Four New Glycosides of Stilbene Trimer from Foeniculi Fructus (Fruit of *Foeniculum vulgare* MILLER)

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Received November 9, 1994; accepted January 13, 1995

Four new glycosides of stilbene trimer, termed foeniculosides I, II, III and IV, were isolated from Foeniculi Fructus (fruit of *Foeniculum vulgare* MILLER) along with two known stilbene trimers, miyabenol C and *cis*-miyabenol C. The structures of foeniculosides I, II, III and IV were characterized as 11a-*O*-*β*-D-glucopyranoside, 13b-*O*-*β*-D-glucopyranoside, 11a,13b-di-*O*-*β*-D-glucopyranoside, 11a,13b,13c-tri-*O*-*β*-D-glucopyranoside of *cis*-miyabenol C, respectively, on the basis of chemical and spectroscopic data.

Key words *Foeniculum vulgare*; stilbene; *cis*-miyabenol C; foeniculoside; Umbelliferae; Foeniculi Fructus

Foeniculum vulgare MILLER (Umbelliferae) is cultivated in many parts of the world, and its fruit (Foeniculi Fructus) is used as flavoring, spice and in folk medicine.[1] A large number of essential oils including anethole, *d*-fenchone, *p*-anisaldehyde and chavicol have been reported to be constituents of this fruit.[2]

One of the present authors recently identified an antihypertensive effect of the fruit,[3] and we therefore reexamined the components to determine the compounds responsible for the antihypertensive effect.

The powdered fruit was extracted with MeOH under reflux and the extract was defatted with *n*-hexane. The residue was subjected successively to Diaion HP 20 column chromatography, silica gel column chromatography and high performance liquid chromatography (HPLC) on octadecyl silica (ODS) to give six compounds (**1**—**6**).

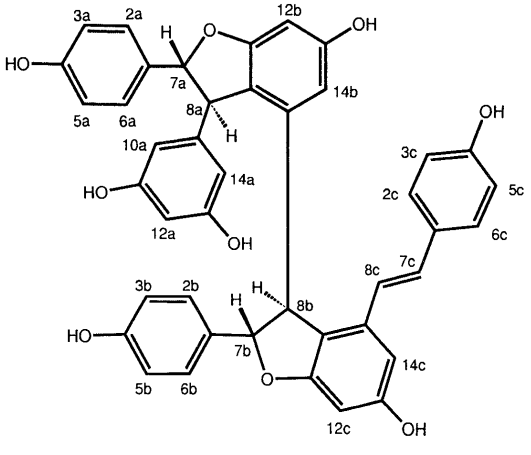
Compound **1**, a yellowish powder, $[\alpha]_D$ +221.4°, was identified as miyabenol C by comparison of its physical and spectral data with the authentic sample.[4]

Compound **2** was obtained as a yellowish powder, $[\alpha]_D$ +98.5°. The negative FAB-MS and positive FAB-MS of **2** exhibited an $[M-H]^-$ ion peak at *m/z* 679 and an $[M+H]^+$ ion peak at *m/z* 681, respectively, indicating its molecular weight to be 680. A high-resolution (HR) positive FAB-MS at 681.2125 suggested the molecular formula of **2** to be $C_{42}H_{32}O_9$, which was the same as that of **1**.

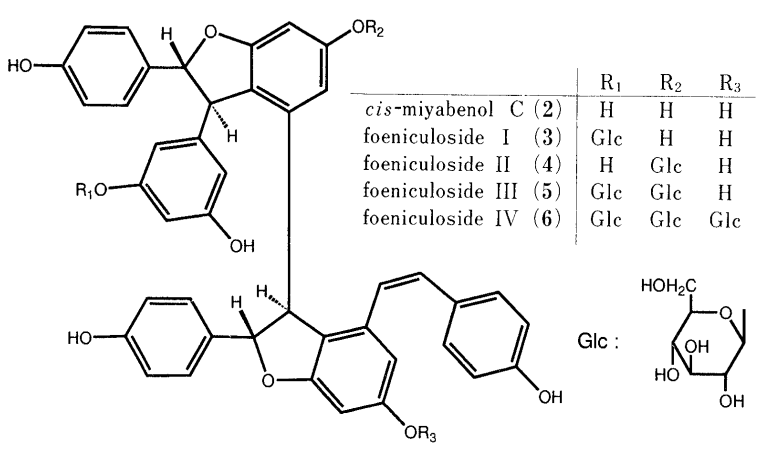
The ^{1}H- and ^{13}C-NMR spectra of **2** were closely analogous to those of **1**, except for the appearance of signals due to two *cis*-coupled olefinic protons [(acetone-d_6) δ: 5.80 (d, J=12.5 Hz) and 5.84 (d, J=12.5 Hz)] and the loss of those due to two *trans*-coupled olefinic protons [(acetone-d_6) δ: 6.59 (d, J=16.5 Hz) and 6.88 (d, J=16.5 Hz)]. These data indicated **2** to be the *cis*-isomer of **1**, that is, *cis*-miyabenol C.[5] This was confirmed by UV irradiation[6] of **1** which was converted to **2**.

Compound **3**, called foeniculoside I, was obtained as a pale yellow powder, $[\alpha]_D$ +46.8°, and it exhibited an $[M-H]^-$ ion peak at *m/z* 841 together with a fragment ion peak at *m/z* 679 $[M-H-\text{hexose}]^-$ in the negative FAB-MS. The ^{1}H- and ^{13}C-NMR spectra of **3** showed 1 mol of monosaccaride signals accompanied by similar signals of **2**, which indicated **3** to be a monoglycoside of **2**.

Enzymatic hydrolysis of **3** with the mixed glycosidase from *Turbo cornutus* gave **2** and a monosaccaride which was identified with D-glucose (Glc) on the basis of *Rf* value



miyabenol C(1)



	R_1	R_2	R_3
cis-miyabenol C (2)	H	H	H
foeniculoside I (3)	Glc	H	H
foeniculoside II (4)	H	Glc	H
foeniculoside III (5)	Glc	Glc	H
foeniculoside IV (6)	Glc	Glc	Glc

Fig. 1. Structures of **1**—**6**

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Table 1. ^{1}H-NMR Spectral Data for **2**—**6** (in DMSO-d_6)

	2[a]	**3**[b]	**4**[a]	**5**[c]	**6**[b]
Ag- 2(6)a	7.02, d (7.8)	7.05, d (8.6)	7.04, d (8.4)	7.07, d (8.6)	7.06, d (8.7)
Ag- 3(5)a	6.73, d (7.8)	6.78, d (8.6)	6.76, d (8.4)	6.77, d (8.6)	6.75, d (8.7)
Ag- 7a	5.26, d (2.9)	5.24, d (2.8)	*ca.* 5.30	5.30, d (2.4)	5.28, d (3.0)
Ag- 8a	4.24, d (2.9)	4.24, d (2.8)	4.27, d (2.8)	4.31, d (2.4)	4.33, d (3.0)
Ag-10a	5.90, s	*ca.* 6.01	5.87, s	6.04, s	6.03, s
Ag-12a	6.11, s	6.34, s	6.11, s	6.33, s	6.31, s
Ag-14a	5.90, s	*ca.* 6.01	5.87, s	6.00, s	5.98, s
Ag- 2(6)b	6.34, d (8.3)	6.32, d (8.4)	6.31, d (8.4)	6.32, d (8.5)	6.32, d (8.5)
Ag- 3(5)b	6.48, d (8.3)	6.50, d (8.4)	6.47, d (8.4)	6.49, d (8.5)	6.48, d (8.5)
Ag- 7b	5.33, s	5.28, s	*ca.* 5.30	5.28, d (1.8)	5.30, d (2.0)
Ag- 8b	3.79, s	3.75, s	3.81, s	3.80, d (1.8)	3.85, d (2.0)
Ag-12b	6.18, s	6.23, s	6.56, s	6.58, d (2.5)	6.59, d (2.0)
Ag-14b	6.08, s	6.05, s	6.22, s	6.21, d (2.5)	6.26, d (2.0)
Ag- 2(6)c	6.71, d (7.8)	6.68, d (8.6)	6.69, d (8.4)	6.70, d (8.5)	6.66, d (8.5)
Ag- 3(5)c	6.49, d (7.8)	6.49, d (8.6)	6.49, d (8.4)	6.51, d (8.5)	6.50, d (8.5)
Ag- 7c	5.75, d (12.7)	5.73, d (12.2)	5.77, d (12.5)	5.77, d (12.3)	5.83, d (12.3)
Ag- 8c	5.78, d (12.7)	5.77, d (12.2)	5.80, d (12.5)	5.79, d (12.3)	5.86, d (12.3)
Ag-12c	6.30, s	6.30, s	6.30, s	6.27, d (1.8)	6.60, d (2.2)
Ag-14c	6.00, s	*ca.* 6.01	6.03, s	6.06, d (1.8)	6.18, d (2.2)
Glc-1		4.73, d (7.9)	4.73, d (7.3)	4.75, d (7.3)	4.73, d (7.7)
Glc′-1				4.73, d (7.3)	4.70, d (7.9)
Glc″-1					4.75, d (7.7)

a) 400 MHz, *b*) 600 MHz, *c*) 500 MHz. δ in ppm from TMS (coupling constants (J) in Hz are given in parentheses).

of its high performance thin layer chromatography (HPTLC) and gas chromatographic (GC) analysis according to Hara *et al.*[7]

To learn the location of the sugar linkage, the ^{1}H- and ^{13}C-NMR signals in **3** were assigned with the aid of ^{1}H–^{1}H shift correlated 2D-NMR (COSY), ^{1}H–^{13}C heteronuclear shift correlated 2D-NMR (HETCOR) and ^{1}H-detected heteronuclear multiple-bond multiple-quantum coherence (HMBC) spectra (J_{C-H}, 7 Hz). Comparison of the ^{1}H- and ^{13}C-NMR signals of **2** showed the signals due to 12a-H, 10a-C and 14a-C of aglycone (Ag) of **3** to be shifted toward downfield by 0.23, 1.0 and 2.7 ppm, respectively.[8] The HMBC spectrum of **3** showed the cross peak between 1-H (δ 4.73) of Glc and 11a-C (δ 159.3) of Ag. Therefore, Glc should be attached to 11a-C of Ag. The coupling constant of anomeric proton signal and ^{13}C-NMR signals of sugar moiety indicated that Glc was pyranose form, and the mode of glycosidic linkage of Glc was β.[9]

Consequently, the structure of **3** was concluded to be *cis*-miyabenol C 11a-*O*-β-D-glucopyranoside (Fig. 1).

Compound **4**, called foeniculoside II, was obtained as a brown powder, $[\alpha]_D$ +89.1°, and its negative FAB-MS was almost superimposable on that of **3**, indicating an $[M-H]^-$ ion and fragment ion peaks at m/z 841 and 679, respectively.

Compound **4**, on enzymatic hydrolysis, gave **2** and Glc, and the ^{1}H- and ^{13}C-NMR spectra of **4** were quite similar to those of **3**. Therefore, **4** was believed to be a positional isomer of **3** in the glycosyl linkage. Comparison of ^{1}H- and ^{13}C-NMR signals of **4** with those of **2** showed downfield shifts at 12b-H, 10b-C and 14b-C of Ag by 0.38, 2.5 and 1.7 ppm, respectively, and the signals of Glc were superimposable on those of **3**.

Accordingly, the structure of **4** was determined to be *cis*-miyabenol C 13b-*O*-β-D-glucopyranoside.

Compound **5**, called foeniculoside III, was isolated as a pale yellow powder, $[\alpha]_D$ +41.9°, and gave an $[M-H]^-$ ion peak at m/z 1003, which was 162 mass units larger than those of **3** and **4**, and fragment ion peaks at m/z 841 $[M-H-\text{hexose}]^-$ and 679 $[M-H-\text{hexose}\times 2]^-$ in the negative FAB-MS. The ^{1}H- and ^{13}C-NMR spectra showed two moles of β-glucopyranosyl signals along with signals similar to those of **2**. Enzymatic hydrolysis of **5** afforded **2** and Glc. From these data, **5** was considered to be a derivative of **3** and/or **4**, in which one of the hydroxyl groups in **3** or **4** was glycosylated with Glc. The ^{1}H- and ^{13}C-NMR signals of Ag moiety of **5** were quite similar to those of **3**, apart from the signals of 12b-H, 10b-C and 14b-C, which were almost superimposable on those of **4**.

Consequently, the structure of **5** was characterized as *cis*-miyabenol C 11a,13b-di-*O*-β-D-glucopyranoside.

Compound **6**, called foeniculoside IV, was obtained as a brown powder, $[\alpha]_D$ +40.7°, and it showed an $[M-H]^-$ ion peak at m/z 1165, which was 162 mass units larger than that of **5**, and fragment ion peaks at m/z 1003 $[M-H-\text{hexose}]^-$, 841 $[M-H-\text{hexose}\times 2]^-$, 679 $[M-H-\text{hexose}\times 3]^-$ in the negative FAB-MS. On enzymatic hydrolysis, **6** furnished **2** and Glc, and also exhibited three moles of β-glucopyranosyl signals in the ^{1}H- and ^{13}C-NMR spectra. From these data, **6** was considered to be a triglucoside of **2**. Comparison of the ^{1}H- and ^{13}C-NMR spectra of **6** with those of **5** showed the signals ascribable to 12c-H, 10c-C and 14c-C of Ag to be shifted toward downfield by 0.33, 3.0 and 1.6 ppm, respectively, while the other signals of Ag were observed at similar positions to those of **5**. The HMBC experiment of **6** showed three cross peaks between 11a-C (δ 159.1) of Ag and 1-H (δ 4.73) of Glc, 13b-C (δ 159.7) and 1-H (δ 4.75) of Glc, 13c-C (δ 158.7) of Ag and 1-H (δ 4.70) of Glc, confirming that three moles of Glc attached to the hydroxyl groups at 11a-C, 13b-C and 13c-C of Ag.

The structure of **6** was therefore defined as *cis*-miyabenol

Table 2. ^{13}C-NMR Spectral Data for **1**—**6** (in DMSO-d_6)

	1[a]	**2**[a]	**3**[b]	**4**[a]	**5**[c]	**6**[b]
Ag- 1a	131.4[d]	132.9	133.1	132.7	132.4	132.3
Ag- 2(6)a	127.1	126.6	126.9	126.8	126.5	126.7
Ag- 3(5)a	115.4	115.2	115.6	115.2[d]	115.2[d]	115.3
Ag- 4a	157.5[e]	157.3	157.4	157.5	157.3	157.4
Ag- 7a	93.2	92.3	92.5	92.6	92.3	92.5
Ag- 8a	55.0	55.4	55.5	55.2	54.9	54.8
Ag- 9a	146.0	146.6	146.9	146.2	146.0	146.0
Ag-10a	105.4	105.3	106.3	105.4	106.1	106.1
Ag-11a	159.3	159.1	159.3	159.3	159.0[e]	159.1
Ag-12a	101.4	101.1	101.9	101.4	101.5	101.5
Ag-13a	159.3	159.1	159.1	159.3	158.9[e]	159.0
Ag-14a	105.4	105.3	108.0	105.4	107.5[f]	107.6
Ag- 1b	131.0[d]	131.8	132.2	131.7	131.6	131.3
Ag- 2(6)b	126.0	125.5	126.1	125.8	125.7	125.8
Ag- 3(5)b	114.7	114.9	115.3	115.0[d]	115.0[d]	115.0[d]
Ag- 4b	156.5	156.4[d]	156.5	156.6[e]	156.3	156.5
Ag- 7b	90.5	90.5	91.1	90.5	90.6	90.9
Ag- 8b	49.7	51.2	51.5	51.2	51.0	50.9
Ag- 9b	142.0	142.0	142.5	142.1	142.0	141.8
Ag-10b	116.9	117.8	118.0	120.3[f]	120.1[g]	120.2
Ag-11b	160.6[f]	160.4[e]	160.7	159.5[g]	160.2	160.3
Ag-12b	95.5	95.2	95.4	95.7	95.5	95.5
Ag-13b	159.1	159.4	159.5	159.7[g]	159.6	159.7
Ag-14b	106.4	105.7	106.2	107.4	107.3[f]	107.6
Ag- 1c	127.4	126.8	127.3	126.3	126.8	126.7
Ag- 2(6)c	127.8	129.8	130.1	129.9	129.7	129.7
Ag- 3(5)c	115.8	114.9	115.3	115.5	114.9[d]	115.1[d]
Ag- 4c	157.7[e]	156.8[d]	156.9	156.9[e]	156.7	156.9
Ag- 7c	130.3	130.4	130.7	130.6	130.3	130.9
Ag- 8c	121.3	124.3	124.7	124.4	124.3	124.1
Ag- 9c	134.4	135.6	136.1	135.7	135.5	135.5
Ag-10c	119.6	120.4	120.7	120.5[f]	120.0[g]	123.0
Ag-11c	160.5[f]	160.1[e]	160.5	160.4	160.2	160.1
Ag-12c	96.5	96.1	96.3	96.2	95.9	96.6
Ag-13c	158.5	158.2	158.4	158.5	158.3	158.7
Ag-14c	103.4	107.2	107.6	107.4	107.2[f]	108.8
Glc-1			100.2	100.9	100.0	100.0
					100.8	100.8
						100.9
Glc-2			73.4	73.3	73.2	73.2
					73.1	73.2
						73.3
Glc-3			76.7	76.7	76.4	76.5
					76.6	76.5
						76.5
Glc-4			69.6	69.6	69.4	69.5
					69.5	69.6
						69.7
Glc-5			76.9	77.1	76.7	76.8
					77.0	76.9
						77.0
Glc-6			60.6	60.6	60.4	60.5
					60.5	60.6
						60.6

a) 100 MHz, *b*) 150 MHz, *c*) 125 MHz. δ in ppm from TMS. *d*—*g*) Assignments may be interchanged in each column.

C 11a,13b,13c-tri-*O*-β-D-glucopyranoside, as shown in Fig. 1.

As far as we know, foeniculosides I—IV are the first examples of the glycoside of *cis*-miyabenol C, and this is the first report on the isolation of oligostilbene from Umbelliferae plants.

The examination of the antihypertensive effect of foeniclosides and further investigation of the constituents of this fruit are in progress.

Experimental

The fruit was purchased from Uchida Wakanyaku Co., Ltd. The optical rotations were measured with a JASCO DIP 360 digital polarimeter. The IR spectrum was taken on a Hitachi IR spectrometer model 270-30. The UV spectra were run on a Hitachi Model 100-50 spectrophotometer. The ^{1}H- and ^{13}C-NMR spectra were recorded on JEOL JNM-GX-400, JEOL alpha 500 and GE Omega 600 spectrometers; chemical shifts were given on a δ (ppm) scale with tetramethylsilane (TMS) as an internal standard. The MS were obtained on JEOL JMS-DX-303HF and JMS-HX110 instruments (ion source, Xe atom beam; accelerating voltage, 3 kV; matrix, glycerol/MeOH or triethylene glycol/MeOH or triethylene glycol/dimethyl sulfoxide (DMSO) or *m*-nitrobenzyl alcohol/DMSO). GC analysis was performed on a Hewlett-Packard HP-5890A gas chromatograph with an H_2 flame ionization detector; column, OV-1 (0.32 mm × 30 m); column temperature, 230 °C; carrier gas, He (2.2 kg/cm^2). Column chromatography was carried out with Silica gel 60 (Merck, Art. 9385), Diaion HP 20 (Mitsubishi Chemical Industries Co., Ltd.) and Sephadex LH 20 (Pharmacia Fine Chemicals). HPTLC was performed on precoated silica gel plates (Merck, Art. 5628) using $CHCl_3$–MeOH–H_2O (6 : 4 : 1) as developing solvent and detection was achieved by spraying the plates with 10% H_2SO_4–MeOH reagent, followed by heating. HPLC separation was run on a Micro Pump KPW-20 (Kusano Kagakukikai Co.) with a UV-Detector KU-331 (Kusano Kagakukikai Co.). For HPLC column chromatography, Inertsil ODS (GL Sciences, 20 mm i.d. × 250 mm), Cosmosil 5C18-Ar (Nacalai Tesque Inc., 6 mm i.d. × 250 mm), YMC-pack S-5 120A ODS (YMC, 20 mm i.d. × 250 mm) with MeOH–H_2O system as developing solvent and Kusano C.I.G. prepacked Si-gel (Kusano Kagakukikai Co., 22 mm i.d. × 300 mm) with $CHCl_3$–MeOH–H_2O (7 : 3 : 0.5) as developing solvent were used.

Extraction and Isolation Powdered fruit of *Foeniculum vulgare* MILLER (4904.9 g) was extracted with MeOH (4 l × 2) under reflux, and the solvent was removed under reduced pressure to afford a brown syrup (423.7 g). This syrup was defatted repeatedly by treatment of *n*-hexane (100 ml × 4) to give *n*-hexane soluble fraction (99.20 g) and the residue (323.5 g). This residue (75.20 g) was chromatographed over Diaion HP 20 (H_2O→30% MeOH→60% MeOH→MeOH→acetone) to afford fraction (fr.) 1 (32.27 g), fr. 2 (5.72 g), fr. 3 (4.32 g), fr. 4 (21.66 g) and fr. 5 (10.76 g). Chromatography of fr. 3 over silica gel ($CHCl_3$–MeOH–H_2O, 14 : 2 : 0.1→10 : 2 : 0.1→8 : 2 : 0.2→7 : 3 : 0.5→6 : 4 : 1→10 : 10 : 1) furnished fr. 6 (253 mg), fr. 7 (525 mg), fr. 8 (49 mg), fr. 9 (55 mg), fr. 10 (83 mg), fr. 11 (185 mg), fr. 12 (159 mg), fr. 13 (79 mg), fr. 14 (267 mg), fr. 15 (158 mg), fr. 16 (189 mg), fr. 17 (137 mg), fr. 18 (579 mg), fr. 19 (328 mg), fr. 20 (789 mg), fr. 21 (288 mg), fr. 22 (325 mg) and fr. 23 (169 mg). Fraction 14 was subjected to HPLC (Inertsil ODS, 45% MeOH) to give **1** (26 mg) and **2** (36 mg). HPLC (Inertsil ODS, 40% MeOH) of fr. 18 gave fr. 24 (113 mg), **3** (54 mg), fr. 25 (13 mg) and fr. 26 (34 mg). HPLC (Cosmosil 5C18-Ar, 40% MeOH) of fr. 24 (55 mg) afforded **4** (24 mg) and fr. 27 (20 mg). Fraction 20 was chromatographed over Sephadex LH 20 (30% MeOH→MeOH) to give fr. 28 (324 mg) and fr. 29 (368 mg). Fraction 29 was subjected repeatedly to HPLC on YMC-pack S-5 120A ODS (50% MeOH) and Kusano C.I.G. prepacked Si-gel columns to give **5** (53 mg). Fraction 22 was subjected to HPLC (Inertsil ODS, 30% MeOH) to afford fr. 30 (98 mg). HPLC (Cosmosil 5C18 AR, 30% MeOH) of fr. 30 (22 mg) furnished **6** (13 mg) and Fr. 31 (7 mg).

1: A yellowish powder, $[\alpha]_D^{28}$ +221.4° (c = 1.1, MeOH). Negative FAB-MS m/z: 679 $[M-H]^-$. ^{13}C-NMR δ: see Table 2. ^{1}H-NMR (acetone-d_6, 400 MHz) δ: 7.15 (2H, d, J = 8.4 Hz, 2(6)a-H), 7.10 (2H, d, J = 8.4 Hz, 2(6)c-H), 6.88 (1H, d, J = 16.5 Hz, 7c-H), 6.83 (2H, d, J = 8.8 Hz, 3(5)a-H), 6.75 (2H, d, J = 8.4 Hz, 3(5)c-H), 6.65 (1H, d, J = 1.8 Hz, 14c-H), 6.59 (1H, d, J = 16.5 Hz, 8c-H), 6.55 (2H, d, J = 8.8 Hz, 3(5)b-H), 6.49 (2H, d, J = 8.8 Hz, 2(6)b-H), 6.33 (1H, d, J = 1.8 Hz, 12c-H), 6.28 (1H, d, J = 1.8 Hz, 12b-H), 6.21 (1H, t, J = 2.2 Hz, 12a-H), 6.15 (2H, d, J = 2.2 Hz, 10(14)a-H), 6.06 (1H, d, J = 1.8 Hz, 14b-H), 5.37 (1H, d, J = 5.5 Hz, 7a-H), 5.18 (1H, d, J = 1.5 Hz, 7b-H), 4.63 (1H, d, J = 5.5 Hz, 8a-H), 4.30 (1H, d, J = 1.5 Hz, 8b-H).

2: A yellowish powder, $[\alpha]_D^{28}$ +98.5° (c = 1.0, MeOH). IR (KBr) cm^{-1}: 3340 (br, OH), 1612 (arom.), 1513 (arom.). UV λ_{max}^{MeOH} nm (log ε): 285 (4.49). HR positive FAB-MS m/z: 681.2125 $[M+H]^+$ (Calcd for $C_{42}H_{33}O_9$: 681.2124). Negative FAB-MS m/z: 679 $[M-H]^-$. Positive FAB-MS m/z: 681 $[M+H]^+$. ^{1}H- and ^{13}C-NMR δ: see Tables 1 and 2. ^{1}H-NMR (in acetone-d_6, 400 MHz) δ: 7.13 (2H, d, J = 8.4 Hz, 2(6)a-H), 6.87 (2H, d, J = 8.4 Hz, 3(5)a-H), 6.76 (2H, d, J = 8.4 Hz, 2(6)c-H), 6.58

(2H, d, J=8.8 Hz, 3(5)b-H), 6.53 (2H, d, J=8.4 Hz, 3(5)c-H), 6.43 (2H, d, J=8.8 Hz, 2(6)b-H), 6.37 (1H, d, J=2.2 Hz, 12c-H), 6.30 (1H, d, J=2.2 Hz, 12b-H), 6.26 (1H, t, J=2.2 Hz, 12a-H), 6.14 (1H, d, J=1.8 Hz, 14b-H), 5.95 (2H, d, J=2.2 Hz, 10(14)a-H), 5.84 (1H, d, J=12.5 Hz, 7c-H), 5.80 (1H, d, J=12.5 Hz, 8c-H), 5.32 (1H, J=2.2 Hz, 7b-H), 5.30 (1H, J=2.9 Hz, 7a-H), 4.28 (1H, d, J=2.9 Hz, 8a-H), 3.88 (1H, d, J=2.2 Hz, 8b-H).

3: A pale yellow powder, $[\alpha]_D^{23}$ +46.8° (c=0.9, MeOH). UV λ_{max}^{MeOH} nm (log ε): 285 (4.53). HR positive FAB-MS m/z: 865.2472 $[M+Na]^+$ (Calcd for $C_{48}H_{42}NaO_{14}$: 865.2472). Negative FAB-MS m/z (%): 841 (100) $[M-H]^-$, 679 (69) [M − H − hexose, Ag − H]$^-$. Positive FAB-MS m/z (%): 865 (20) $[M+Na]^+$, 843 (75) $[M+H]^+$, 681 (100) [M + H − hexose, Ag + H]$^+$. ^{1}H- and ^{13}C-NMR δ: see Tables 1 and 2.

4: A brown powder, $[\alpha]_D^{28}$ +89.1° (c=0.9, MeOH). UV λ_{max}^{MeOH} nm (log ε): 285 (4.53). HR positive FAB-MS m/z: 865.2468 $[M+Na]^+$ (Calcd for $C_{48}H_{42}NaO_{14}$: 865.2472). Negative FAB-MS m/z (%): 841 (100) $[M-H]^-$, 679 (44) [M − H − hexose, Ag − H]$^-$. Positive FAB-MS m/z (%): 865 (50) $[M+Na]^+$, 843 (100) $[M+H]^+$, 681 (40) [M + H − hexose, Ag + H]$^+$. ^{1}H- and ^{13}C-NMR δ: see Tables 1 and 2.

5: A pale yellow powder, $[\alpha]_D^{23}$ +41.9° (c=1.0, MeOH). UV λ_{max}^{MeOH} nm (log ε): 285 (4.64). HR positive FAB-MS m/z: 1027.3005 $[M+Na]^+$ (Calcd for $C_{54}H_{52}NaO_{19}$: 1027.3000). Negative FAB-MS m/z (%): 1003 (100) $[M-H]^-$, 841 (39) [M − H − hexose]$^-$, 679 (23) [M − H − hexose × 2, Ag − H]$^-$. Positive FAB-MS m/z (%): 1027 (34) $[M+Na]^+$, 1005 (60) $[M+H]^+$, 843 (62) [M + H − hexose]$^+$, 681 (100) [M + H − hexose × 2, Ag + H]$^+$. ^{1}H- and ^{13}C-NMR δ: see Tables 1 and 2.

6: A brown powder, $[\alpha]_D^{23}$ +40.7° (c=0.8, MeOH). UV λ_{max}^{MeOH} nm (log ε): 285 (4.53). HR positive FAB-MS m/z: 1189.3547 $[M+Na]^+$ (Calcd for $C_{60}H_{62}NaO_{24}$: 1189.3528). Negative FAB-MS m/z (%): 1165 (100) $[M-H]^-$, 1003 (60) [M − H − hexose]$^-$, 841 (23) [M − H − hexose × 2]$^-$, 679 (29) [M − H − hexose × 3, Ag − H]$^-$. Positive FAB-MS m/z (%): 1189 (80) $[M+Na]^+$, 1167 (84) $[M+H]^+$, 1005 (69) [M + H − hexose]$^+$, 843 (63) [M + H − hexose × 2]$^+$, 681 (100) [M + H − hexose × 3, Ag + H]$^+$. ^{1}H- and ^{13}C-NMR δ: see Tables 1 and 2.

Enzymatic Hydrolysis of 3—6 Compounds **3** (5.0 mg), **4** (6.3 mg), **5** (10 mg) and **6** (5.6 mg) were each dissolved in AcOH–AcONa buffer solution (pH 6.22, 3.0 ml), and glycosidase [glycosidases "mixed" (*T. cornutus*) lot No. ET90X01, Seikagaku Kogyo Co., Ltd., 4.4—5.7 mg] was added, respectively. The mixture was left to stand at 37 °C for one month. After removal of the solvent under reduced pressure, the residue was extracted with MeOH, and the MeOH extract was chromatographed on Sephadex LH 20 (MeOH) to give a sugar fraction (1.2 mg from **3**, 0.9 mg from **4**, 1.7 mg from **5**, 2.3 mg from **6**) and an aglycone fraction.

The sugar fractions of **3**—**6** were each subjected to HPTLC analysis [Rf, 0.33 (glucose) for **3**—**6**]. Each was converted into trimethylsilyl ether of the methyl thiazolidine 4(R)-carboxylate derivatives and was subjected GC analysis according to Hara *et al.*[7] [t_R (min): 20.08—20.77 (D-glucose) for **3**—**6**].

The aglycone fraction was subjected to HPLC (Cosmosil ODS 5C18Ar, 45% MeOH) to afford aglycone (0.4 mg from **3**, 1.3 mg form **4**, 1.2 mg from **5**, 0.4 mg from **6**). The aglycones of **3**—**6** were each identical with *cis*-miyabenol C on HPLC analysis [(column, Cosmosil ODS 5C18Ar, 50% MeOH) t_R (min): 13,00—13.18 (*cis*-miyabenol C) for **3**—**6**] and the positive sign of optical rotations [(+0.051) − (+0.156) for **3**—**6**].

UV Irradiation of 1 A solution of **1** (20 mg) in MeOH (3 ml) was irradiated with UV (254 nm, Atto Co., Ltd., SJ-1031A) for 20 min. After removal of the solvent, the residue was subjected to HPLC (YMC S-5 120A ODS, 50% MeOH) to give **1** (3.5 mg) and an isomer (9.2 mg, $[\alpha]_D^{28}$ +97.0° (c=0.88, MeOH)). The ^{1}H-NMR spectrum (acetone-d_6, 400 MHz) of the isomer was identical with that of **2**.

Acknowledgment We are grateful to Dr. Y. Shirataki of Josai University for providing NMR data and physical data of *cis*-miyabenol C. We also express our appreciation to Professor H. Okabe and Mr. H. Harazono of Fukuoka University for their measurement of FAB-MS, Professor K. Miyahara and Dr. M. Nishi of Setsunan University for their measurement of HMBC spectra, and Mr. K. Takeda of Kumamoto University for measurement of the NMR spectra.

References and Notes

1) Mabey R., "The Complete New Herbal," Shogakukan, Tokyo, 1990, p. 127.
2) Marotti M., Piccaglia R., *J. Essent. Oil Res.*, **4**, 569 (1992); Fujita S., Asami Y., Nozaki K., *Nippon Nogei Kagaku Kaishi*, **54**, 765 (1980).
3) Foeniculi Fructus exhibited antihypertensive effect on the hypertensive model rat; unpublished data.
4) Kurihara H., Kawabata J., Ichikawa S., Mishima M., Mizutani J., *Phytochemistry*, **30**, 649 (1991).
5) Shirataki Y., Komatsu M., Yokoe I., Tomimori T., Toda S., Onishi M., Abstracts of Papers, The 112th Annual Meeting of the Pharmaceutical Society of Japan, Fukuoka, April 1992, Part 2, p. 165.
6) Hathway D. E., *Biochem. J.*, **83**, 80 (1962).
7) Hara S., Okabe H., Mihashi K., *Chem. Pharm. Bull.*, **34**, 1843 (1986); *idem*, *ibid.*, **35**, 501 (1987).
8) Sakamoto I., Tanaka T., Tanaka O., Tomimori T., *Chem. Pharm. Bull.*, **30**, 4088 (1982).
9) Kasai R., Okihara M., Asakawa J., Mizutani K., Tanaka O., *Tetrahedron*, **35**, 1427 (1979).