjected to HPLC [ODS, MeCN–H_2O (1 : 19)] to give **7** (7 mg) and **8** (5 mg). Fraction $B_{6\text{-}5}$ was subjected to HPLC [CHA, MeCN–H_2O (39 : 7)] and then ODS [MeCN–H_2O (7 : 33)] to give **14** (11 mg). Fraction $B_{6\text{-}6}$ was subjected to silica gel column chromatography [$CHCl_3$–MeOH–H_2O (17 : 3 : 0.2)] and then HPLC [CHA, MeCN–H_2O (97 : 3)] to give **10** (302 mg). Fraction B_7 (0.99 g) was subjected to a Lobar RP-8 column [MeCN–H_2O (3 : 17)] and Sephadex LH-20 (MeOH) to give **16** (38 mg). Fraction B_8 (0.60 g) was subjected to a Lobar RP-8 column [MeCN–H_2O (3 : 17)] and HPLC [ODS, MeCN–H_2O (1 : 19)] to give **5** (5 mg), **6** (16 mg), and **9** (25 mg), respectively. Fraction B_{10} (1.38 g) was also subjected to a Lobar RP-8 column [MeCN–H_2O (3 : 17)] to give eight fractions (frs. $B_{10\text{-}1}$—$B_{10\text{-}8}$). Fraction $B_{10\text{-}2}$ was subjected to silica gel column chromatography [$CHCl_3$–MeOH–H_2O (8 : 2 : 0.2)] to give **4** (98 mg). Fraction B_{14} (1.44 g) was passed through a Lobar RP-8 column [MeCN–H_2O (3 : 17)] to give eight fractions (frs. $B_{14\text{-}1}$—$B_{14\text{-}8}$), and fr. $B_{14\text{-}3}$ was acetylated with Ac_2O and pyridine, and the acetylated fraction was subjected to silica gel column chromatography [$CHCl_3$–MeOH (20 : 1)] and then HPLC [ODS, MeCN–H_2O (2 : 3)] to give two fractions. These two fractions were deacetylated by heating in a water bath with 5% NH_4OH–MeOH for 2 h. From the former fraction, **11** (16 mg) and **13** (2 mg) were isolated by HPLC [CHA, MeCN–H_2O (7 : 13)], and from the latter fraction, **12** (9 mg) was isolated by Sephadex LH-20 (MeOH) column chromatography.

The following compounds were identified by comparison with authentic compounds or published physical and spectral data: (1*S*,2*S*,4*R*)-*p*-menth-8-ene-1,2-diol (**1**) and (4*S*)-*p*-menth-1-ene-7,8-diol 8-*O*-β-D-glucopyranoside (**16**).

(4*S*,8*R*)-8,9-Dihydroxy-8,9-dihydrocarvone (2) An amorphous powder, $[\alpha]_D^{25}$ −6° (*c*=0.1, MeOH). Positive FAB-MS *m*/*z*: 369 $[2M+H]^+$, 223 $[M+K]^+$, 207 $[M+Na]^+$ (base), 185.1175 $[M+H]^+$ (Calcd for $C_{10}H_{17}O_3$: 185.1177), 167 $[M-H_2O+H]^+$, 149 $[M-2H_2O+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. CD: (*c*=0.0100 M, MeOH) Δε (nm): −0.48 (250).

(4*S*,8*S*)-8,9-Dihydroxy-8,9-dihydrocarvone (3) An amorphous powder, $[\alpha]_D^{25}$ −7° (*c*=0.2, MeOH). Positive FAB-MS *m*/*z*: 369 $[2M+H]^+$, 223 $[M+K]^+$, 207 $[M+Na]^+$ (base), 185.1180 $[M+H]^+$ (Calcd for $C_{10}H_{17}O_3$: 185.1177), 167 $[M-H_2O+H]^+$, 149 $[M-2H_2O+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. CD:

(c=0.0125 M, MeOH) $\Delta\varepsilon$ (nm): −0.39 (240). HMBC correlations: H-3_{ax}/C-2, C-4, C-5; H-3_{eq}/C-1, C-2, C-4, C-5, C-8; H-4_{ax}/C-2, C-3, C-5, C-8, C-9, C-10; H-5_{ax}/C-1, C-3, C-4, C-6; H-5_{eq}/C-3, C-4; H-6/C-4, C-5, C-7; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9.

4β*H*-*cis*-*p*-Menthane-2α,6α,8,9-tetrol (4) An amorphous powder, $[\alpha]_D^{21}$ +4° (c=1.6, MeOH). Positive FAB-MS m/z: 205.1448 $[M+H]^+$ (base, Calcd for $C_{10}H_{21}O_4$: 205.1439), 187 $[M-H_2O+H]^+$, 169 $[M-2H_2O+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. HMBC correlations: H-1_{eq}/C-2, C-3, C-5, C-6, C-7; H-2_{ax}/C-1, C-3, C-4, C-6, C-7; H-3_{ax}/C-1, C-2, C-4, C-5, C-8; H-3_{eq}/C-1, C-2, C-4, C-5; H-4_{ax}/C-2, C-3, C-5, C-6, C-8, C-9, C-10; H-5_{ax}/C-1, C-3, C-4, C-6, C-8; H-5_{eq}/C-1, C-3, C-4, C-6; H-6_{ax}/C-1, C-2, C-5, C-7; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9.

(1*S*,2*S*,4*R*,8*S*)-*p*-Menthane-1,2,8,9-tetrol (5) An amorphous powder, $[\alpha]_D^{22}$ +30° (c=0.4, MeOH). Positive FAB-MS m/z: 243 $[M+K]^+$, 227.1245 $[M+Na]^+$ (Calcd for $C_{10}H_{20}O_4Na$: 227.1259), 205 $[M+H]^+$, 187 $[M-H_2O+H]^+$, 169 $[M-2H_2O+H]^+$ (base). ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. HMBC correlations: H-2_{eq}/C-1, C-4; H-3_{ax}/C-4, C-5, C-8; H-3_{eq}/C-5; H-4_{ax}/C-5, C-9; H-5_{ax}/C-6; H-5_{eq}/C-6; H-6_{ax}/C-1, C-2, C-4, C-7; H-6_{eq}/C-1, C-2, C-5; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9.

(1*R*,2*S*,4*R*,8*R*)-*p*-Menthane-1,2,8,9-tetrol (6) An amorphous powder, $[\alpha]_D^{22}$ +27° (c=0.8, MeOH). Positive FAB-MS m/z: 243 $[M+K]^+$, 227 $[M+Na]^+$, 205.1424 $[M+H]^+$ (Calcd for $C_{10}H_{21}O_4$: 205.1439), 187 $[M-H_2O+H]^+$, 169 $[M-2H_2O+H]^+$ (base). ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1.

rel-(1*S*,2*R*,4*R*,8*S*)-*p*-Menthane-1,2,8,9-tetrol (7) An amorphous powder, $[\alpha]_D^{23}$ +11° (c=0.1, MeOH). Positive FAB-MS m/z: 243 $[M+K]^+$, 227 $[M+Na]^+$, 205.1438 $[M+H]^+$ (Calcd for $C_{10}H_{21}O_4$: 205.1439), 187 $[M-H_2O+H]^+$ (base), 169 $[M-2H_2O+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. HMBC correlations: H-2_{ax}/C-1, C-4, C-6; H-3_{ax}/C-4, C-5, C-8; H-3_{eq}/C-1, C-5, C-8; H-4_{ax}/C-3, C-5, C-6, C-8, C-9; H-5_{ax}/C-3, C-4, C-6; H-5_{eq}/C-4, C-6; H-6_{ax}/C-2, C-4, C-5, C-7; H-6_{eq}/C-1, C-2, C-4, C-7; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9.

rel-(1*S*,2*R*,4*R*,8*R*)-*p*-Menthane-1,2,8,9-tetrol (8) An amorphous powder, $[\alpha]_D^{23}$ +26° (c=0.1, MeOH). Positive FAB-MS m/z: 227 $[M+Na]^+$, 205.1425 $[M+H]^+$ (base, Calcd for $C_{10}H_{21}O_4$: 205.1439), 187 $[M-H_2O+H]^+$, 169 $[M-2H_2O+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1.

rel-(1*R*,2*R*,4*R*,8*S*)-*p*-Menthane-1,2,8,9-tetrol (9) An amorphous powder, $[\alpha]_D^{21}$ −3° (c=0.2, MeOH). Positive FAB-MS m/z: 409 $[2M+H]^+$, 227 $[M+Na]^+$, 205.1429 $[M+H]^+$ (base, Calcd for $C_{10}H_{21}O_4$: 205.1439), 187 $[M-H_2O+H]^+$, 169 $[M-2H_2O+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1.

(1*S*,2*S*,4*R*)-*p*-Menth-8-ene-1,2-diol 2-*O*-β-D-Glucopyranoside (10) Colorless needles (MeOH), mp 154—156 °C, $[\alpha]_D^{25}$ +13° (c=1.7, MeOH). Positive FAB-MS m/z: 665 $[2M+H]^+$, 371 $[M+K]^+$, 355.1731 $[M+Na]^+$ (Calcd for $C_{16}H_{28}O_7Na$: 355.1733), 333 $[M+H]^+$, 315 $[M-H_2O+H]^+$, 153 $[M-C_6H_{12}O_6+H]^+$ (base). ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. HMBC correlations: H-2_{eq}/C-1, C-4, C-6, C-7, Glc C-1; H-3_{ax}/C-1, C-2, C-4, C-5; H-3_{eq}/C-1, C-2, C-4, C-5; H-4_{ax}/C-3, C-5, C-6, C-10; H-5_{ax}/C-1, C-3, C-4, C-6; H-5_{eq}/C-1, C-3, C-4, C-6; H-6_{ax}/C-5; H-6_{eq}/C-1, C-2, C-4, C-5, C-7; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-10; H_3-10/C-4, C-8, C-9; Glc H-1/C-2.

Enzymatic Hydrolysis of 10 A mixture of **10** (11 mg) and hesperidinase (5 mg, ICN Biomedicals Inc., lot 72635) in water (5 ml) was shaken in a water bath at 37 °C for 20 d. The mixture was concentrated *in vacuo* to dryness and the residue was chromatographed over silica gel [$CHCl_3$–MeOH–H_2O (4 : 1 : 0.1 and 1 : 1 : 0.1)] to afford **1** (3 mg) and a sugar fraction. The sugar fraction was passed through Sephadex LH-20 (MeOH) to give a syrup, and HPLC [carbohydrate analysis (waters), detector; JASCO RI-930 detector and JASCO OR-990 chiral detector, solv.; MeCN–H_2O (17 : 3), 2 ml/min; t_R 4.50 min (same location as that of D-glucose)] showed the presence of D-glucose.

(1*S*,2*S*,4*R*,8*S*)-*p*-Menthane-1,2,8,9-tetrol 2-*O*-β-D-Glucopyranoside (11) Colorless needles (MeOH), mp 137—138 °C, $[\alpha]_D^{24}$ +22° (c=1.3, MeOH). Positive FAB-MS m/z: 389 $[M+Na]^+$, 367.1983 $[M+H]^+$ (Calcd for $C_{16}H_{31}O_9$: 367.1968), 349 $[M-H_2O+H]^+$, 187 $[M-C_6H_{12}O_6+H]^+$ (base). ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. HMBC correlations: H-2_{eq}/C-1, C-4; H-3_{ax}/C-4, C-5, C-8; H-3_{eq}/C-5; H-4_{ax}/C-5, C-9; H-5_{ax}/C-6; H-5_{eq}/C-6; H-6_{ax}/C-1, C-2, C-4, C-7; H-6_{eq}/C-1, C-2, C-5; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9; Glc H-1/C-2.

Enzymatic Hydrolysis of 11 A mixture of **11** (8 mg) and β-glucosidase (5 mg, Toyobo Co., Ltd., lot 52275) in water (5 ml) was shaken in a water bath at 37 °C for 16 d. The mixture was treated in the same way described for **10** to afford **5** (4 mg) and a sugar fraction. D-Glucose was detected from the sugar fraction, as described for **10**.

(1*S*,2*S*,4*R*,8*R*)-*p*-Menthane-1,2,8,9-tetrol 2-*O*-β-D-Glucopyranoside (12) An amorphous powder, $[\alpha]_D^{24}$ +17° (c=0.7, MeOH). Positive FAB-MS m/z: 389 $[M+Na]^+$, 367.1982 $[M+H]^+$ (Calcd for $C_{16}H_{31}O_9$: 367.1968), 349 $[M-H_2O+H]^+$, 187 $[M-C_6H_{12}O_6+H]^+$ (base). ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. HMBC correlations: H-2_{eq}/C-1, C-4, C-6; H-3_{ax}/C-2, C-4, C-5, C-8; H-3_{eq}/C-1, C-2, C-5, C-8; H-4_{ax}/C-2, C-3, C-8, C-9, C-10; H-5_{ax}/C-1, C-4, C-6, C-8; H-5_{eq}/C-3; H-6_{ax}/C-1, C-4, C-5, C-7; H-6_{eq}/C-1, C-2, C-5; H_3-7/C-1, C-2, C-6; H_2-9/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9; Glc H-1/C-2.

Enzymatic Hydrolysis of 12 A mixture of **12** (6 mg) and β-glucosidase in water (5 ml) was shaken in a water bath at 37 °C for 16 d. The mixture was treated in the same way as described for **10** to afford **6** (3 mg) and a sugar fraction. D-Glucose was detected from the sugar fraction, as described for **10**.

rel-(1*R*,2*R*,4*R*,8*S*)-*p*-Menthane-1,2,8,9-tetrol 9-*O*-β-D-Glucopyranoside (13) An amorphous powder, $[\alpha]_D^{23}$ −15° (c=0.2, MeOH). Positive FAB-MS m/z: 733 $[2M+H]^+$, 405 $[M+K]^+$, 389.1782 $[M+Na]^+$ (base, Calcd for $C_{16}H_{30}O_9Na$: 389.1788), 367 $[M+H]^+$, 187 $[M-C_6H_{12}O_6+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1.

(1*S*,2*R*,4*R*)-*p*-Menth-8-ene-2,10-diol 2-*O*-β-D-Glucopyranoside (14) An amorphous powder, $[\alpha]_D^{25}$ −26° (c=0.9, MeOH). Positive FAB-MS m/z: 665 $[2M+H]^+$, 355 $[M+Na]^+$, 333.1921 $[M+H]^+$ (base, Calcd for $C_{16}H_{29}O_7$: 333.1913), 153 $[M-C_6H_{12}O_6+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. HMBC correlations: H-1_{eq}/C-2, C-3, C-5, C-6, C-7; H-2_{ax}/C-1, C-3, C-4, C-6, C-7; H-3_{ax}/C-1, C-4, C-5, C-8; H-3_{eq}/C-1, C-4, C-5, C-8; H-4_{ax}/C-2, C-5, C-6, C-8, C-9, C-10; H-5_{ax}/C-1, C-3, C-4, C-8; H-5_{eq}/C-3, C-4; H-6_{ax}/C-1, C-4, C-5, C-7; H-6_{eq}/C-1, C-2, C-4, C-5, C-7; H_3-7/C-1, C-6; H-9a/C-4, C-8, C-10; H-9b/ C-4, C-8, C-10; H_3-10/C-4, C-8, C-9; Glc H-1/C-2.

Enzymatic Hydrolysis of 14 A mixture of **14** (8 mg) and β-glucosidase (5 mg) in water (5 ml) was shaken in a water bath at 37 °C for 7 d. The mixture was treated in the same way as described for **10** to afford **14a** (4 mg) and a sugar fraction. D-Glucose was detected from the sugar fraction, as described for **10**.

(1*S*,2*R*,4*R*)-*p*-Menth-8-ene-2,10-diol (14a) An amorphous powder, $[\alpha]_D^{22}$ −11° (c=0.3, MeOH). Positive FAB-MS m/z: 171 $[M+H]^+$ (base). ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: 5.46 (1H, d, J=2.0 Hz, H-9b), 5.09 (1H, d, J=2.0 Hz, H-9a), 4.45 (2H, br s, H_2-10), 4.07 (1H, ddd, J=4.5, 4.5, 12.0 Hz, H-2_{ax}), 2.29 (1H, m, H-1_{eq}), 2.28 (1H, dddd, J=3.0, 3.0, 12.0, 12.0 Hz, H-4_{ax}), 2.13 (1H, ddd, J=3.0, 4.5, 12.0 Hz, H-3_{eq}), 1.86 (1H, ddd, J=12.0, 12.0, 12.0 Hz, H-3_{ax}), 1.63 (1H, dddd, J=3.0, 3.0, 12.0, 12.0 Hz, H-6_{ax}), 1.54—1.61 (2H, m, H-5_{eq}, H-6_{eq}), 1.51 (1H, dddd, J=3.0, 12.0, 12.0, 12.0 Hz, H-5_{ax}), 1.19 (3H, d, J=7.0 Hz, H_3-7). ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1.

(4*R*,6*S*)-7-Hydroxycarveol 7-*O*-β-D-Glucopyranoside (15) An amorphous powder, $[\alpha]_D^{24}$ +12° (c=0.4, MeOH). Positive FAB-MS m/z: 661 $[2M+H]^+$, 369 $[M+K]^+$, 331.1755 $[M+H]^+$ (base, Calcd for $C_{16}H_{27}O_7$: 331.1757), 151 $[M-C_6H_{12}O_6+H]^+$. ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: Table 2. ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1. HNBC correlations: H-2_{eq}/C-4; H-3_{ax}/C-4, C-5, C-8; H-3_{eq}/C-2, C-5; H-4_{ax}/C-3, C-5, C-6, C-8, C-9, C-10; H-5_{ax}/C-1, C-4, C-6, C-8; H-5_{eq}/C-1, C-3, C-4, C-6, C-8; H-6/C-2, C-4, C-5, C-7; H_2-7/C-1, C-2, C-6, Glc C-1; H-9a/ C-4, C-8, C-10; H-9b/C-4, C-8, C-10; H_3-10/C-4, C-8, C-9; Glc H-1/C-7.

Enzymatic Hydrolysis of 15 A mixture of **15** (6 mg) and β-glucosidase (5 mg) in water (5 ml) was shaken in a water bath at 37 °C for 10 d. The mixture was treated in the same way as described for **10** to afford **15a** (3 mg) and a sugar fraction. D-Glucose was detected from the sugar fraction, as described for **10**.

(4*R*,6*S*)-7-Hydroxycarveol (15a) An amorphous powder, $[\alpha]_D^{22}$ +36° (c=0.2, MeOH). Positive FAB-MS m/z: 169 $[M+H]^+$ (base). ^{1}H-NMR (pyridine-d_5, 500 MHz) δ: 6.05 (1H, br d, J=4.0 Hz, H-6), 4.80 (1H, br s, H-9b), 4.77 (1H, br s, H-9a), 4.73 (1H, dd, J=4.0, 4.0 Hz, H-2_{eq}), 4.70 (1H, d, J=13.0 Hz, H-7b), 4.64 (1H, d, J=13.0 Hz, H-7a), 2.83 (1H, dddd, J=4.0, 4.0, 13.0, 13.0 Hz, H-4_{ax}), 2.21 (1H, ddd, J=4.0, 4.0, 13.0 Hz, H-3_{eq}), 2.18 (1H, ddd, J=4.0, 4.0, 17.5 Hz, H-5_{eq}), 1.93 (1H, br dd, J=13.0, 17.5 Hz, H-5_{ax}), 1.68 (3H, s, H_3-10), 1.65 (1H, ddd, J=4.0, 13.0, 13.0 Hz, H-3_{ax}). ^{13}C-NMR (pyridine-d_5, 125 MHz) δ: Table 1.

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