

Structures of New Aromatics Glycosides from a Japanese Folk Medicine, the Roots of *Angelica furcijuga*

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Received July 14, 2004; accepted August 25, 2004

Three new aromatics glycosides, hyuganosides II, IIIa, and IIIb, were isolated from a Japanese folk medicine, the roots of *Angelica furcijuga* KITAGAWA. The structures of the new glycosides were determined on the basis of chemical and physicochemical evidence.

Key words *Angelica furcijuga*; hyuganoside; hyuganol; Japanese folk medicine; phenylpropanoid; neolignan

The Umbelliferae plant *Angelica furcijuga* KITAGAWA is indigenous to Japan (Japanese name, hyugatouki) and the roots have been used for the treatment of hepatopathy, allergosis, inflammation, diabetes, and hypertension as a Japanese folk medicine. During the course of our characterization studies on Japanese folk medicines,^{1–6} we have reported the structure elucidation of four acylated khellactone-type coumarins called hyuganins A–D and the vasorelaxant activities of the principal constituents from the roots of *A. furcijuga*.¹⁾ Furthermore, we communicated that the methanolic extract and principal constituents including hyuganosides II and III from this folk medicine showed nitric oxide (NO) production inhibitory and hepatoprotective activities.²⁾ In this paper, we describe a full account of the isolation and structure elucidation of hyuganosides II (**1**), IIIa (**2**), and IIIb (**3**).

The methanolic extract from the fresh roots of *A. furcijuga* cultivated in Miyazaki prefecture, Japan, was subjected to Diaion HP-20 column chromatography to give H₂O-, MeOH-, and acetone-eluted fractions as described.^{1,2)} The MeOH-eluted fraction was additionally purified by ordinary- and reversed-phase silica gel column chromatographies and finally HPLC to give three glycosides, hyuganosides II (**1**, 0.0030% from the fresh roots), IIIa (**2**, 0.0008%), and IIIb (**3**, 0.0010%) together with 4-[β -D-apiofuranosyl-(1 $\rightarrow$ 6)- β -D-glucopyranosyloxy]-3-methoxypropiphenone⁷⁾ (**4**, 0.0009%), hymexelsin¹⁾ (**5**, 0.0006%), and (*R*)-peucedanol 7-*O*- β -D-glucopyranoside¹⁾ (**6**, 0.004%).

Structure of Hyuganoside II (1) Hyuganoside II (**1**) was isolated as a white powder with positive optical rotation ($[\alpha]_D^{25} + 8.7^\circ$, MeOH). The IR spectrum of **1** showed absorption bands at 3410, 1719, 1708, 1613, 1560, 1509, 1075, and

812 cm⁻¹ ascribable to glycosidic and carbonyl functions and aromatic ring, while its UV spectrum showed absorption maxima at 230 (sh, log ϵ 3.82), 285 (3.43), and 323 (3.24) nm. The positive-ion FAB-MS of **1** showed quasimolecular ion peaks at m/z 857 (2M+H)⁺ and 451 (M+Na)⁺, while quasimolecular ion peaks were observed at m/z 855 (2M-H)⁻ and 427 (M-H)⁻ in the negative-ion FAB-MS. The molecular formula C₂₀H₂₈O₁₀ of **1** was characterized from the positive- and negative-ion FAB-MS and by high-resolution MS measurement. Acid hydrolysis of **1** with 1.0 M hydrochloric acid (HCl) liberated D-glucose, which was identified by HPLC analysis using an optical rotation detector.^{8,9)} The aglycon of **1**, hyuganol II (**1a**) with positive optical rotation ($[\alpha]_D^{25} + 47.3^\circ$, MeOH), was obtained by enzymatic hydrolysis of **1** with naringinase. The ¹H-NMR (CD₃OD) and ¹³C-NMR (Table 1) spectra¹⁰⁾ of **1** and **1a** indicated the presence of two methyls [**1**: δ 1.22, 1.24 (3H each, both s, 3'-gem-CH₃); **1a**: δ 1.21, 1.23 (3H each, both s, 3'-gem-CH₃)], three methylenes [**1**: δ [2.55 (1H, br dd, $J=ca.$ 7, 16 Hz), 2.60 (1H, br dd, $J=ca.$ 8, 16 Hz), 8-H₂], [2.89 (1H, ddd, $J=7.6, 7.9, 14.4$ Hz), 2.97 (1H, ddd, $J=7.0, 7.3, 14.4$ Hz), 7-H₂], [3.29 (1H, dd, $J=8.8, 16.2$ Hz), 3.35 (1H, dd, $J=9.5, 16.2$ Hz), 1'-H₂]; **1a**: δ 2.51 (2H, t, $J=7.2$ Hz, 8-H₂), 2.78 (2H, t, $J=7.2$ Hz, 7-H₂), [3.03 (1H, dd, $J=8.5, 15.6$ Hz), 3.07 (1H, dd, $J=9.2, 15.6$ Hz), 1'-H₂]], a methine bearing an oxygen function [**1**: δ 4.55 (1H, dd, $J=8.8, 9.5$ Hz, 2'-H); **1a**: δ 4.54 (1H, dd, $J=8.5, 9.2$ Hz, 2'-H)], and two aromatic protons [**1**: δ 6.43 (1H, d, $J=8.1$ Hz, 6-H), 6.91 (1H, d, $J=8.1$ Hz, 5-H); **1a**: δ 6.19 (1H, d, $J=7.9$ Hz, 6-H), 6.79 (1H, d, $J=7.9$ Hz, 5-H)] together with an β -D-glucopyranosyl part [**1**: δ 4.86 (1H, d, $J=7.3$ Hz, Glc-1-H)]. The planar

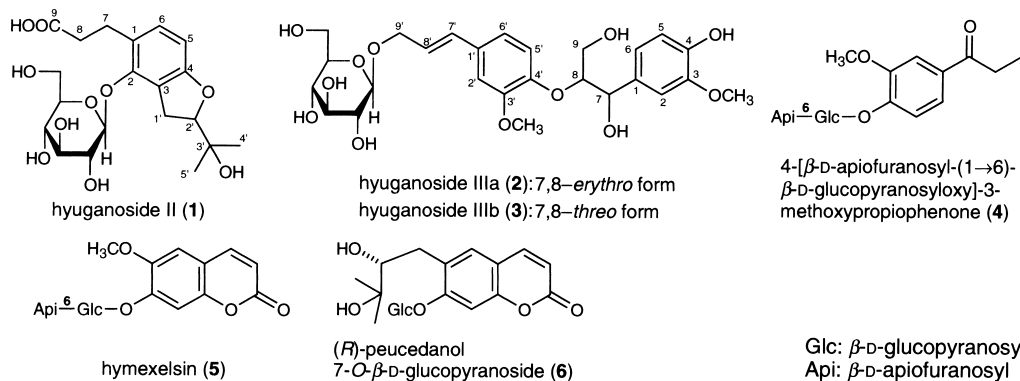


Chart 1

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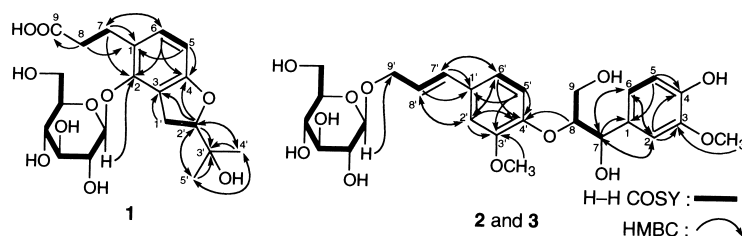


Fig. 1

structure of **1** was constructed on the basis of the ^1H – ^1H correlation spectroscopy (^1H – ^1H COSY) and heteronuclear multiple bond correlation (HMBC) experiments as shown in Fig. 1. Thus, the ^1H – ^1H COSY experiment of **1** indicated the presence of partial structures in bold lines (C-5—C-6, C-7—C-8, C-1'—C-2', and Glc-C-1—Glc-C-6). In the HMBC experiment of **1**, long-range correlations were observed between the following protons and carbons: 5-H and 1, 4-C; 6-H and 2, 4, 7-C; 7- H_2 and 1, 2, 6-C; 8- H_2 and 1, 9-C; 1'- H_2 and 3-C; 2'-H and 3, 4, 3'—5'-C; 4'-H and 2', 3', 5'-C; 5'-H and 2'—4'-C; Glc-1-H and 2-C (Fig. 1), so that the connectivities of the quaternary carbons, the substitution pattern of the aromatic ring, and the position of the glycosidic linkage in **1**, were clarified. Consequently, the structure of hyuganoside II (**1**) was determined.

Structures of Hyuganosides IIIa (**2**) and IIIb (**3**)

Hyuganosides IIIa (**2**) and IIIb (**3**) were obtained as a white powder with negative optical rotation (**2**: $[\alpha]_{\text{D}}^{25} -6.1^\circ$, **3**: $[\alpha]_{\text{D}}^{25} -16.9^\circ$, both in MeOH), respectively. The IR spectrum of **2** showed absorption bands at 3410, 1607, 1508, 1076, and 1032 cm^{-1} ascribable to hydroxyl, aromatic, and ether functions. In the UV spectrum of **2**, an absorption maximum was observed at 267 (log ϵ 4.16) nm. The IR and UV spectra of **3** resembled those of **2** [IR: 3432, 1603, 1508, 1076, and 1030 cm^{-1} , UV: 270 (3.96) nm]. The positive- and negative-ion FAB-MS of **2** and **3** showed the same quasimolecular ion peaks at m/z 561 ($\text{M} + \text{Na}$) $^+$ and 537 ($\text{M} - \text{H}$) $^-$, and high-resolution MS analysis revealed the molecular formula of **2** and **3** to be $\text{C}_{26}\text{H}_{34}\text{O}_{12}$. Acid hydrolysis of **2** and **3** with 1.0 M HCl liberated D-glucose.^{8,9} The ^1H -NMR (DMSO- d_6) and ^{13}C -NMR (Table 1) spectra¹⁰ of **2** showed signals assignable to two methylenes and two methines bearing an oxygen function [δ 3.60 (2H, br s, 9- H_2), 4.18, 4.40 (1H each, both br dd, $J = ca.$ 6, 13 Hz, 9'- H_2), 4.31 (1H, br q, $J = ca.$ 5 Hz, 8-H), 4.70 (1H, br s, 7-H)], two methoxyl protons [δ 3.72, 3.73 (3H each, both s, 3, 3'- OCH_3)], two *trans*-olefinic protons [δ 6.21 (1H, ddd, $J = 5.8, 6.1, 15.9\text{ Hz}$, 8'-H), 6.54 (1H, br d, $J = ca.$ 16 Hz, 7'-H)], and six aromatic protons [δ 6.67 (1H, d, $J = 7.9\text{ Hz}$, 5-H), 6.77 (1H, dd, $J = 1.5, 7.9\text{ Hz}$, 6-H), 6.86 (1H, dd, $J = 1.5, 8.5\text{ Hz}$, 6'-H), 6.92 (1H, d, $J = 8.5\text{ Hz}$, 5'-H), 6.99 (1H, d, $J = 1.5\text{ Hz}$, 2-H), 7.00 (1H, d, $J = 1.5\text{ Hz}$, 2'-H)] together with an β -D-glucopyranosyl part [δ 4.21 (1H, d, $J = 7.6\text{ Hz}$, Glc-1-H)]. As shown in Fig. 1, the ^1H – ^1H correlation spectroscopy (^1H – ^1H COSY) experiment on **2** indicated the presence of partial structures written in the bold lines and the HMBC experiment were observed between the following proton and carbon pairs of **2** (2-H and 3, 4, 6, 7-C; 5-H and 4, 1-C; 6-H and 2, 7-C; 7-H and 1, 2, 6-C; 8-H and 4'-C; 2'-H and 3', 4', 6', 8'-C; 5'-H and 1', 3', 4'-C; 6'-H and 2', 4', 7'-C; 7'-H and 1', 6'-C; 8'-H and 1', 2'-C; Glc-1-H and 9'-C; 3- OCH_3 and 3-C; 3'- OCH_3 and 3'-C). The stereostructure

Table 1. ^{13}C -NMR Data for Hyuganosides II (**1**), IIIa (**2**), and IIIb (**3**), and Hyuganol II (**1a**)

	1 ^{a)}	1a ^{a)}	2 ^{b)}	3 ^{b)}
C-1	126.2	121.7	133.1	132.8
C-2	153.1	152.8	111.6	110.9
C-3	118.7	114.4	146.9	146.9
C-4	161.8	161.2	145.4	145.3
C-5	105.6	101.7	114.6	114.6
C-6	130.4	130.4	119.5	118.9
C-7	26.7	26.8	71.7	70.9
C-8	36.4	37.3	83.8	84.2
C-9	178.1	179.9	60.2	60.0
C-1'	30.9	29.4	129.7	129.6
C-2'	90.8	90.7	110.2	109.8
C-3'	72.6	72.6	149.7	149.6
C-4'	25.3	25.1	147.9	148.1
C-5'	25.4	25.4	115.7	115.3
C-6'			119.3	119.3
C-7'			131.3	131.3
C-8'			124.0	124.0
C-9'			68.7	68.7
3- OCH_3			55.5	55.3
3'- OCH_3			55.6	55.5
Glc-1	103.8		102.0	102.0
Glc-2	75.6		73.5	73.4
Glc-3	78.1		76.7	76.7
Glc-4	71.5		70.2	70.0
Glc-5	78.2		76.8	76.8
Glc-6	62.7		61.1	61.0

Measured in a) CD_3OD and b) $\text{DMSO}-d_6$.

of the 7 and 8-positions in **2** was clarified by the nuclear Overhauser enhancement spectroscopy (NOESY) experiment on the acetone derivative (**2b**). Namely, enzymatic hydrolysis of **2** with β -glucosidase followed by treatment with 2,2-dimethoxypropane in the presence of *p*-toluene sulfonic acid (*p*-TsOH) yielded the 7,9-acetone derivative (**2b**). The NOESY experiment on **2b** showed NOE correlations as shown in Fig. 2, so that the stereostructure of the 7 and 8-positions in **2** was determined to be the *erythro*-form.

On the other hand, the proton and carbon signals of **3** in ^1H -NMR (DMSO- d_6) and ^{13}C -NMR (Table 1) spectra¹⁰ were almost superimposable on those of **2** [two methylenes and two methines bearing an oxygen function [δ 3.25, 3.58 (1H each, both m, 9- H_2), 4.18, 4.42 (1H each, both br dd, $J = ca.$ 6, 13 Hz, 9'- H_2), 4.28 (1H, br q, $J = ca.$ 5 Hz, 8-H), 4.71 (1H, br s, 7-H)], two methoxyl protons [δ 3.72, 3.80 (3H each, both s, 3, 3'- OCH_3)], two *trans*-olefinic protons [δ 6.24 (1H, ddd, $J = 5.6, 6.1, 15.9\text{ Hz}$, 8'-H), 6.56 (1H, br d, $J = ca.$ 16 Hz, 7'-H)], and six aromatic protons [δ 6.68 (1H, d, $J = 8.1\text{ Hz}$, 5-H), 6.76 (1H, dd, $J = 1.2, 8.1\text{ Hz}$, 6-H), 6.89 (1H, br d, $J = ca.$ 8 Hz, 6'-H), 6.98 (1H, d, $J = 8.2\text{ Hz}$, 5'-H), 6.97 (1H, br s, 2-H), 7.06 (1H, d, $J = 1.2\text{ Hz}$, 2'-H)], and an β -D-glucopyra-

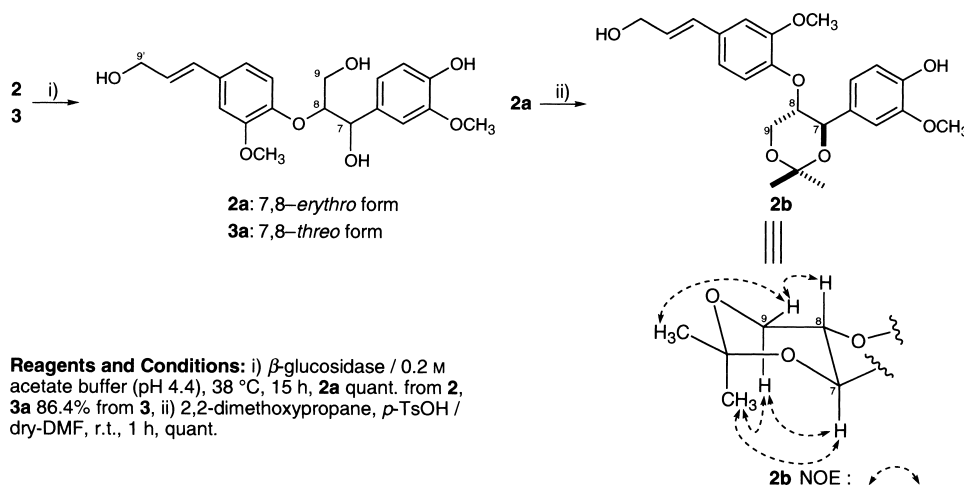


Fig. 2

nosyl part [δ 4.21 (1H, d, $J=7.6$ Hz, Glc-1-H)]. By various 2D-NMR experiments, the planar structure of **3** was elucidated to be the same structure of **2**. Treatment of **3** with β -glucosidase furnished its aglycon (**3a**),¹¹⁾ and the stereostructure of **3** was determined to be the 7,8-threo-form.

Experimental

The following instruments were used to obtain physical data: specific rotations, Horiba SEPA-300 digital polarimeter ($l=5$ cm); UV spectra, Shimadzu UV-1600 spectrometer; IR spectra, Shimadzu FTIR-8100 spectrometer; EI-MS and high-resolution MS, JEOL JMS-GCMATE mass spectrometer; FAB-MS and high-resolution MS, JEOL JMS-SX 102A mass spectrometer; ^1H -NMR spectra, JNM-LA500 (500 MHz) spectrometer; ^{13}C -NMR spectra, JNM-LA500 (125 MHz) spectrometer with tetramethylsilane as an internal standard; and HPLC detector, Shimadzu RID-6A refractive index, Shimadzu SPD-10Avp UV-VIS, and Shodex OR-2 optical rotation detectors.

The following experimental conditions were used for chromatography: ordinary-phase silica gel column chromatography, Silica gel BW-200 (Fuji Silysia Chemical, Ltd., 150–350 mesh); reversed-phase silica gel column chromatography, Chromatorex ODS DM1020T (Fuji Silysia Chemical, Ltd., 100–200 mesh); TLC, precoated TLC plates with Silica gel 60F₂₅₄ (Merck, 0.25 mm) (ordinary phase) and Silica gel RP-18 F_{254S} (Merck, 0.25 mm) (reverse phase); reverse-phase HPTLC, precoated TLC plates with Silica gel RP-18 WF_{254S} (Merck, 0.25 mm); and detection was achieved by spraying with 1% Ce(SO₄)₂–10% aqueous H₂SO₄, followed by heating.

Extraction and Isolation The extraction and isolation from the fresh roots of *A. furciguga* KITAGAWA (cultivated in Miyazaki prefecture, Japan) were described in our previous paper.^{1,2)} The methanolic extract from the fresh roots of *A. furciguga* was subjected to Diaion HP-20 column chromatography to afford H₂O-eluted fraction and three fractions (Fr. 1–3). Fraction 2 was separated by ordinary- and reversed-phase column chromatographies to give five fractions (Fr. 2-7-1–2-7-5).^{1,2)} Fraction 2-7-3 (554 mg) was purified by HPLC [detection: RI, column: YMC-pack R&D-ODS-5-A, 20×250 mm i.d. (YMC Co., Ltd., Japan), mobile phase: MeOH–H₂O (30:70, v/v) and 2-PrOH–H₂O (10:90, v/v)] to give hyuganosides **1** (1, 93 mg, 0.003% from the fresh roots), **IIIa** (**2**, 25 mg, 0.0008%), and **IIIb** (**3**, 44 mg, 0.001%) together with 4- $[\beta$ -D-apiofuranosyl-(1→6)- β -D-glucopyranosyloxy]-3-methoxypropiophenone (**4**, 30 mg, 0.0009%), hymexelsin (**5**, 18 mg, 0.0006%), and (*R*)-peucedanol 7-*O*- β -D-glucopyranoside (**6**, 120 mg, 0.004%).

Compounds **4**–**6** were identified by comparison of its physical data ($[\alpha]_D$, MS, ^1H -, and ^{13}C -NMR) with reported values.^{1,7)}

Hyuganoside II (1): A white powder, $[\alpha]_D^{25} +8.7^\circ$ ($c=1.11$, MeOH). High-resolution positive-ion FAB-MS: Calcd for C₂₀H₂₈O₁₀Na (M+Na)⁺: 451.1580. Found: 451.1576. UV (MeOH, nm, log ϵ): 230 (sh, 3.82), 285 (3.43), 323 (3.24). IR (KBr): 3410, 1719, 1708, 1613, 1560, 1509, 1075, 812 cm⁻¹. ^1H -NMR (500 MHz, CD₃OD) δ : 1.22, 1.24 (3H each, both s, 3'-gem-CH₃), [2.55 (1H, brdd, $J=ca.$ 7, 16 Hz), 2.60 (1H, brdd, $J=ca.$ 8, 16 Hz), 8-H₂], [2.89 (1H, ddd, $J=7.6, 7.9, 14.4$ Hz), 2.97 (1H, ddd, $J=7.0, 7.3, 14.4$ Hz), 7-H₂], [3.29 (1H, dd, $J=8.8, 16.2$ Hz), 3.35 (1H, dd, $J=9.5, 16.2$ Hz), 1'-H₂], [3.70 (1H, dd, $J=5.2, 11.9$ Hz), 3.85 (1H, dd, $J=2.4,$

11.9 Hz), Glc-6-H₂], 4.55 (1H, dd, $J=8.8, 9.5$ Hz, 2'-H), 4.86 (1H, d, $J=7.3$ Hz, Glc-1-H), 6.43 (1H, d, $J=8.1$ Hz, 6-H), 6.91 (1H, d, $J=8.1$ Hz, 5-H). ^{13}C -NMR (125 MHz, CD₃OD) δ_C : given in Table 1. Positive-ion FAB-MS: m/z 857 (2M+H)⁺, 451 (M+Na)⁺. Negative-ion FAB-MS m/z : 855 (2M-H)⁻, 427 (M-H)⁻, 265 (M-C₆H₁₁O₅)⁻.

Hyuganoside IIIa (2): A white powder, $[\alpha]_D^{25} -6.1^\circ$ ($c=0.22$, MeOH). High-resolution positive-ion FAB-MS: Calcd for C₂₆H₃₄O₁₂Na (M+Na)⁺: 561.1948. Found: 561.1953. UV (MeOH, nm, log ϵ): 267 (4.16). IR (KBr): 3410, 1607, 1508, 1076, 1032 cm⁻¹. ^1H -NMR (500 MHz, DMSO-*d*₆) δ : 3.46, 3.69 (1H each, both brd, $J=ca.$ 12 Hz, Glc-6-H₂), 3.60 (2H, brs, 9-H₂), 3.72, 3.73 (3H each, both s, 3, 3'-OCH₃), 4.18, 4.40 (1H each, both brdd, $J=ca.$ 6, 13 Hz, 9'-H₂), 4.21 (1H, d, $J=7.6$ Hz, Glc-1-H), 4.31 (1H, brq, $J=ca.$ 5 Hz, 8-H), 4.70 (1H, brs, 7-H), 6.21 (1H, ddd, $J=5.8, 6.1, 15.9$ Hz, 8'-H), 6.54 (1H, brd, $J=ca.$ 16 Hz, 7'-H), 6.67 (1H, d, $J=7.9$ Hz, 5-H), 6.77 (1H, dd, $J=1.5, 7.9$ Hz, 6-H), 6.86 (1H, dd, $J=1.5, 8.5$ Hz, 6'-H), 6.92 (1H, d, $J=8.5$ Hz, 5'-H), 6.99 (1H, d, $J=1.5$ Hz, 2-H), 7.00 (1H, d, $J=1.5$ Hz, 2'-H). ^{13}C -NMR (125 MHz, DMSO-*d*₆) δ_C : given in Table 1. Positive-ion FAB-MS: m/z 561 (M+Na)⁺. Negative-ion FAB-MS m/z : 537 (M-H)⁻.

Hyuganoside IIIb (3): A white powder, $[\alpha]_D^{23} -16.9^\circ$ ($c=0.51$, MeOH). High-resolution positive-ion FAB-MS: Calcd for C₂₆H₃₄O₁₂Na (M+Na)⁺: 561.1948. Found: 561.1961. UV (MeOH, nm, log ϵ): 270 (3.96). IR (KBr): 3432, 1603, 1508, 1076, 1030 cm⁻¹. ^1H -NMR (500 MHz, DMSO-*d*₆) δ : 3.25, 3.58 (1H each, both m, 9-H₂), [3.45 (1H, dd, $J=6.3, 10.6$ Hz), 3.69 (1H, brd, $J=ca.$ 11 Hz), Glc-6-H₂], 3.72, 3.80 (3H each, both s, 3, 3'-OCH₃), 4.18, 4.42 (1H each, both brdd, $J=ca.$ 6, 13 Hz, 9'-H₂), 4.21 (1H, d, $J=7.6$ Hz, Glc-1-H), 4.28 (1H, brq, $J=ca.$ 5 Hz, 8-H), 4.71 (1H, brs, 7-H), 6.24 (1H, ddd, $J=5.6, 6.1, 15.9$ Hz, 8'-H), 6.56 (1H, brd, $J=ca.$ 16 Hz, 7'-H), 6.68 (1H, d, $J=8.1$ Hz, 5-H), 6.76 (1H, dd, $J=1.2, 8.1$ Hz, 6-H), 6.89 (1H, brd, $J=ca.$ 8 Hz, 6'-H), 6.98 (1H, d, $J=8.2$ Hz, 5'-H), 6.97 (1H, brs, 2-H), 7.06 (1H, d, $J=1.2$ Hz, 2'-H). ^{13}C -NMR (125 MHz, DMSO-*d*₆) δ_C : given in Table 1. Positive-ion FAB-MS: m/z 561 (M+Na)⁺. Negative-ion FAB-MS m/z : 537 (M-H)⁻.

Acid Hydrolysis of 1–3 A solution of **1**–**3** (2.0 mg each) in 1.0 M HCl (0.1 ml) were heated under reflux for 1 h. After cooling, the reaction mixture was extracted with AcOEt (0.1 ml). The H₂O layer was analyzed by HPLC under the following conditions [detection: optical rotation, column: Kaseisorb LC NH₂-60-5, 4.6×250 mm i.d., 5 μm (Tokyo Kasei Kogyo Co., Ltd., Japan), mobile-phase: CH₃CN–H₂O (3:1, v/v), flow rate: 0.8 ml/min, injection volume: 10 μl , column temperature: room temperature]. Identification of D-glucose present in the H₂O layer was carried out by comparison of its retention time and optical rotation with that of authentic sample. t_R : 12.3 min (D-glucose, positive optical rotation).

Enzymatic Hydrolysis of 1 A solution of **1** (12.6 mg, 0.029 mmol) in 0.2 M acetate buffer (pH 3.8, 1.5 ml) was treated with naringinase (15.0 mg, Sigma), and the solution was stood at 38 °C for 24 h. After treatment of the reaction mixture with EtOH, the mixture was evaporated to dryness under reduced pressure and the residue was purified by ordinary-phase silica gel column chromatography [1.0 g, CHCl₃–MeOH–H₂O (10:3:1, v/v/v, lower layer)] to give hyuganol II (**1a**, 7.8 mg, quant.).

Hyuganol II (1a): A white powder, $[\alpha]_D^{25} +47.3^\circ$ ($c=0.41$, MeOH). High-resolution EI-MS: Calcd for C₁₄H₁₈O₅ (M⁺): 266.1154. Found: 266.1156.

UV (MeOH, nm, log ϵ): 215 (3.94), 227 (sh, 3.77), 281 (3.11). IR (KBr): 3400, 1718, 1701, 1611, 1560, 1508, 1061, 798 cm^{-1} . $^1\text{H-NMR}$ (500 MHz, CD_3OD) δ : 1.21, 1.23 (3H each, both s, 3'-gem- CH_3), 2.51 (2H, t, $J=7.2$ Hz, 8- H_2), 2.78 (2H, t, $J=7.2$ Hz, 7- H_2), [3.03 (1H, dd, $J=8.5$, 15.6 Hz), 3.07 (1H, dd, $J=9.2$, 15.6 Hz), 1'- H_2], 4.54 (1H, dd, $J=8.5$, 9.2 Hz, 2'-H), 6.19 (1H, d, $J=7.9$ Hz, 6-H), 6.79 (1H, d, $J=7.9$ Hz, 5-H). $^{13}\text{C-NMR}$ (125 MHz, CD_3OD) δ_{C} : given in Table 1. EI-MS m/z (%): 266 (M^+ , 11), 248 ($\text{M}^+-\text{H}_2\text{O}$, 30), 190 (100).

Preparation of Acetonide Derivative (2b) A solution of **2** (5.4 mg, 0.010 mmol) in 0.2 M acetate buffer (pH 4.4, 1.0 ml) was treated with β -glucosidase (5.0 mg, Oriental Yeast Co., Ltd., Japan), and the solution was stood at 38 °C for 15 h. After treatment of the reaction mixture with EtOH, the mixture was evaporated to dryness under reduced pressure, and the residue was purified by ordinary-phase silica gel column chromatography [0.5 g, CHCl_3 -MeOH- H_2O (10:3:1, v/v/v, lower layer)] to give an aglycon (**2a**, 3.7 mg, quant.).¹¹⁾ **2a**: $[\alpha]_{\text{D}}^{24} -2.3^\circ$ ($c=0.19$, MeOH). High-resolution EI-MS: Calcd for $\text{C}_{20}\text{H}_{24}\text{O}_7$ (M^+): 376.1522. Found: 376.1514. UV (MeOH, nm, log ϵ): 270 (4.60). IR (KBr): 3450, 1654, 1564, 1509, 1270, 1135, 1030 cm^{-1} . EI-MS m/z (%): 376 (M^+ , 9), 358 ($\text{M}^+-\text{H}_2\text{O}$, 43), 206 (65), 180 (53), 163 (22), 153 (22), 137 (100), 124 (53), 91 (67), 77 (48). A solution of **2a** (2.0 mg, 0.005 mmol) in dry-DMF (0.3 ml) was treated with 2,2-dimethoxypropane (0.1 ml) and *p*-toluenesulfonic acid (*ca.* 2 mg), and the mixture was stirred at room temperature for 1 h. The reaction mixture was poured into H_2O and the whole was extracted with AcOEt. The AcOEt extract was treated in the usual manner to give a residue, which was purified by ordinary-phase silica gel column chromatography [0.5 g, CHCl_3 -MeOH- H_2O (30:3:1, v/v/v, lower layer)] to give an acetonide derivative (**2b**, 2.2 mg, quant.).

2b: Colorless oil. $^1\text{H-NMR}$ (500 MHz, CDCl_3) δ : 1.51, 1.63 (3H each, both s, $-\text{CH}_{3\text{eq}}$, $-\text{CH}_{3\text{ax}}$), 3.77, 3.84 (3H each, both s, 3, 3'- OCH_3), 4.00 (1H, dd, $J=8.7$, 10.8 Hz, 9- H_{ax}), 4.15 (1H, ddd, $J=3.7$, 8.7, 8.8 Hz, 8-H), 4.16 (1H, dd, $J=3.7$, 10.8 Hz, 9- H_{eq}), 4.28 (2H, br d, $J=ca.$ 6 Hz, 9'- H_2), 4.88 (1H, d, $J=8.8$ Hz, 7-H), 6.19 (1H, td, $J=5.7$, 15.9 Hz, 8'-H), 6.44 (1H, d, $J=8.2$ Hz, 5'-H), 6.47 (1H, br d, $J=ca.$ 16 Hz, 7'-H), 6.72 (1H, dd, $J=2.1$, 8.2 Hz, 6'-H), 6.83 (1H, d, $J=2.1$ Hz, 2'-H), 6.86 (1H, d, $J=8.1$ Hz, 5-H), 6.99 (1H, d, $J=1.8$ Hz, 2-H), 7.02 (1H, dd, $J=1.8$, 8.1 Hz, 6-H).

Enzymatic Hydrolysis of 3 A solution of **3** (6.0 mg, 0.022 mmol) in 0.2 M acetate buffer (pH 4.4, 1.0 ml) was treated with β -glucosidase (5.0 mg,

Oriental Yeast Co., Ltd., Japan), and the solution was stood at 38 °C for 15 h. After treatment of the reaction mixture with EtOH, the mixture was evaporated to dryness under reduced pressure, and the residue was purified by ordinary-phase silica gel column chromatography [0.5 g, CHCl_3 -MeOH- H_2O (10:3:1, v/v/v, lower layer)] to give an aglycon (**3a**, 7.2 mg, 86.4%).¹¹⁾ **3a**: $[\alpha]_{\text{D}}^{24} -7.8^\circ$ ($c=0.20$, MeOH). High-resolution EI-MS: Calcd for $\text{C}_{20}\text{H}_{24}\text{O}_7$ (M^+): 376.1522. Found: 376.1528. UV (MeOH, nm, log ϵ): 272 (4.73). IR (KBr): 3453, 1655, 1561, 1509, 1271, 1136, 1032 cm^{-1} . EI-MS m/z (%): 376 (M^+ , 6), 358 ($\text{M}^+-\text{H}_2\text{O}$, 9.2), 206 (45), 180 (56), 163 (23), 153 (51), 137 (100), 124 (57), 91 (43), 77 (51). The aglycon (**3a**) was identified by comparison of the ^1H - and ^{13}C -NMR data with reported values.¹¹⁾

References and Notes

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