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# TWO CAFFEIC ACID TETRAMERS HAVING ENANTIOMERIC PHENYLDIHYDRONAPHTHALENE MOIETIES FROM *MACROTOMIA EUCHROMA*

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**Key Word Index**—*Macrotomia euchroma*; Boraginaceae; roots; caffeic acid tetramer; 1,2-dihydro-1-(3′,4′-dihydroxyphenyl)-naphthalene 2,3-dicarboxylic acid enantiomers; 3-(3′,4′-dihydroxyphenyl)-(*R*)-lactic acid; circular dichroism; 2D COSY; HMBC.

**Abstract**—Two caffeic acid tetramers were isolated from the dried root of *Macrotomia euchroma*, and the structures were established on the basis of spectral data and chemical conversion. These two compounds are shown to have enantiomeric 1,2-dihydro-1-(3′,4′-dihydroxyphenyl)-naphthalene 2,3-dicarboxylic acid [caffeic acid dimer] moieties linked to two molecules of 3-(3′,4′-dihydroxyphenyl)-(*R*)-lactic acid.

## INTRODUCTION

The dried root of *Macrotomia euchroma* Pauls (Boraginaceae) has been used as an alternative to *Lithosperumum erythrorhizon* Sieb. et Zucc. (Boraginaceae), an anti-inflammatory traditional herbal medicine in China and Japan [1]. *Macrotomia euchroma* contains shikonin and its related compounds; however, the amounts and type of shikonin derivatives were different from those of *L. erythrorhizon* [2, 3]. We are now comparing the water soluble fractions of these two plants, and have isolated two caffeic acid tetramers from *Macrotomia euchroma*.

## RESULTS AND DISCUSSION

The water soluble portion of 50% aqueous acetone extract of *Macrotomia euchroma* was fractionated on Diaion HP-20 using water–methanol as the eluate. The fractions eluted with 20 and 30% methanol, were combined and chromatographed over ODS columns repeatedly to give **1** and **2**. These two compounds can be separated on HPLC using methanol–water–formic acid as the solvent system; however, they have same retention times using methyl cyanide–water–formic acid as eluent.

Compound **1**, an amorphous powder, showed $[M+H]^+$ ion peak at *m/z* 719 in the FAB mass spectrum. The high resolution FAB mass spectrum indicated the molecular formula as $C_{36}H_{30}O_{16}$. The $^1$H NMR spectrum of **1** revealed the signals due to three sets of 1,3,4-trisubstituted benzene rings, two hydroxymethine protons, four methylene protons, two methine protons and three singlets of aromatic or olefinic protons. The $^{13}$C NMR spectrum showed 26 signals in the aromatic or olefinic carbon region, four signals in the carboxyl carbon region and six signals in the aliphatic carbon region (see Table 1).

The analyses of $^1$H–$^1$H and $^1$H–$^{13}$C COSY, and HMBC spectra demonstrated that **1** has a 1,2-dihydro-6,7-dihydroxy-1-(3′,4′-dihydroxyphenyl)-naphthalene 2,3-dicarboxylic acid moiety with two molecules of 3-(3,4-dihydroxyphenyl)-lactic acid. On methylation with diazomethane followed by dimethylsulphate and $K_2CO_3$, **1** gave the octamethyl ether dimethyl ester (**1a**), which showed $[M]^+$ at *m/z* 858 in EIMS. On treatment with sodium methoxide in methanol, **1a** gave the dicarboxylic acid dimethyl ester (**1b**) and 3-(3′,4′-dimethoxyphenyl)-(*R*)-lactic acid methyl ester (**3**). The structure of **3** was determined by comparing its spectral data with those of the literature [4]. These results and the specific rotation ($[\alpha]_D-50°$) indicated that **1** is identical with rabdosiin isolated from *Rabdosia japonica* [5]. The signals in the $^{13}$C NMR spectrum were assigned by HMBC experiment (Table 1).

Compound **2**, an amorphous powder, $[\alpha]_D+140°$, was shown to have the same molecular formula as **1** by the HR-FAB mass spectrum. The $^1$H, $^{13}$C and 2D NMR spectra indicated that **2** is an isomer of **1**. On the treatment with sodium methoxide in methanol, the octamethyl ether dimethyl ester of **2** (**2a**) gave **2b** and **3**. The $^1$H NMR spectrum and other spectral data of **2b** were identical with those of **1b**, however, the $[\alpha]_D$ value ($+53°$) of **2b** was opposite to that of **1b** ($-51°$). Therefore, **2b** is the enantiomer of **1b**. The CD spectra of **1b** and **2b** also confirmed this (Fig. 1). The structures of **1** and **2** were further confirmed by the CD spectra of **1c** and **2c**, which were obtained as single products by hydrogenation of **1b** and **2b** on Pd/C in ethyl acetate, respectively. The CD spectrum of **1c**, which is identical with *β*-conidendric acid dimethyl ether dimethyl ester (1*R*,2*S*) [6], showed positive first Cotton effect at 289 nm. On the other hand, the CD spectrum of **2c** showed negative first Cotton effect at 289 nm (Fig. 2). Therefore, **2c** has 1*S*,2*R* configuration [7] and **2** has the structure shown.

In the HPLC chromatogram of the water soluble portion obtained from *Lithospermum erythrorhizon*, no peak corresponding to **1** and **2** was recognized, so these compounds are characteristic of *Macrotomia euchroma*. There have been reports of a caffeic acid trimer (litho-

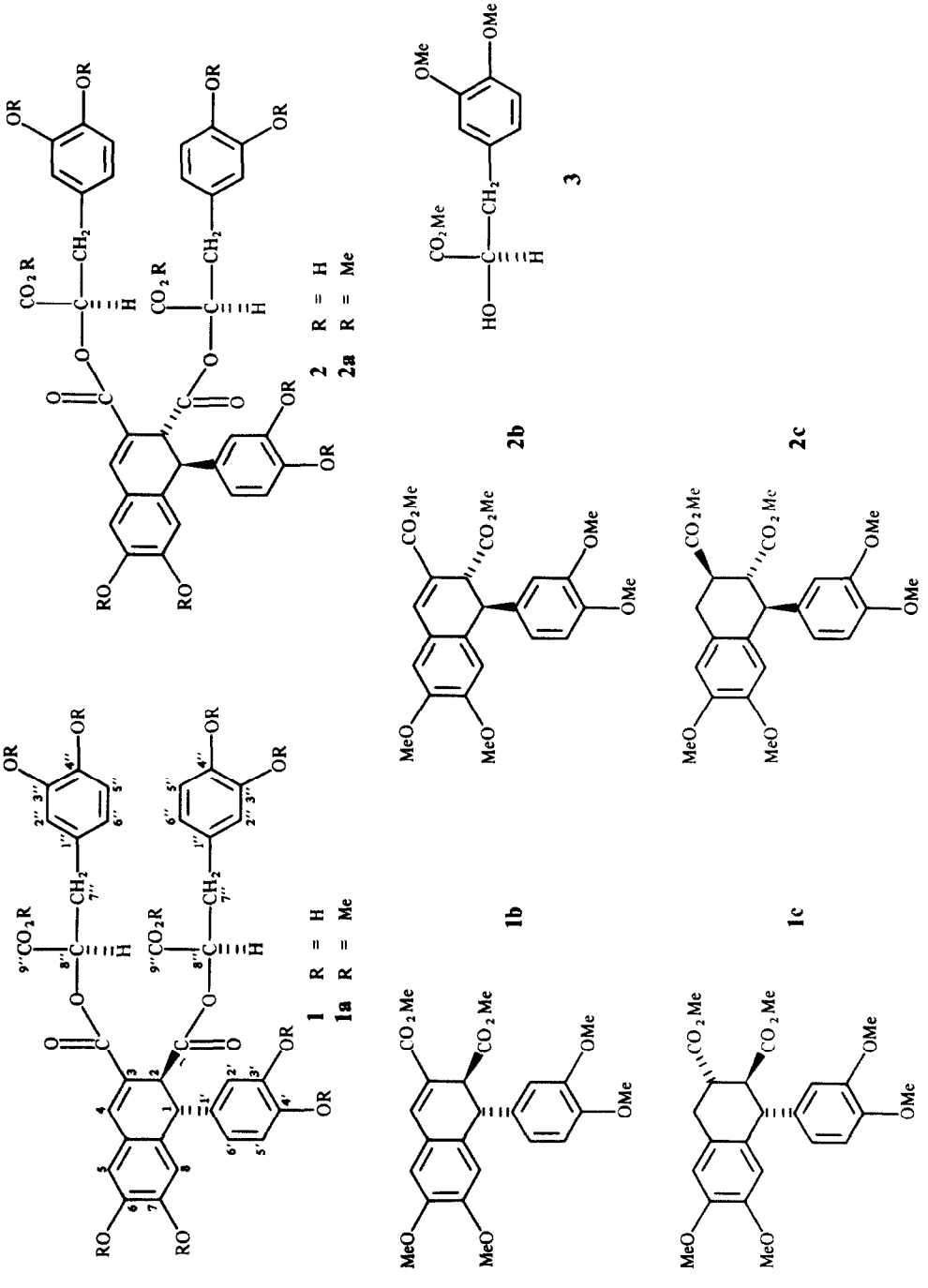
1 R = H
1a R = Me
2 R = H
2a R = Me
3
1b
1c
2b
2c

Table 1. $^1H$ and $^{13}C$ NMR data of compounds **1** and **2**

| | **1** | | **2** | |
|---|---|---|---|---|
| | $\delta_C$ | $\delta_H$ | $\delta_C$ | $\delta_H$ |
| 1 | 45.6 | 4.57 (*br s*) | 45.9 | 4.23 (*d*, $J=1.5$ Hz) |
| 2 | 47.9 | 3.95 (*d*, $J=1.5$ Hz) | 47.8 | 3.97 (*d*, $J=1.5$ Hz) |
| 3 | 130.1 | | 131.0 | |
| 4 | 139.9 | 7.64 (*s*) | 139.9 | 7.63 (*s*) |
| 4a | 136.7 | | 136.4 | |
| 5 | 116.9 | 6.94 (*s*) | 116.9 | 6.91 (*s*) |
| 6 | 144.7 | | 144.7 | |
| 7 | 148.2 | | 148.2 | |
| 8 | 117.3 | 6.57 (*s*) | 117.1 | 6.50 (*s*) |
| 8a | 124.6 | | 124.5 | |
| 1′ | 121.5 | | 121.9 | |
| 2′ | 115.3 | 6.38 (*d*, $J=2.1$ Hz) | 115.4 | 6.45 (*d*, $J=2.0$ Hz) |
| 3′ | 144.4 | | 144.4 | |
| 4′ | 144.9 | | 144.9 | |
| 5′ | 116.0 | 6.68 (*d*, $J=8.4$ Hz) | 116.2 | 6.65 (*d*, $J=7.9$ Hz) |
| 6′ | 119.7 | 6.43 (*dd*, $J=2.1$, 8.4 Hz) | 119.7 | 6.40 (*dd*, $J=2.0$, 7.9 Hz) |
| 1″ | 129.0 | | 129.2 | |
| | 129.0 | | 129.2 | |
| 2″ | 117.5 | 6.82 (*d*, $J=2.0$ Hz) | 117.3 | 6.82 (*d*, $J=2.0$ Hz) |
| | 117.5 | 6.87 (*d*, $J=2.0$ Hz) | 117.5 | 6.82 (*d*, $J=2.0$ Hz) |
| 3″ | 144.7 | | 144.7 | |
| | 144.7 | | 144.7 | |
| 4″ | 145.5 | | 145.4 | |
| | 145.6 | | 145.5 | |
| 5″ | 119.7 | 6.74 (*d*, $J=8.1$ Hz) | 119.7 | 6.73 (*d*, $J=8.1$ Hz) |
| | 119.7 | 6.76 (*d*, $J=8.0$ Hz) | 119.7 | 6.78 (*d*, $J=8.1$ Hz) |
| 6″ | 121.9 | 6.61 (*dd*, $J=2.2$, 8.1 Hz) | 121.9 | 6.63 (*dd*, $J=2.0$, 8.1 Hz) |
| | 121.9 | 6.65 (*dd*, $J=2.0$, 8.0 Hz) | 121.9 | 6.64 (*dd*, $J=2.0$, 8.1 Hz) |
| 7″ | 37.2 | 3.05 (*m*, 4H) | 37.4 | 3.03 (*m*, 2H) |
| | 37.5 | | 37.4 | 2.94 (*m*, 2H) |
| 8″ | 74.2 | 5.05 (*t*, $J=6.2$ Hz) | 74.1 | 5.12 (*t*, $J=6.3$ Hz) |
| | 74.2 | 5.09 (*dd*, $J=5.5$, 7.0 Hz) | 74.4 | 5.02 (*dd*, $J=4.8$, 8.8 Hz) |
| 9″ | 171.0 | | 171.1 | |
| | 170.7 | | 170.9 | |
| 2-COO | 171.7 | | 171.9 | |
| 3-COO | 165.5 | | 166.5 | |

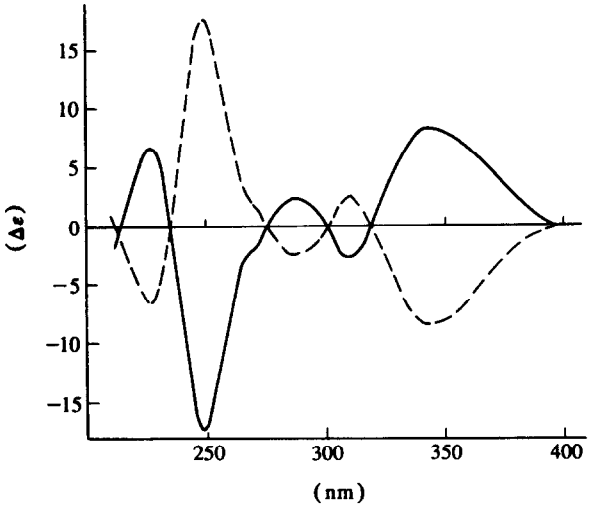


Fig. 1. CD spectra of **1b** (----) and **2b** (—).

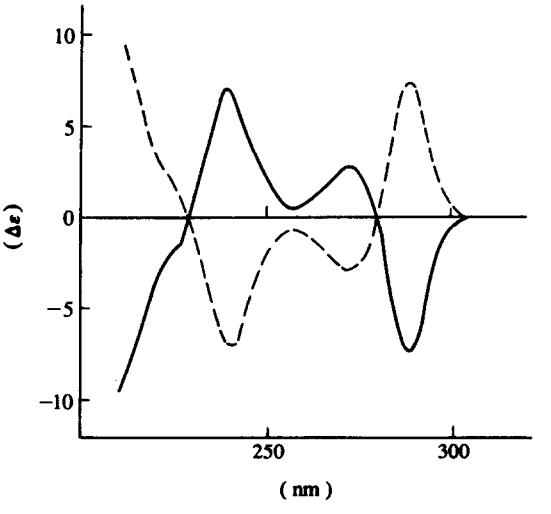


Fig. 2. CD spectra of **1c** (----) and **2c** (—).

spermic acid A) [8] and a dimer rosmarinic acid) from *Lithospermum ruderale* [9, 10]. The present work is the first report of the caffeic acid tetramers from a member of the Boraginaceae. To our knowledge, moreover, this is the first report of enantiomeric 1,2-dihydro-1-(3',4'-dihydroxyphenyl)-naphthalene 2,3-dicarboxylic acids from the same plant.

## EXPERIMENTAL

Mps: uncorr. Column chromatography was performed on Diaion HP-20 using $H_2O$–MeOH as a solvent system. Prep. HPLC was performed on a Fujigel RQ-3 column, a Senshu ODS-5251-SH column and a column of TSK-ODS 80 Tm using MeCN–$H_2O$–$HCO_2H$ and MeOH–$H_2O$–$HCO_2H$ as the solvent systems. HPLC was carried out on an apparatus consisting of a Jasco 880-PU pump, a Jasco 850-UV detector (operated at 280 or 330 nm), a Rheodyne 7125 sample injector using a TSK-ODS 80 Tm or a Wakosil 5C18-II columns (each 4.6 mm i.d. × 250 mm) and following solvent systems (flow rate 1.0 ml $min^{-1}$); MeCN–$H_2O$–$HCO_2H$ (30:70:1) and MeOH–$H_2O$–$HCO_2H$ (40:60:1) as solvent systems.

*Plant material.* The dried root of *Macrotomia euchroma* produced in Mengku providence (inner Mongolia), China, was obtained from Mikuni Co. Ltd.

*Extraction and isolation.* Powdered root of *Macrotomia euchora* (4 kg) was extracted with hexane (5 l × 2) and $CHCl_3$ (5 l × 2) to remove pigments and fatty substances. The residue was extracted with 50% aq. $Me_2CO$ (5 l × 3). The combined extract was evapd under red. pres. to 500 ml, and then the $H_2O$ layer was extracted with EtOAc (500 ml × 3). The $H_2O$ soluble portion was applied to a column of Diaion HP-20 (4 cm i.d. × 40 cm). The column was eluted with $H_2O$–MeOH increasing MeOH content stepwisely. The combined fractions of 20 and 30% MeOH eluate (9.75 g) was repeatedly fractionated by ODS prep. HPLC, and compounds **1** (517 mg) and **2** (83 mg) were obtained.

*Compound* **1** *(rabdosiin).* Amorphous powder, $[\alpha]_D$ −51° ($H_2O$; *c* 1.3), mp 175–177°. IR $\nu_{max}^{Nujol}$ $cm^{-1}$: 3200–3400, 1720, 1610, 1590, 1520. UV $\lambda_{max}^{MeOH}$ nm (log ε): 346 (4.03), 317sh, 284 (4.05), 255 (4.23). FABMS *m/z* 719 $[M+H]^+$, 539, 521, 492, 312, 295, 181, HR FABMS *m/z* 719.1608 ($[M+H]^+$, Calcd for $C_{36}H_{31}O_{16}$: 719.1612), $^1H$ and $^{13}C$ NMR see Table 1.

*Methylation of* **1**. The product of methylation (ethereal $CH_2N_2$, then $Me_2SO_4$–$K_2CO_3$) was applied to a silica gel column using $CHCl_3$–MeOH (200:1 to 50:1) as the eluent, and 192 mg **1a** was obtained. $[\alpha]_D$ −96° ($CHCl_3$; *c* 0.8). IR $\nu_{max}^{Nujol}$ $cm^{-1}$: 1740, 1705, 1605, 1590, 1565. UV $\lambda_{max}^{MeOH}$ nm (log ε): 344 (4.07), 314sh, 283 (3.99), 254sh, 235 (4.45). EIMS *m/z* 858 $[M]^+$. $^1H$ NMR ($CDCl_3$): δ7.72 (1H, *d*, *J* = 1.8 Hz), 7.71 (1H, *d*, *J* = 1.8 Hz), 7.63 (1H, *s*), 6.79 (1H, *d*, *J* = 7.3 Hz), 6.78 (1H, *d*, *J* = 7.3 Hz), 6.72 (1H, *s*), 6.67 (1H, *d*, *J* = 8.2 Hz), 6.66 (1H, *dd*, *J* = 1.8, 7.3 Hz), 6.64 (1H, *dd*, *J* = 1.8, 7.3 Hz), 6.61 (1H, *s*), 6.53 (1H, *d*, *J* = 1.8 Hz), 6.41 (1H, *dd*, *J* = 1.8, 8.2 Hz), 5.22 (1H, *t*, *J* = 6.4 Hz), 5.13 (1H, *t*, *J* = 6.4 Hz), 4.63 (1H, *d*, *J* = 1.8 Hz), 4.03 (1H, *d*, *J* = 1.8 Hz), 3.92 (3H, *s*), 3.85 (9H, *s*), 3.83 (9H, *s*), 3.81 (3H, *s*), 3.80 (3H, *s*), 3.73 (3H, *s*), 3.13 (2H, *d*, *J* = 6.4 Hz), 3.05 (2H, *d*, *J* = 6.4 Hz). $^{13}C$ NMR ($CDCl_3$): δ171.5, 170.1, 169.6, 165.7, 151.1, 148.1 (3C), 147.9 (4C), 138.8, 135.0, 130.5, 128.4 (2C), 123.7, 121.4 (2C), 121.1, 119.5, 112.7 (2C), 112.1, 111.8, 111.1 (3C), 110.6, 73.5 (2C), 55.8 (8C), 52.1 (2C), 46.7, 45.2, 37.1, 36.7.

*Methanolysis of* **1a**. The solution of **1a** (136 mg) in 0.5% NaOMe–MeOH was kept at room temp. for 3 hr. After neutralized with Dowex 50W × 8 ($H^+$ form), the reaction mixture was concd to dryness. The products [**1b** (46 mg) and **3** (24 mg)] were obtained by silica gel chromatography using $C_6H_6$–$Me_2CO$ as the eluent. Compound **1b**. $[\alpha]_D$ −51° ($CHCl_3$; *c* 0.8), EIMS *m/z* 442 $[M]^+$. UV $\lambda_{max}^{MeOH}$ nm (log ε): 336 (4.18), 311sh, 289sh, 246 (4.41). CD: $\Delta\varepsilon_{343}$ −8.5, $\Delta\varepsilon_{310}$ +2.7, $\Delta\varepsilon_{287}$ −2.5, $\Delta\varepsilon_{249}$ +17.3, $\Delta\varepsilon_{227}$ −6.8 (EtOH; *c* 2.08 × $10^{-5}$). $^1H$ NMR ($CDCl_3$): δ7.67 (1H, *s*), 6.87 (1H, *s*), 6.68 (1H, *d*, *J* = 8.0 Hz), 6.66 (1H, *s*), 6.64 (1H, *d*, *J* = 1.8 Hz), 6.43 (1H, *dd*, *J* = 1.8, 8.0 Hz), 4.65 (1H, *d*, *J* = 2.6 Hz), 4.00 (1H, *d*, *J* = 2.6 Hz), 3.91 (3H, *s*), 3.83 (3H, *s*), 3.81 (3H, *s*), 3.79 (3H, *s*), 3.75 (3H, *s*), 3.64 (3H, *s*). $^{13}C$ NMR ($CDCl_3$): δ172.9, 167.1, 151.0, 149.0, 148.3, 148.1, 137.6, 135.1, 130.4, 124.4, 122.6, 119.8, 112.3, 111.9, 111.3, 111.1, 56.0 (4C), 52.5, 51.9, 47.4, 45.3. Compound **3**. $[\alpha]_D$ −5.0° (MeOH; *c* 0.8), EIMS *m/z* 240 $[M]^+$, $^1H$ NMR ($CDCl_3$): δ6.82–6.72 (3H), 4.44 (1H, *td*, *J* = 6.3, 4.4 Hz), 3.87 (3H, *s*), 3.86 (3H, *s*), 3.78 (3H, *s*), 3.08 (1H, *ddd*, *J* = 4.4, 13.9 Hz), 2.92 (1H, *dd*, *J* = 6.3, 13.9 Hz), 2.69 (1H, *d*, *J* = 6.3 Hz). $^{13}C$ NMR ($CDCl_3$): δ174.5, 148.8, 148.0, 128.3, 121.5, 112.7, 111.2, 71.4, 55.8 (2C), 52.3, 40.1.

*Hydrogenation of* **1b**. Compound **1b** (34 mg) in EtOAc (1 ml) was hydrogenated over 10% Pd/C for 6 hr at room temp. The product (**1c**, 34 mg) was purified by prep. HPLC (silica) using hexane–EtOH as the eluate. Compound **1c**. $[\alpha]_D$ −20° ($CHCl_3$; *c* 0.6), mp 125.5–128°. IR $\nu_{max}^{Nujol}$ $cm^{-1}$: 1740, 1520. EIMS *m/z* 444 $[M]^+$. UV $\lambda_{max}^{MeOH}$ nm (log ε): 282 (3.79), 236 (4.18). CD: $\Delta\varepsilon_{289}$ +7.3, $\Delta\varepsilon_{272}$ +2.9, $\Delta\varepsilon_{240}$ +7.0 (EtOH; *c* 1.89 × $10^{-5}$). $^1H$ NMR ($CDCl_3$): δ6.79 (1H, *d*, *J* = 8.2 Hz), 6.68 (1H, *dd*, *J* = 2.0, 8.2 Hz), 6.60 (1H, *s*), 6.58 (1H, *d*, *J* = 2.0 Hz), 6.23 (1H, *s*), 4.18 (1H, *d*, *J* = 10.9 Hz), 3.88 (3H, *s*), 3.86 (3H, *s*), 3.80 (3H, *s*), 3.70 (3H, *s*), 3.59 (3H, *s*), 3.48 (3H, *s*), 3.21 (1H, *dt*, *J* = 10.9, 5.9 Hz), 3.13–3.10 (2H), 3.03 (1H, *t*, *J* = 10.9 Hz). $^{13}C$ NMR ($CDCl_3$): δ173.6, 173.1, 148.1, 147.1, 146.9, 146.7, 134.5, 128.7, 125.1, 120.6, 111.3, 110.9, 110.0, 109.9, 54.9 (4C), 51.0, 50.7 (2C), 47.8, 30.8.

*Compound* **2**. An amorphous powder $[\alpha]_D$ +140° ($H_2O$; *c* 0.8), mp 174°. IR $\nu_{max}^{Nujol}$ $cm^{-1}$: 3200–3400, 1720, 1610, 1590, 1520. UV $\lambda_{max}^{MeOH}$ nm (log ε): 346 (4.04), 317sh, 284 (4.08), 255 (4.29). FABMS *m/z* 719 $[M+H]^+$, 539, 521, HR FABMS *m/z* 719.1611 $[M+H]^+$, Calcd. for $C_{36}H_{31}O_{16}$: 719.1612). $^1H$ and $^{13}C$ NMR see Table 1.

*Methylation of* **2**. Compound **2** (8.2 mg) was treated with ethereal $CH_2N_2$ and then with $Me_2SO_4$–$K_2CO_3$ to give **2a** (4.0 mg). $[\alpha]_D$ +127° ($CHCl_3$; *c* 0.13). IR $\nu_{max}^{Nujol}$ $cm^{-1}$: 1740, 1705, 1605, 1590, 1565. UV $\lambda_{max}^{MeOH}$ nm (log ε): 344 (4.11), 314sh, 283 (4.05), 254sh, 235 (4.49). EIMS *m/z* 858 $[M]^+$. $^1H$ NMR ($CDCl_3$): δ7.71 (1H, *s*), 6.83 (1H, *s*), 6.77–6.65 (7H), 6.58 (1H, *d*, *J* = 2.2 Hz), 6.51 (1H, *s*), 6.40 (1H, *dd*, *J* = 2.2, 9.8 Hz), 5.23 (1H, *t*, *J* = 6.4 Hz), 5.08 (1H, *dd*, *J* = 5.1, 7.7 Hz), 4.44 (1H, *d*, *J* = 1.5 Hz), 4.05 (1H, *d*, *J* = 2.2 Hz), 3.91 (3H, *s*), 3.84–3.83 (12H), 3.81 (6H, *s*), 3.74 (3H, *s*), 3.62 (3H, *s*), 3.51 (3H, *s*), 3.10 (2H, *m*), 2.98 (2H, *m*).

*Methanolysis of* **2a**. Compound **2a** (4.0 mg) was treated with 5% NaOMe–MeOH to give **2b** (0.9 mg) and **3** (0.9 mg). Compound **2b**. $[\alpha]_D$ −19° ($CHCl_3$; *c* 0.04), EIMS *m/z* 442 $[M]^+$. UV $\lambda_{max}^{MeOH}$ nm (log ε) 337 (4.15), 310sh, 290sh, 247 (4.40). CD: $\Delta\varepsilon_{343}$ +8.6, $\Delta\varepsilon_{310}$ −2.8, $\Delta\varepsilon_{287}$ +2.6, $\Delta\varepsilon_{249}$ −17.2, $\Delta\varepsilon_{227}$ +6.8 (EtOH; *c* 2.6 × $10^{-5}$). $^1H$ NMR ($CDCl_3$): δ7.67 (1H, *s*), 6.87 (1H, *s*), 6.68 (1H, *d*, *J* = 8.0 Hz), 6.66 (1H, *s*), 6.64 (1H, *d*, *J* = 1.8 Hz), 6.43 (1H, *dd*, *J* = 1.8, 8.0 Hz), 4.65 (1H, *d*, *J* = 2.6 Hz), 4.00 (1H, *d*, *J* = 2.6 Hz), 3.91 (3H, *s*), 3.83 (3H, *s*), 3.81 (3H, *s*), 3.79 (3H, *s*), 3.75 (3H, *s*), 3.64 (3H, *s*). Compound **3**. $[\alpha]_D$ −6.0° (MeOH; *c* 0.09), EIMS *m/z* 240 $[M]^+$. $^1H$ NMR ($CDCl_3$) δ6.82–6.72 (3H), 4.44 (1H, *td*, *J* = 6.3, 4.4 Hz), 3.87 (3H, *s*), 3.86 (3H, *s*), 3.78 (3H, *s*), 3.68 (1H, *dd*, *J* = 6.3, 13.9 Hz), 2.92 (1H, *dd*, *J* = 6.3, 13.9 Hz), 2.69 (1H, *d*, *J* = 6.3 Hz).

*Hydrogenation of* **2b**. Compound **2b** (0.9 mg) was hydrogenated to give **2c** (0.8 mg). Compound **2c**. $[\alpha]_D$ +10° ($CHCl_3$; *c* 0.04). EIMS *m/z* 444 $[M]^+$, UV $\lambda_{max}^{MeOH}$ nm (ε): 282 (3.79), 236 (4.18). CD: $\Delta\varepsilon_{289}$ +7.3, $\Delta\varepsilon_{272}$ +2.9, $\Delta\varepsilon_{240}$ +7.0 (EtOH; *c* 1.89 × $10^{-5}$). $^1H$ NMR ($CDCl_3$) δ6.79 (1H, *d*, *J* = 8.2 Hz), 6.68 (1H, *dd*, *J* = 2.0, 8.2 Hz), 6.60 (1H, *s*), 6.58 (1H, *d*, *J* = 2.0 Hz), 6.23 (1H, *s*), 4.18 (1H, *d*, *J* = 10.9 Hz), 3.88 (3H, *s*), 3.86 (3H, *s*), 3.80 (3H, *s*), 3.70 (3H, *s*),

3.59 (3H, *s*), 3.48 (3H, *s*), 3.22 (1H, *dt*, $J = 10.9$, 5.9 Hz), 3.13–3.09 (2H), 3.03 (1H, *t*, $J = 10.9$ Hz).

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