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The Constituents of *Eucommia ulmoides* OLIV. V. Isolation of Dihydroxydehydrodiconiferyl Alcohol Isomers and Phenolic Compounds

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Two new lignans, *erythro*-dihydroxydehydrodiconiferyl alcohol (**1**) and its *threo* isomer (**2**), were isolated from the bark of *Eucommia ulmoides* OLIV. (Eucommiaceae), together with six known lignans and three known phenolic compounds. Their structures were elucidated on the basis of spectroscopic analyses and chemical evidence.

Keywords—*Eucommia ulmoides*; lignan; dihydroxydehydrodiconiferyl alcohol; dihydrobenzofuran; phenolic compound; ¹³C-NMR; HPLC

The bark of *Eucommia ulmoides* OLIV. (Eucommiaceae) is the origin of the crude drug, Eucommiae Cortex which has been used as a staminal tonic and hypotensor in China and Japan. In previous papers, we have reported the isolation of lignan glucosides¹⁻⁴⁾ and iridoids.⁴⁾ We now wish to report the isolation of non-glucosidic phenolic compounds. Two new lignans, *erythro*-dihydroxydehydrodiconiferyl alcohol (**1**) and its *threo* isomer (**2**), were isolated from this crude drug, together with six known lignans, dihydrodehydrodiconiferyl alcohol (**3**),⁵⁾ (+)-epipinoresinol (**4**),⁶⁾ (+)-pinoresinol (**5**),^{1,7)} (+)-medioresinol (**6**),^{1,7)} (+)-syringaresinol (**7**),^{1,7)} and (+)-1-hydroxypinoresinol (**8**),^{2,6)} and three known phenolic compounds, *erythro*- and *threo*-guaiacylglycerol- β -coniferyl aldehyde ether (**9**),⁸⁾ caffeic acid (**10**)⁹⁾ and methyl chlorogenate (**11**),¹⁰⁾ and genipin (**12**).¹¹⁾

The extraction and separation were carried out as described in the experimental section.

Compound **3** was isolated as a colorless syrup, $[\alpha]_D^{25} + 5.5^\circ$ (MeOH). Acetylation of **3** gave a triacetate (**3a**) as a colorless syrup, which gave peaks at m/z 486 (M^+), 426 ($M^+ - CH_3COOH$) and 348 in the mass spectrum (MS). Compounds **3** and **3a** were identified as dihydrodehydrodiconiferyl alcohol⁵⁾ and its triacetate,⁵⁾ respectively, by comparison with authentic samples.

Compound **9** was obtained as a colorless syrup, $[\alpha]_D^{25} + 20.0^\circ$ (MeOH), which gave peaks at m/z 374 (M^+) and 356 ($M^+ - H_2O$) in the MS. The signals in the carbon-13 nuclear magnetic resonance (¹³C-NMR) spectrum of **9** were assigned as shown in Table I, by comparison with those of ($\pm$)-*erythro*- and *threo*-guaiacylglycerol (**13**),³⁾ hedytol C^{4,12)} and coniferyl alcohol.¹³⁾ Acetylation of **9** gave a triacetate (**9a**) as a colorless syrup. Compounds **9** and **9a** were identified as *erythro*- and *threo*-guaiacylglycerol- β -coniferyl aldehyde ether⁸⁾ and its triacetate⁸⁾ by comparison with authentic samples.

Fraction A was obtained as a colorless syrup, $[\alpha]_D^{26} 0^\circ$ (MeOH), which showed a spot at R_f 0.56 on thin layer chromatography (TLC) with $CHCl_3$ -MeOH-water (70:30:5) as a developing solvent. The MS of fraction A gave peaks at m/z 392 (M^+), 374 ($M^+ - H_2O$), 356

($M^+ - 2 \times H_2O$) and 344. The proton nuclear magnetic resonance (1H -NMR) spectrum showed the signals due to two methoxyl groups (δ 3.82 and 3.88), and five aromatic protons (δ 6.79 and 6.93). The ^{13}C -NMR chemical shifts were assigned as shown in Table I, by comparison with those of **13** and dehydrodiconiferyl alcohol^{5b)} (**14**). The shifts of the aromatic and α -, β - and γ -carbons of fraction A were in good agreement with those of **14**. The signals of the C- β' and C- γ atoms of fraction A appeared as doublets at δ 75.5 and 76.1, and at δ 64.3 and 64.6, due to the *erythro* and *threo* isomers, respectively. From these findings, fraction A was concluded to be a mixture of *erythro*- and *threo*-dihydroxydehydrodiconiferyl alcohol. Fraction A was separated into two peaks (**1** and **2**) by high-performance liquid chromatography (HPLC). Peaks **1** and **2** were each isolated and purified by preparative HPLC, yielding **1** and **2**. Compound **1** was obtained as a colorless syrup, $[\alpha]_D^{20}$ 0° (water). The infrared (IR) spectrum showed the presence of hydroxyl groups (3432 cm^{-1}) and aromatic rings (1610 and 1522 cm^{-1}). The ultraviolet (UV) spectrum of **1** showed absorption maxima at 228, 283 and 288 nm. The bathochromic shift of the absorption maxima in the presence of base was very similar to that of **3**. Compound **2** was obtained as a colorless syrup, $[\alpha]_D^{20}$ 0° (water). The IR and UV spectra of **2** were very similar to those of **1**. Acetylation of **1** and **2** gave pentaacetates, **1a** and **2a**, respectively. The MS of **1a** and **2a** were almost identical with each other, showing peaks at m/z 602 (M^+) and 542 ($M^+ - CH_3COOH$). The 1H -NMR spectrum of **1a** showed signals due to four alcoholic acetyl groups (δ 2.00, 2.05 and 2.13), a phenolic acetyl group (δ 2.30), two aromatic methoxyl groups (δ 3.82 and 3.91), and five aromatic protons (δ 6.83 and 6.99). That of **2a** showed similar signals. It was reported that *erythro*-guaiacylglycerol tetraacetate and its *threo* isomer could be distinguished on the basis of the chemical shifts and the coupling constants of the benzylic protons.^{3,14)} The benzylic proton signals of **1a** and **2a** appeared at δ 5.93 (d, $J=5.72\text{ Hz}$) and δ 5.89 (d, $J=7.48\text{ Hz}$), which showed **1a** and **2a** to be the *erythro* and *threo* isomers, respectively. From the above results, compounds **1** and **2** were established to be *erythro*-dihydroxydehydrodiconiferyl alcohol and its *threo* isomer, respectively.

Chart 1

TABLE I. ^{13}C -NMR Chemical Shifts

	Fraction A ^{a)} (1 and 2)	13 ^{a)}	14 ^{b)}	9 ^{c)}	Guaiacylglycerol moiety of hedyotol C ^{c)}
C-1	134.7	134.7	134.3	132.7, 132.9	133.2
C-1'	136.8 ^{d)}		130.4	126.7	
C-2	110.7	111.8, 112.0	110.7	111.2	111.2
C-2'	112.9		111.8	111.6	
C-3	148.9	148.8	148.6	146.9	147.0
C-3'	145.2		145.1	151.3, ^{d)} 151.5 ^{d)}	
C-4	147.6	147.1	147.5	145.5	145.4
C-4'	149.1		148.9	149.6 ^{d)}	
C-5	116.1	115.8, 115.9	115.8	114.6	114.7
C-5'	129.8 ^{d)}		132.0	123.2	
C-6	119.7	120.7, 121.0	119.5	119.0, 119.6	119.4
C-6'	116.6		116.2	114.6	
OCH ₃	56.4	56.5		55.4	55.9
OCH ₃	56.8			55.7	
α	89.1	76.6, ^{d)} 77.5	88.3	71.1, 71.6	72.2
α'	77.4		130.9	153.3	
β	55.2	76.1, ^{d)} 75.5	54.6	83.4, 83.9	86.1
β'	75.5, 76.1		128.0	126.3	
γ	64.8	64.3, 64.5	64.5	60.2	59.9
γ'	64.3, 64.6		63.3	193.8	

a) In MeOH- d_4 . b) Data from ref. 5b, in Me₂CO- d_6 -D₂O (9:1). c) In DMSO- d_6 . d) The assignments may be interchanged in each column.

Compounds **4**–**8**, **10**, **11** and **12** were identified as (+)-epipinoresinol,⁶⁾ (+)-pinore-sinol,^{1,7)} (+)-medioresinol,^{1,7)} (+)-syringaresinol,^{1,7)} (+)-1-hydroxypinoresinol,^{2,6)} caffeic acid,⁹⁾ methyl chlorogenate¹⁰⁾ and genipin¹¹⁾ by comparison with authentic samples (see Experimental).

Experimental

All melting points are uncorrected. The following instruments were used; melting point, Mettler FP-61; optical rotation value, JASCO DIP-4; HPLC, Hitachi 638 with a UV detector; UV spectra, Hitachi 200-20; IR spectra, Hitachi 270-30; MS, Hitachi RMU-7L; ^1H -NMR spectra, JEOL JNM-FX-90; ^{13}C -NMR spectra, JEOL JNM-FX-60, with tetramethylsilane ($\delta=0$) as an internal reference. The abbreviations used for NMR data are as follows: s, singlet; d, doublet; dt, doublet-triplet; t, triplet; m, multiplet.

Precoated TLC plates (Silica gel 60 F₂₅₄, Merck) were used for TLC. The spots were detected by spraying the plates with 20% H₂SO₄ and by heating. Silica gel (Wako gel C-300, Wako Pure Chemical Co.) and Diaion HP-20 (Nippon Rensui Co.) were used for column chromatography. TSK gel HW-40 (Toyo Soda Co.) was used for gel filtration.

Isolation—The air-dried bark of *Eucommia ulmoides* OLIV. (10 kg, commercial crude drug produced in China) was chopped and extracted with 50% MeOH (20 l $\times$ 2) under reflux. The extract was filtered and the filtrate was evaporated under reduced pressure to a small volume, which was suspended in water. This suspension was extracted with EtOAc (3 l $\times$ 2) and *n*-BuOH (3 l $\times$ 3), successively. The EtOAc extract was evaporated under reduced pressure to afford the residue, which showed spots at *Rf* 0.08 [(+)-cyclo-olivill], 0.10 [(–)-olivill], 0.25 (**3**), 0.33 (**9**), 0.35 (**12**), 0.39 (**8**), 0.53 (**5**), 0.54 (**4**), 0.55 (**6**) and 0.56 (**7**) on TLC with CHCl₃–MeOH (10:1) as a developing solvent. This residue was subjected to silica gel chromatography with CHCl₃–MeOH (40:1, 10:1), and the eluate was separated into three fractions (frs. 1–3). Fraction 1 was applied to a silica gel column, and eluted successively with CHCl₃–MeOH (20:1), benzene–EtOAc (5:1, 1:1) and *n*-hexane–acetone (1:1). The eluates showing TLC spots at *Rf* 0.53 (**5**), 0.54 (**4**), 0.55 (**6**) and 0.56 (**7**) were each collected and purified by repeated silica gel chromatography and then gel filtration on TSK gel HW-40 with MeOH, yielding **4** (0.5 g), **5** (3.5 g), **6** (0.6 g) and **7** (0.4 g). After repeated chromatography and gel filtration of fr. 2 and fr. 3, under the same conditions, pure **8** (1.0 g), **9** (0.3 g), **12** (2 g) and **3** (0.1 g) were isolated. The

n-BuOH extract was evaporated under reduced pressure to give the residue, which was subjected to silica gel chromatography with CHCl_3 -MeOH-water (100:10:1, 80:20:3). The eluates were monitored by TLC with CHCl_3 -MeOH-water (70:30:5) as a developing solvent. The fractions showing a TLC spot at *R_f* 0.59 (fraction A), 0.38 (**10**) and 0.11 (**11**) were each collected and purified by repeated silica gel chromatography and gel filtration on TSK gel HW-40 with MeOH, yielding fraction A (0.5 g), **10** (0.1 g) and **11** (0.1 g), respectively. Fraction A was separated into two peaks at *t_R* (min) 6.33 (**1**) and 7.14 (**2**) by HPLC. Conditions: column, Hitachi gel 3056, 4 mm $\times$ 25 cm; eluent, CH_3CN -water (15:85); flow rate, 1.0 ml/min; detector, UV detector (270 nm). Peaks **1** and **2** were each collected by repeated HPLC under the above conditions, yielding **1** (1.8 mg) and **2** (2.0 mg).

Fraction A (1 and 2)—A colorless syrup, $[\alpha]_{\text{D}}^{20} 0^\circ$ ($c=0.11$, MeOH). UV $\lambda_{\text{max}}^{\text{MeOH}}$ nm: 235, 285. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 3680 (OH), 1608, 1518 (aromatic ring). MS *m/z*: 392 (M^+), 374 ($\text{M}^+ - \text{H}_2\text{O}$), 356 ($\text{M}^+ - 2 \times \text{H}_2\text{O}$), 344. $^1\text{H-NMR}$ (in CD_3OD) δ : 3.82, 3.88 (3H, 3H, each s, $2 \times \text{OCH}_3$), 5.54 (1H, d, $J=5.71$ Hz, $\text{C}_2\text{-H}$), 6.79, 6.93 (2H, 3H, each s, arom. H).

erythro-Dihydroxydehydrodiconiferyl Alcohol (1)—A colorless syrup, $[\alpha]_{\text{D}}^{20} 0^\circ$ ($c=0.1$, water). UV $\lambda_{\text{max}}^{\text{EtOH}}$ nm: 228, 283, 288. UV $\lambda_{\text{max}}^{\text{EtOH} + \text{NaOH}}$ nm: 247, 290. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 3432 (OH), 1610, 1522 (aromatic ring). MS *m/z*: 392 (M^+ , 1), 374 ($\text{M}^+ - \text{H}_2\text{O}$, 32), 356 ($\text{M}^+ - 2 \times \text{H}_2\text{O}$, 56), 344 (100), 326 (56), 314 (90), 312 (60), 297 (44), 285 (78). $^1\text{H-NMR}$ (in CD_3OD) δ : 3.81, 3.88 (3H, 3H, each s, $2 \times \text{OCH}_3$), 5.53 (1H, d, $J=5.71$ Hz, $\text{C}_2\text{-H}$), 6.78, 6.93 (2H, 3H, each s, arom. H).

threo-Dihydroxydehydrodiconiferyl Alcohol (2)—A colorless syrup, $[\alpha]_{\text{D}}^{20} 0^\circ$ ($c=0.15$, water). UV $\lambda_{\text{max}}^{\text{EtOH}}$ nm: 229, 282, 288. UV $\lambda_{\text{max}}^{\text{EtOH} + \text{NaOH}}$ nm: 247.5, 290. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 3424 (OH), 1608, 1520 (aromatic ring). MS *m/z*: 392 (M^+ , 1), 374 ($\text{M}^+ - \text{H}_2\text{O}$, 14), 356 ($\text{M}^+ - 2 \times \text{H}_2\text{O}$, 38), 345 (60), 344 (56), 326 (44), 314 (92), 312 (100), 297 (40), 285 (58). $^1\text{H-NMR}$ (in CD_3OD) δ : 3.81, 3.87 (3H, 3H, each s, $2 \times \text{OCH}_3$), 5.53 (1H, d, $J=6.15$ Hz, $\text{C}_2\text{-H}$), 6.75–7.00 (5H, m, arom. H). Compounds **1** and **2** were acetylated with acetic anhydride-pyridine, yielding the pentaacetates **1a** and **2a**, respectively.

erythro-Dihydroxydehydrodiconiferyl Alcohol Pentaacetate (1a)—A colorless syrup. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 1764, 1224 (OCOCH_3), 1610, 1506 (aromatic ring). $^1\text{H-NMR}$ (in CDCl_3) δ : 2.00, 2.05, 2.13 (3H, 6H, 3H, each s, $4 \times$ alcoholic OCOCH_3), 2.30 (3H, s, a phenolic OCOCH_3), 3.82, 3.91 (3H, 3H, each s, $2 \times \text{OCH}_3$), 5.53 (1H, d, $J=7.03$ Hz, $\text{C}_2\text{-H}$), 5.93 (1H, d, $J=5.72$ Hz, $\text{C}_2\text{-H}$, *erythro*), 6.83, 6.99 (2H, 3H, each s, arom. H). MS *m/z*: 602 (M^+ , 64), 542 ($\text{M}^+ - \text{CH}_3\text{COOH}$, 60), 500 ($\text{M}^+ - \text{CH}_3\text{COOH} - \text{CH}_2\text{CO}$, 100), 482 ($\text{M}^+ - 2 \times \text{CH}_3\text{COOH}$, 17), 440 (20).

threo-Dihydroxydehydrodiconiferyl Alcohol Pentaacetate (2a)—A colorless syrup. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 1764, 1228 (OCOCH_3), 1610, 1506 (aromatic ring). $^1\text{H-NMR}$ (in CDCl_3) δ : 2.03, 2.07, 2.08 (12H, each s, $4 \times$ alcoholic OCOCH_3), 2.31 (3H, s, a phenolic OCOCH_3), 3.82, 3.91 (3H, 3H, each s, $2 \times \text{OCH}_3$), 5.54 (1H, d, $J=7.03$ Hz, $\text{C}_2\text{-H}$), 5.89 (1H, d, $J=7.48$ Hz, $\text{C}_2\text{-H}$, *threo*), 6.83, 6.99 (2H, 3H, each s, arom. H). MS *m/z*: 602 (M^+ , 52), 542 ($\text{M}^+ - \text{CH}_3\text{COOH}$, 46), 500 ($\text{M}^+ - \text{CH}_3\text{COOH} - \text{CH}_2\text{CO}$, 100), 440 (12).

Dihydrodehydrodiconiferyl Alcohol (3)—A colorless syrup, $[\alpha]_{\text{D}}^{25} +5.5^\circ$ ($c=0.18$, MeOH). UV $\lambda_{\text{max}}^{\text{EtOH}}$ nm: 228, 283, 288. UV $\lambda_{\text{max}}^{\text{EtOH} + \text{NaOH}}$ nm: 248, 293. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 3408 (OH), 1608, 1520, 1502 (aromatic ring). $^1\text{H-NMR}$ (in CDCl_3) δ : 1.60–2.10 (3H, m, $\text{C}_\beta\text{-H}$, $\text{C}_\beta\text{-H}$), 2.50–2.75 (2H, m, $\text{C}_2\text{-H}$), 3.40–4.00 (2H, m, $\text{C}_7\text{-H}$), 3.66 (2H, t, $J=6.6$ Hz, $\text{C}_7\text{-H}$), 3.83, 3.86 (3H, 3H, each s, $2 \times \text{OCH}_3$), 5.51 (1H, d, $J=7.47$ Hz, $\text{C}_2\text{-H}$), 6.65, 6.70–6.80 (2H, s, 3H, m, arom. H). Acetylation of **3** with acetic anhydride-pyridine gave a triacetate (**3a**).

Dihydrodehydrodiconiferyl Alcohol Triacetate (3a)—A colorless syrup. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 1768, 1740, 1248 (OCOCH_3), 1608, 1506 (aromatic ring). $^1\text{H-NMR}$ (in CDCl_3) δ : 1.80–2.00 (2H, m, $\text{C}_\beta\text{-H}$), 2.05, 2.07 (3H, 3H, each s, $2 \times$ alcoholic OCOCH_3), 2.31 (3H, s, a phenolic OCOCH_3), 2.50–2.75 (2H, m, $\text{C}_2\text{-H}$), 3.82, 3.90 (3H, 3H, each s, $2 \times \text{OCH}_3$), 4.10 (2H, t, $J=6.6$ Hz, $\text{C}_7\text{-H}$), 4.25–4.60 (2H, m, $\text{C}_7\text{-H}$), 5.52 (1H, d, $J=6.6$ Hz, $\text{C}_2\text{-H}$), 6.65, 6.90–7.10 (2H, s, 3H, m, arom. H).

erythro- and threo-Guaiacylglycerol- β -coniferyl Aldehyde Ether (9)—A colorless syrup. $[\alpha]_{\text{D}}^{25} +20.0^\circ$ ($c=0.1$, MeOH). UV $\lambda_{\text{max}}^{\text{MeOH}}$ nm: 229, 287, 332. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 3404 (OH), 1670 (CHO), 1662, 1598, 1514 (aromatic ring). MS *m/z*: 374 (M^+), 356 ($\text{M}^+ - \text{H}_2\text{O}$), 326, 204, 178. $^1\text{H-NMR}$ (in CDCl_3) δ : 3.88, 3.91 (3H, 3H, each s, $2 \times \text{OCH}_3$), 4.10–4.40 (1H, m, $\text{C}_\beta\text{-H}$), 4.98 (1H, d, $J=6.16$ Hz, $\text{C}_2\text{-H}$), 6.61, 6.62 (1H $2 \times$ dd, $J=7.48$, 15.39 Hz, $\text{C}_\beta\text{-H}$), 6.80–7.50 (7H, m, $\text{C}_2\text{-H}$, arom. H), 9.66, 9.68 (1H, $2 \times$ d, $J=7.48$ Hz, CHO). $^{13}\text{C-NMR}$: Table I. Acetylation of **9** gave a triacetate (**9a**).

erythro- and threo-Guaiacylglycerol- β -coniferyl Aldehyde Ether Triacetate (9a)—A colorless syrup. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 1746, 1222 (OCOCH_3), 1678 (CHO), 1626, 1600, 1514 (aromatic ring). $^1\text{H-NMR}$ (in CDCl_3) δ : 1.99, 2.03, 2.06, 2.09 (6H, $2 \times$ alcoholic OCOCH_3), 2.30 (3H, s, a phenolic OCOCH_3), 3.83, 3.88 (3H, 3H, each s, $2 \times \text{OCH}_3$), 3.95–4.45 (2H, m, $\text{C}_7\text{-H}$), 4.60–4.90 (1H, m, $\text{C}_\beta\text{-H}$), 6.06, 6.11 (1H, $2 \times$ d, $J=5.0$ Hz; *erythro*, $J=6.16$ Hz; *threo* $\text{C}_2\text{-H}$), 6.61 (1H, dd, $J=7.92$, 15.83 Hz, $\text{C}_\beta\text{-H}$), 6.90–7.20 (6H, m, arom. H), 7.40 (1H, d, $J=15.83$ Hz, $\text{C}_2\text{-H}$), 9.67 (1H, d, $J=7.92$ Hz, CHO).

(+)-Epipinosinol (4)—A white powder (from EtOH), mp 121°C . $[\alpha]_{\text{D}}^{25} +70.0^\circ$ ($c=0.1$, MeOH). UV $\lambda_{\text{max}}^{\text{MeOH}}$ nm: 230, 281. IR $\nu_{\text{max}}^{\text{KBr}}$ cm^{-1} : 3440 (OH), 1608, 1516 (aromatic ring). $^1\text{H-NMR}$ (in dimethylsulfoxide- d_6 ($\text{DMSO}-d_6$)) δ : 3.76 (6H, s, $2 \times \text{OCH}_3$), 4.28 (1H, d, $J=7$ Hz, $\text{C}_6\text{-H}$), 4.74 (1H, d, $J=5$ Hz, $\text{C}_2\text{-H}$), 6.77–6.88 (6H, m, arom. H). $^{13}\text{C-NMR}$ (in $\text{DMSO}-d_6$) δ : 49.5 (5), 53.8 (1), 55.8 (OCH_3), 68.4 (4), 70.4 (8), 81.4 (6), 86.9 (2), 110.1, 110.5 (2', 2''), 115.2 (5', 5''), 118.0, 118.6 (6', 6''), 129.7 (1'), 132.5 (1'), 145.4, 146.0 (4', 4''), 147.3, 147.5 (3', 3'). MS *m/z*:

358 (M^+ , 88), 327 (27), 205 (43), 196 (26), 163 (56), 151 (100), 137 (69), 131 (48), 124 (37).

(+)-**Pinoresinol (5)**—An amorphous powder, $[\alpha]_D^{25} + 51^\circ$ ($c=0.1$, $CHCl_3$). UV λ_{max}^{MeOH} nm: 232, 281. IR ν_{max}^{KBr} cm^{-1} : 3400 (OH), 1610, 1510 (aromatic ring). 1H -NMR (in $CDCl_3$) δ : 3.0–3.2 (2H, m, $C_{1,5}$ -H), 3.87 (6H, s, $2 \times OCH_3$), 3.64–4.36 (4H, m, $C_{4,8}$ -H), 4.73 (2H, d, $J=5$ Hz, $C_{2,6}$ -H), 6.80–6.92 (6H, m, arom. H). ^{13}C -NMR (in $DMSO-d_6$) δ : 53.7 (1,5), 55.8 ($OCCH_3$), 71.0 (4, 8), 85.2 (2, 6), 110.6 (2', 2''), 115.2 (5', 5''), 118.6 (6', 6''), 132.4 (1', 1''), 146.0 (4', 4''), 147.6 (3', 3'').

(+)-**Medioresinol (6)**—An amorphous powder, $[\alpha]_D^{25} + 44.7^\circ$ ($c=0.1$, MeOH). UV λ_{max}^{MeOH} nm: 231.5, 280. IR ν_{max}^{KBr} cm^{-1} : 3464 (OH), 1614, 1518 (aromatic ring). 1H -NMR (in $DMSO-d_6$) δ : 2.92–3.16 (2H, m, $C_{1,5}$ -H), 3.76 (9H, s, $3 \times OCH_3$), 3.80–4.40 (4H, m, $C_{4,8}$ -H), 4.52–4.68 (2H, m, $C_{2,6}$ -H), 6.52–6.92 (5H, m, arom. H).

(+)-**Syringaresinol (7)**—Colorless needles (from EtOH), mp $183.5^\circ C$. $[\alpha]_D^{25} + 44^\circ$ ($c=0.1$, MeOH). UV λ_{max}^{MeOH} nm: 237, 273. IR ν_{max}^{KBr} cm^{-1} : 3428 (OH), 1614, 1520 (aromatic ring). 1H -NMR (in $CDCl_3$) δ : 2.92–3.18 (2H, m, $C_{1,5}$ -H), 3.64–4.27 (4H, m, $C_{4,8}$ -H), 3.87 (12H, s, $4 \times OCH_3$), 4.61 (2H, d, $J=4$ Hz, $C_{2,6}$ -H), 6.60 (4H, s, arom. H).

(+)-**1-Hydroxypinoresinol (8)**—An amorphous powder, $[\alpha]_D^{25} + 27^\circ$ ($c=0.1$, MeOH). UV λ_{max}^{MeOH} nm: 232, 281. IR ν_{max}^{KBr} cm^{-1} : 3440 (OH), 1616, 1518 (aromatic ring). 1H -NMR (in $DMSO-d_6$) δ : 2.80–3.04 (1H, m, C_5 -H), 3.46–4.08 (3H, m, C_{4a} -H, C_8 -H), 3.66 (6H, s, $2 \times OCH_3$), 4.20–4.48 (1H, m, C_{4e} -H), 4.52 (1H, s, C_2 -H), 4.76 (2H, d, $J=5$ Hz, C_6 -H), 6.60–7.04 (6H, m, arom. H).

Caffeic Acid (10)—A white powder (from EtOH), mp $163.6^\circ C$. IR ν_{max}^{KBr} cm^{-1} : 3440 (OH), 3000–2000, 1646 (COOH), 1620, 1526 (aromatic ring). 1H -NMR (in MeOH- d_4) δ : 6.20 (1H, d, $J=16$ Hz, C_2 -H), 6.60–7.10 (3H, m, arom. H), 7.52 (1H, d, $J=16$ Hz, C_6 -H). ^{13}C -NMR (in MeOH- d_4) δ : 115.2, 115.7 (2, β), 116.5 (5), 122.7 (6), 127.9 (1), 146.6, 146.9 (3, α), 149.2 (4), 171.0 (γ).

Methyl Chlorogenate (11)—A white powder (from EtOH). mp $100^\circ C$. $[\alpha]_D^{25} - 26.4^\circ$ ($c=0.1$, MeOH). UV λ_{max}^{MeOH} nm: 220, 242, 298, 330. IR ν_{max}^{KBr} cm^{-1} : 3416 (OH), 1734, 1694 (COO), 1604, 1520 (aromatic ring). 1H -NMR (in MeOH- d_4) δ : 3.60 (3H, s, $COOCH_3$), 5.20 (1H, d, $J=6.4$ Hz, anomeric H), 6.10 (1H, d, $J=16$ Hz, C_2 -H), 6.60–7.00 (3H, m, arom. H), 7.42 (1H, d, $J=16$ Hz, C_6 -H). ^{13}C -NMR (in MeOH- d_4) δ : 38.2 (4', 6'), 53.0 (8'), 70.7 (3'), 72.0, 73.0 (1', 2'), 76.0 (5'), 115.2 (2, β), 116.5 (5), 122.9 (6), 127.7 (1), 146.6, 147.0 (3, α), 149.4 (4), 168.3 (γ), 175.3 (7'). Acetylation of **11** gave a pentaacetate. A white powder, mp $167.9^\circ C$. 1H -NMR (in $CDCl_3$) δ : 2.01, 2.10, 2.16 (9H, each s, $3 \times$ alcoholic $OCOCH_3$), 2.32 (6H, s, $2 \times$ phenolic $OCOCH_3$), 3.74 (3H, s, $COOCH_3$), 6.32 (1H, d, $J=16$ Hz, C_2 -H), 7.12–7.48 (3H, m, arom. H), 7.60 (1H, d, $J=16$ Hz, C_6 -H).

Genipin (12)—An amorphous powder, $[\alpha]_D^{24} + 95.4^\circ$ ($c=1.0$, MeOH). UV λ_{max}^{MeOH} nm: 239. IR ν_{max}^{KBr} cm^{-1} : 3420 (OH), 1692 ($C=O$). High-resolution MS m/z : 226.0849 (M^+ , $C_{11}H_{14}O_5$), 208.0747 ($M^+ - H_2O$, $C_{11}H_{12}O_4$). 1H -NMR (in MeOH- d_4) δ : 3.70 (3H, s, $COOCH_3$), 4.22 (2H, s, C_{10} -H), 5.64–5.92 (1H, m, C_7 -H), 7.48 (1H, s, C_3 -H).

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