Synthesis of *threo*-(±)-9,9-dibenzoylsecoisolariciresinol and its isomer

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The total synthesis of *threo*-(±)-9,9-dibenzoylsecoisolariciresinol and its isomer based on two Stobbe reactions as C–C bond-forming steps used a protected vanillin and diethyl; succinate to give the skeleton of lignan, followed by reduction to afford *threo*- and *meso*-(±)-secoisolariciresinol Both were treated with benzoyl chloride to obtain the natural product *threo*-(±)-9,9-dibenzoylsecoisolariciresinol and Its isomer *meso*-(±)-9,9-dibenzoylsecoisolariciresinol for the first time.

Keywords: lignan, 9,9-dibenzoylsecoisolariciresinol, dibenzylbutane

Lignans are a diverse family of biologically active plant metabolites that contain two phenylpropanoid units as the key structural components.[1] Lignans are found in all parts of plants, including the roots, stems, leaves, fruit, and seeds and they exhibit a wide range of biological activities.[2–5] Some natural products have been used medicinally for thousands of years. In many cases, the active principle of lignan-based traditional medicines is not known, and a detailed study of the active principles may provide useful leads in the development of new pharmaceutical agents.[6–11] In 2009, the new lignan 9,9-dibenzoylsecoisolariciresinol (**1**) was isolated from the aerial parts of *Maytenus apurimacensis* which belongs to the Celastraceae family and is used in South American folk medicine. 9,9-Dibenzoylsecoisolariciresinol has the classic lignan skeleton and it seems likely that it is formed by metabolism of a naturally occurring lignan in an as yet unproven fashion.[12]

The core of 9,9-dibenzoylsecoisolariciresinol is the dibenzylbutane. A great deal of effort has been put into synthetic work on lignans of this type.[13–15] Among them, the alkylation of β-substituted γ-butyrolactone with an appropriate benzylic halide is the most widely used.[16] Gezginci reported the synthesis of *meso*-nordihydroguaiaretic acid from 3,4-dimethoxyphenyl acetone using a low-valency Ti-induced carbonyl–coupling reaction of the ketone as the key step.[17] Rao has described the synthesis of analogues of (–)-saururenin from *Saururus cernuus*, along with (–)-austrobailignan-5 by regioselective cleavage of the methylenedioxyphenyl groups.[18]

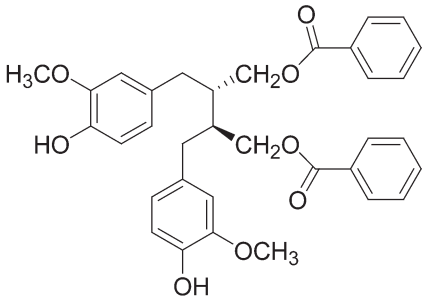
Here, we first report an efficient route for the synthesis of natural product *threo*-(±)-9,9-dibenzoylsecoisolariciresinol (**1**) and its isomer *meso*-(±)-9,9-dibenzoylsecoisolariciresinol (**2**). The syntheses were based on a strategy involving Stobbe condensation to give the skeleton of the lignan, and the resolution of *threo*- and *meso*-isomers, followed by treatment with benzoyl chloride to obtain the target compound.

Results and discussion

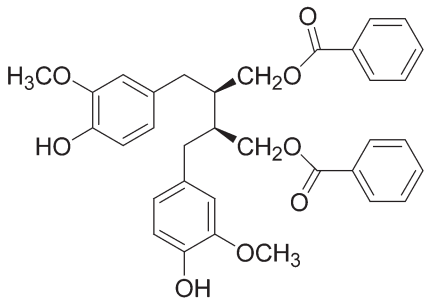
Our approach to the synthesis of the natural product *threo*-(±)-9,9-dibenzoylsecoisolariciresinol (**1**) and its *meso*-isomer (**2**) is outlined in Scheme 2. It was anticipated that condensation of **3** with diethyl succinate would furnish **4**, which after the second condensation of with **3** to form (*E*)-**5** and subsequent hydrogenation with a 10% palladium on charcoal catalyst, gave a readily separable mixture of *meso*-secoisolariciresinol **(6a)** and *threo*-(±)-secoisolariciresinol (**6b**). Acylation of *meso*-(±)-**6a** or *threo*-(±)-**6b** with benzoyl chloride produced *meso*-(±)-9,9-dibenzoylsecoisolariciresinol (**2**) or *threo*-(±)-9,9-dibenzoylsecoisolariciresinol (**1**).

Our investigations began with cheap vanillin as a raw material. The 4-hydroxyl group of vanillina was protected with benzyl chloride to afford the product **3**. Compound **3** underwent a Stobbe condensation with diethyl succinate in the presence of sodium ethoxide in ethanol to produce compound **4**. The *trans*-(*E*)-configuration of the olefinic double bond was evident from the appearance of the deshielded vinylic proton at δ7.87 in its ^{1}H NMR spectrum.[19] Compound **4** was methylated with diazomethane in methanol to yield the diester **7**. The second Stobbe condensation of **7** with **3** in methanol with the presence of sodium methoxide yielded compound **8**. The deshielded vinylic proton at δ7.96 in the ^{1}H NMR spectrum of **8** again indicated the *trans*-(*E*)-configuration for both the olefinic double bonds.[20] Compound **8** was again methylated to produce a diester **9**. Treatment of **9** with $LiAlH_4/AlCl_3$ afforded the unsaturated diol **5**, followed by hydrogenation with a 10% palladium on charcoal catalyst to produce a readily separable mixture (approximate **1**) of diols *meso*-secoisolariciresinol **(6a)** and *threo*-(±)-secoisolariciresinol (**6b**). *threo*-(±)-**6b** had consistently larger R_f values than those of the corresponding *meso*-**6a**, and each pair was easily separated by flash column chromatography over silica gel. The configuration of *threo*-(±)-**6b** was agreement with those reported in the literature.[21]

The 4-hydroxyl group of *meso*-(±)-**6a** or *threo*-(±)-**6b** was protected with benzyl chloride to afford *meso*-(±)-**10a** or *threo*-(±)-**10b**. After acylation of *meso*-(±)-**10a** or *threo*-(±)-**10b** with benzoyl chloride, and then hydrogenation, natural product *meso*-(±)-9,9-Dibenzoylsecoisolariciresinol (**2**) or *threo*-(±)-9,9-Dibenzoylsecoisolariciresinol (**1**) was obtained



threo-(±)-9,9-Dibenzoylsecoisolariciresinol (**1**)



meso-(±)-9,9-Dibenzoylsecoisolariciresinol (**2**)

Scheme 1

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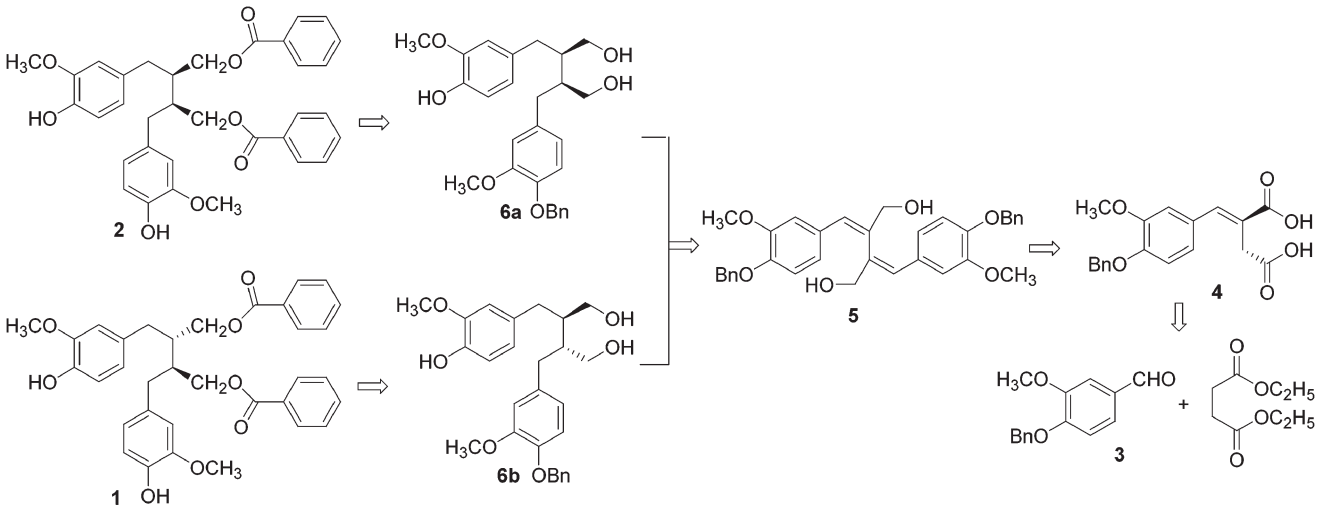
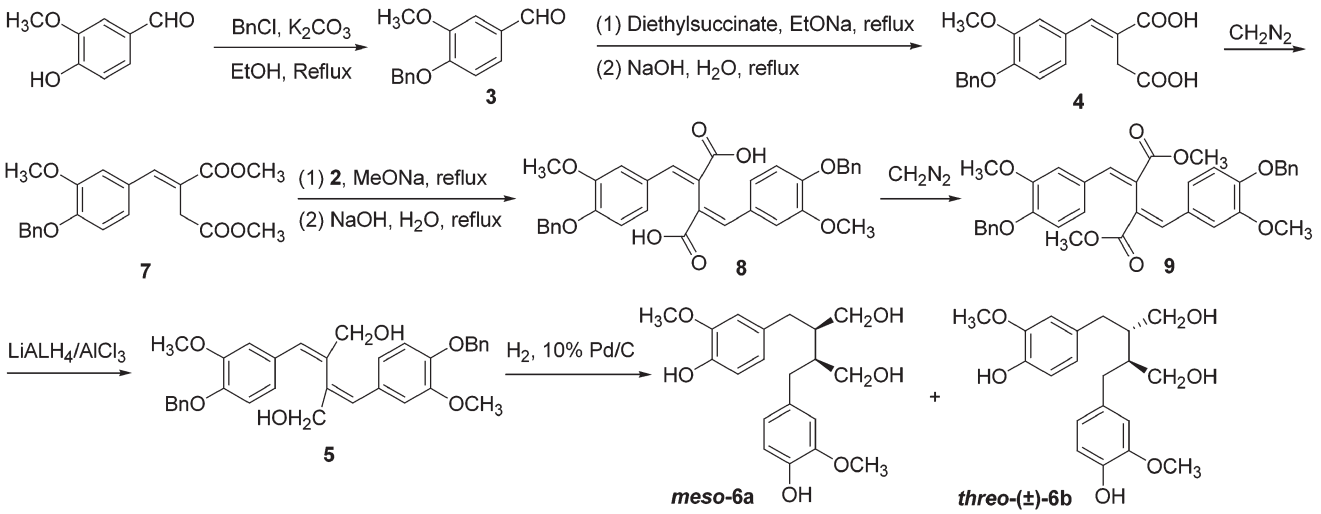


Scheme 2



Scheme 3

(Scheme 4). The spectroscopic data of natural product **1** was in agreement with those found in the literature[12].

In summary, we have developed an efficient and practical synthesis of a dibenzylbutyl benzoate lignan based on a Stobbe reaction to construct the skeleton of lignan. The natural product *threo*-(±)-9,9-Dibenzoylsecoisolariciresinol(**1**) and its isomer *meso*-(±)-9,9-Dibenzoylsecoisolariciresinol (**2**) were obtained by this route for the first time.

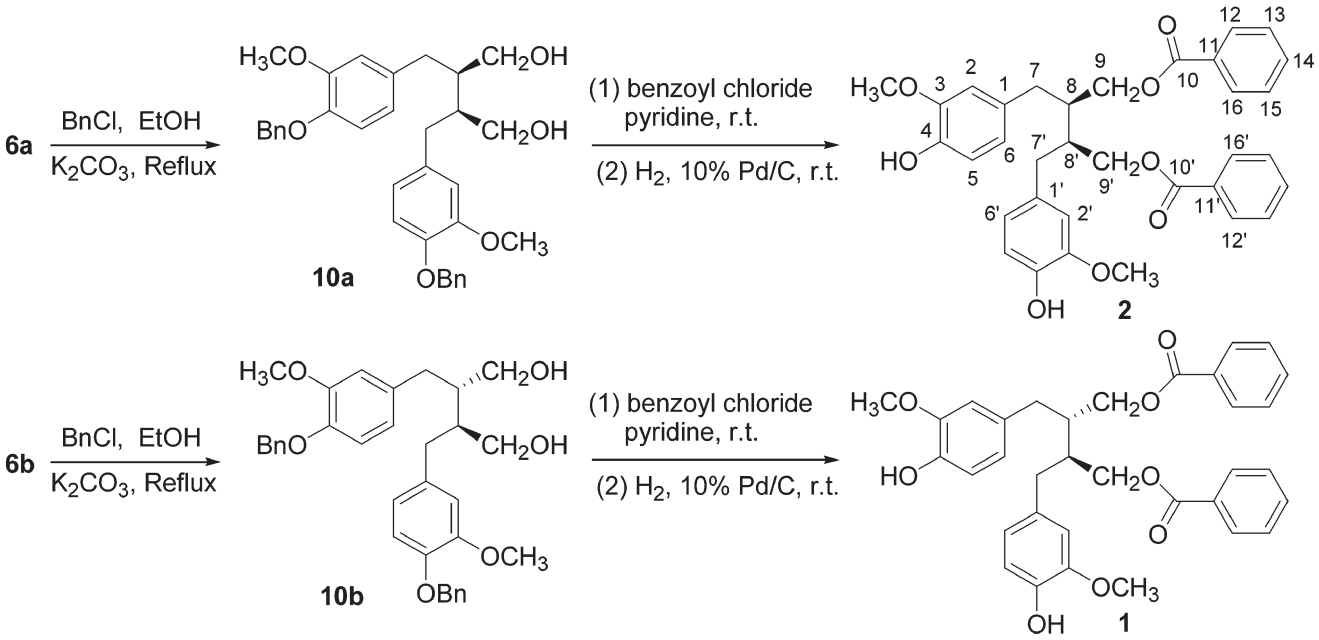
Experimental

Melting points were taken on Gallenkamp melting point apparatus which are uncorrected. IR spectra were recorded on a Nicolet NEXUS 670 FT–IR. The ^{1}HNMR and ^{13}CNMR spectra were recorded on a Bruker AM–500 MHz spectrometers. Mass spectra were recorded on a *ZAB–HS* spectrometer. HRMS were obtained on a Bruker Daltonics APEXII47e spectrometer. Flash column chromatography was performed on silica gel (200–300 mesh) and TLC inspections on silica gel GF_{254} plates.

4-Benzyloxy-3-methoxybenzaldehyde (**3**): A mixture of Vanillin (60.8 g, 400 mmol), benzyl bromide and anhydrous potassium carbonate (83.2 g, 400 mmol) in acetone were stirred overnight at room temperature. The reaction mixture was filtered, and the solvent was removed *in vacuo*. The residue was crystallised from EtOH to give the compound **3** as yellow crystals (92.0 g, 95%). m.p. 65–67 °C. ^{1}H NMR (DMSO–d_6, 500 MHz) δ: 3.84 (s, 3H, OCH_3), 5.16 (s, 2H, $ArCH_2O$), 6.87–7.54 (m, 8H, ArH), 9.85 (s, 1H, ArCHO).

*(*E*)-2-(4′-benzyloxy-3′-methoxybenzylidene)succinic acid* (**4**): The compound **3** (72.6 g, 300 mmol) and diethylsuccinate (52.2 g, 300 mmol) were added to a solution of NaOEt (40.8 g, 600 mmol) in EtOH (500 mL). The mixture was heated under reflux for 4 h, and the ethanol was removed. The residue was cooled and acidified with HCl (5 N). This was then extracted with EtOAc (3 × 70 mL). The EtOAc layer was then re-extracted with saturated solution of $NaHCO_3$ (300 mL). Acidification of the aq. $NaHCO_3$ extract with HCl (5 N) provided an oily layer, which was again extracted with EtOAc (3 × 70 mL). The combined organic layer was dried over $MgSO_4$ and concentrated *in vacuo*. This residue was added to a solution of 20% aqueous NaOH (500 mL) and refluxed for 3 h. After cooling to room temperature, the mixture was washed with EtOAc (3 × 70 mL). The solution was decolourised with active carbon and the mixture was acidified with HCl (5 N) to yield white solids. The crude product was crystallised from EtOH to give the diacid **4** as a yellow crystal (120.0 g, 83%). m.p. 131–133 °C. ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 3.57 (s, 2H, CH_2), 3.86 (s, 3H, OCH_3), 5.15 (s, 2H, $ArCH_2O$), 6.68–7.43 (m, 8H, ArH), 7.87 (s, 1H, ArCH=C). EI–MS (*m/z*, %): 342 (M^+, 26), 324 (12), 297 (27), 175 (16), 91 (100).

(E)-*Dimethyl 2-(4′-benzyloxy-3′-methoxybenzylidene)succinate* (**7**): The diacid **4** (68.4 g, 200 mmol) was added to an ice-cold solution of excess CH_2N_2 in Et_2O. The mixture was stirred for 12 h, and concentrated *in vacuo*. Flash column chromatography of the residue gave the diester **7** as a yellow oil (71.8 g, 97%). ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 3.69 (s, 3H, $COOCH_3$), 3.78 (s, 3H, $COOCH_3$), 3.83 (s, 3H, OCH_3), 5.15 (s, 2H, $ArCH_2O$), 6.68–7.45 (m, 8H, ArH), 7.88



Scheme 4

(s, 1H, ArCH=C). EI–MS (*m/z*, %): 370 (M^+, 36), 338 (18), 307 (14), 175 (23), 91 (100).

Trans-*(E)-2,3-dis(4′-benzyloxy-3′-methoxybenzylidene)succinic acid* (**8**): Diester **7** (37.1 g, 100 mmol) on Stobbe condensation (following the above mentioned procedure) with compound **3** (24.2 g, 100 mmol) gave a light-yellow solid which was purified by recrystallisation from MeOH to yield product **8** (42.5 g, 75%). m.p. 151–153 °C. IR (KBr, cm^{-1}) *v*: 3350, 2900, 1740, 1496, 1241, 1042. ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 3.78 (s, 6H, 2 × OCH_3), 5.16 (s, 4H, 2 × $ArCH_2O$), 6.78–7.44 (m, 16H, ArH), 7.96 (s, 2H, 2 × ArCH=C). ^{13}C NMR ($CDCl_3$, 125 MHz) δ: 55.7 (2 × OCH_3), 70.7 (2 × $ArCH_2$), 112.7, 113.1, 123.3, 124.9, 127.2, 127.3, 128.0, 128.6 (2 × ArCH=*C*), 136.4 (2 × Ar*C*H=C), 144.2, 149.2, 150.1, 172.7 (2 × C=O). EI–MS (*m/z*, %): 566 (M^+, 2.1), 549 (4.3), 325 (11), 175 (35), 151 (5.2), 91 (100). HRMS Calcd for $C_{34}H_{31}O_8$ ($M+H^+$): 567.2014. Found: 567.2012.

Trans-*(E)-dimethyl 2,3-bis(4′-benzyloxy-3′-methoxybenzylidene)succinate* (**9**): Following the procedure described for the preparation of **7**, and starting with the diacid **8** (28.3 g, 50 mmol), gave a light-yellow solid which was purified by recrystallisation from 10% hexane in EtOAc to yield the diester **9** (28.0 g, 94%). m.p. 143–146 °C. IR (KBr, cm^{-1}) *v*: 3010, 2951, 2842, 1710, 1600, 1513, 1427, 916. ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 3.67 (s, 6H, 2 × OCH_3), 3.75 (s, 6H, 2 × $COOCH_3$), 5.15 (s, 4H, 2 × $ArCH_2O$), 6.79–7.41 (m, 16H, ArH), 7.87 (s, 2H, 2 × ArCH=C). ^{13}C NMR ($CDCl_3$, 125 MHz) δ: 52.5 (2 × OCH_3), 55.8 (2 × OCH_3), 70.8 (2 × $ArCH_2$), 112.4, 113.2, 124.5, 124.6, 127.3, 127.9, 128.1, 128.7 (2 × ArCH=*C*), 136.6 (2 × Ar*C*H=C), 142.4, 149.3, 149.7, 167.8 (2 × C=O). HRMS Calcd for $C_{36}H_{35}O_8$ ($M+H^+$): 595.2327. Found: 595.2325.

Trans-*(E)-dimethyl 2,3-bis(4′-benzyloxy-3′-methoxybenzylidene)-1,4-butanediol* (**5**): Diester **9** (17.8 g, 30 mmol) in dry THF was added dropwise during 1 h to a mixture of $LiAlH_4/AlCl_3$(3:1, 6.0 g), in dry THF and stirred under nitrogen at room temperature. Then the reaction was quenched by ice water and filtered. The filtrate was dried by $MgSO_4$ and concentrated *in vacuo*. Flash column chromatography of the residue gave *trans*-(*E*)-diol **5** (13.7 g, 85%). IR (KBr, cm^{-1}) *v*: 3320, 2931, 1512, 1247, 1032. ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 3.74 (s, 6H, 2 × OCH_3), 4.12–4.13 (d, 4H, 2 × CH_2OH), 5.12 (s, 4H, 2 × $ArCH_2O$), 6.63 (s, 2H, 2 × ArCH), 6.79–7.44 (m, 16H, ArH) . ^{13}C NMR ($CDCl_3$, 125 MHz) δ: 55.7 (2 × OCH_3), 66.6 (2 × CH_2OH), 70.8 (2 × $ArCH_2O$), 111.5 (C-2, C-2′), 113.6 (C-5, C-5′), 121.1 (C-6, C-6′), 127.2, 127.4, 127.8, 128.5, 128.8 (2 × ArCH=*C*), 129.8, 136.9 (2 × Ar*C*H=C), 137.5 (C-1, C-1′), 147.7 (C-4, C-4′), 149.3 (C-3, C-3′). HRMS Calcd for $C_{34}H_{38}NO_6$($M+NH_4^+$): 556.2694. Found: 556.2699.

Meso-*secoisolariciresinol,* **6a** *and* threo-*(±)-secoisolariciresi*nol (**6b**): Diol **5** (13.5 g, 25 mmol) in MeOH (250 mL) was stirred under hydrogen atmosphere for 36 h in the presence of 10% Pd/C (5.6 g). The reaction mixture was filtered through a pad of Celite. Then, the solvent was removed *in vacuo* and flash column chromatography of the residue gave the colourless oil *meso*-secoisolariciresinol **6a** (3.69 g, 40.7%) and a white crystal *threo*-**(±)-**secoisolariciresinol **6b** (4.1 g, 45.2%).

Meso-*secoisolariciresinol* **6a**: IR (KBr/cm^{-1}): 3310, 2910, 1498, 1251, 1042, 928. ^{1}H NMR (acetone–d_6, 500 MHz) δ: 1.90–2.01 (m, 2H, 2 × $ArCH_2CH$), 2.57–2.62 (m, 4H, 2 × $ArCH_2CH$), 3.41 (dd, 2H, *J* = 11.0, 3.5 Hz, CH_2OH), 3.52 (dd, 2H, *J* = 11.0, 6.5 Hz, CH_2OH), 3.75 (s, 6H, 2 × OCH_3), 6.62–6.74 (m, 6H, ArH). ^{13}C NMR (acetone–d_6, 125 MHz) δ: 33.2 (C-7, C-7′), 44.6 (C-8, C-8′), 55.3 (2 × OCH_3), 62.2 (C-9, C-9′), 112.5 (C-2, C-2′), 114.5 (C-5, C-5′), 121.6 (C-6, C-6′), 132.7 (C-1, C-1′), 144.6 (C-4, C-4′), 147.3 (C-3, C-3′). HRMS Calcd for $C_{20}H_{30}NO_6$($M+NH_4^+$): 380.2068. Found: 380.2073.

Threo-*(±)-secoisolariciresinol* **6b**: M.p. 127–128°C. IR (KBr/cm^{-1}): 3354, 2910, 1512, 1240, 1032, 928. ^{1}H NMR (acetone–d_6, 125 MHz) δ: 1.86–1.91 (m, 2H, $ArCH_2CH$), 2.58–2.70 (m, 4H, 2 × $ArCH_2CH$), 3.49 (dd, 2H, *J* = 11.0, 4.5 Hz, CH_2OH), 3.62 (dd, 2H, *J* = 11.0, 3.5 Hz, CH_2OH), 3.71 (s, 6H, 2 × OCH_3), 6.55–6.68 (m, 6H, ArH). ^{13}C NMR (acetone-d_6, 125 MHz) δ: 36.2 (C-7, C-7′), 44.8 (C-8, C-8′), 56.3 (2 × OCH_3), 61.4 (C-9, C-9′), 113.5 (C-2, C-2′), 115.6 (C-5, C-5′), 122.5 (C-6, C-6′), 133.8 (C-1, C-1′), 145.6 (C-4, C-4′), 148.3 (C-3, C-3′). HRMS Calcd for $C_{20}H_{30}NO_6$($M+NH_4^+$): 380.2068. Found: 380.2065. The data are consistent with the literature.[21]

Meso-*2,3-bis(4′-benzyloxy-3′-methoxybenzyl)-1,4-butanediol* (**10a**): Following the procedure described for the preparation of **3**, and starting with the diol **6a** (3.62 g, 10 mmol), compound **10a** was obtained as a yellow oil (4.9 g, 90%). IR (KBr/cm^{-1}): 3293, 2925, 1488, 1246, 1037, 931. ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 2.01–2.10 (m, 2H, 2 × $ArCH_2CH$), 2.69–2.76 (m, 4H, 2 × $ArCH_2CH$), 3.54–3.56 (m, 2H, CH_2OH), 3.60–3.62 (m, 2H, CH_2OH), 3.84 (s, 6H, 2 × OCH_3), 5.10 (s, 4H, 2 × $ArCH_2O$), 6.62–6.80 (m, 6H, ArH) , 7.27–7.39 (m, 10H, ArH). ^{13}C NMR ($CDCl_3$, 125 MHz) δ: 33.4 (C-3, C-4), 43.9 (C-7′, C-7″), 56.1 (2 × OCH_3), 60.9 (C-1, C-4), 71.3 (2 × $ArCH_2O$), 73.3 (C-2, C-5), 113.0 (C-2′, C-2″), 114.4 (C-5′, C-5″), 121.0 (C-6′, C-6″), 127.3, 127.8, 128.5, 133.7 (C-1′, C-1″), 137.4, 146.6 (C-4′, C-4″), 149.7 (C-3′, C-3″). HRMS Calcd for $C_{34}H_{42}NO_6$($M+NH_4^+$): 560.3007. Found: 560.3012.

Threo-*(±)-2,3-bis(4′-benzyloxy-3′-methoxybenzyl)-1,4-butanediol* (**10b**): Following the procedure described for the preparation of **3**, and starting with the diester **6b** (3.6 g, 10 mmol), compound **10b** was obtained as a yellow oil (4.8 g, 89%). IR (KBr/cm^{-1}): 3383, 2921,1521, 1245, 1037, 928. ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 1.85–1.95 (m, 2H, 2 × $ArCH_2CH$), 2.62–2.67 (m, 4H, 2 × $ArCH_2CH$), 3.54–3.56 (m, 2H, CH_2OH), 3.60–3.62 (m, 2H, CH_2OH), 3.80 (s, 6H, 2 × OCH_3), 5.13 (s, 4H, 2 × $ArCH_2O$), 6.61–6.71 (m, 6H, ArH) , 7.27–7.37 (m, 10H, ArH). ^{13}C NMR ($CDCl_3$, 125 MHz) δ: 35.9 (C-3, C-4), 45.0 (C-7′, C-7″), 56.1 (2 × OCH_3), 63.4 (C-1, C-4), 71.3 (2 × $ArCH_2O$), 113.0

(C-2′, C-2″), 114.4 (C-5′, C-5″), 121.0 (C-6′, C-6″), 127.3, 127.8, 128.5, 133.9 (C-1′, C-1″), 137.4, 146.7 (C-4′, C-4″), 149.8 (C-3′, C-3″). HRMS Calcd for $C_{34}H_{42}NO_6(M+NH_4^+)$: 560.3007. Found: 560.3012.

Meso-*(±)-9,9-dibenzoylsecoisolariciresinol* (**2**): Benzoyl chloride (0.9 g, 6 mmol) in dry dichloromethane (10 mL) was added dropwise during 1 h to the mixture of diol **10a** (1.6 g, 3 mmol), pyridine (0.5 g, 6 mmol) and dry dichloromethane (20 mL). The mixture was stirred under nitrogen at room temperature for 5 h, and then filtered. The filtrate was concentrated *in vacuo*. Flash column chromatography of the residue gave compound **2** as a white oil (1.5 g, 89%). IR (KBr/cm^{-1}): 3448, 2928, 2842, 1712, 1605, 1515, 1450, 1265, 1035. ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 2.28–2.37 (m, 2H, $ArCH_2CH$), 2.67–2.75 (m, 4H, 2 × $ArCH_2CH$), 3.76 (s, 6H, 2 × OCH_3), 4.24 (m, 2H, H-9b, H-9b′), 4.52 (m, 2H, H-9a, H-9a′), 6.53–6.78 (m, 6H, ArH), 7.45–8.05 (m, 10H, ArH). ^{13}C NMR ($CDCl_3$, 125 MHz) δ: 33.6 (C-7, C-7′), 40.5 (C-8, C-8′), 55.3 (2 × OCH_3), 66.5 (C-9, C-9′), 110.6 (C-2, C-2′), 113.8 (C-5, C-5′), 120.7 (C-6, C-6′), 128.4 (C-13, C-13′, C-15, C-15′), 129.2 (C-12, C-12′, C-16, C-16′), 130.1 (C-11, C-11′), 130.5 (C-1, C-1′), 133.2 (C-14, C-14′), 143.3 (C-4, C-4′), 145.8 (C-3, C-3′), 166.5 (C-10, C-10′). HRMS Calcd for $C_{34}H_{38}NO_8(M+NH_4^+)$: 588.2592. Found: 588.2594.

Threo-*(±)-9,9-dibenzoylsecoisolariciresinol* (**1**): Following the procedure described for the preparation of **2**, and starting with the diester **10b** (1.6 g, 3 mmol), compound **1** was obtained as a white oil (1.6 g, 92%). IR (KBr/cm^{-1}): 3420, 2930, 2856, 1715, 1605, 1512, 1454, 1270, 1031. ^{1}H NMR ($CDCl_3$, 500 MHz) δ: 2.30–2.41 (m, 2H, $ArCH_2CH$), 2.75–2.88 (m, 4H, 2 × $ArCH_2CH$), 3.77 (s, 6H, 2 × OCH_3), 4.33 (m, 2H, H-9b, H-9b′), 4.52 (m, 2H, H-9a, H-9a′), 6.53–6.80 (m, 6H, ArH), 7.43–8.05 (m, 10H, ArH). ^{13}C NMR ($CDCl_3$, 125 MHz) δ: 35.2 (C-7, C-7′), 40.8 (C-8, C-8′), 55.6 (2 × OCH_3), 65.1 (C-9, C-9′), 111.4 (C-2, C-2′), 114.7 (C-5, C-5′), 121.5 (C-6, C-6′), 128.6 (C-13, C-13′, C-15, C-15′), 129.4 (C-12, C-12′, C-16, C-16′), 130.1 (C-11, C-11′), 131.6 (C-1, C-1′), 133.1 (C-14, C-14′), 144.0 (C-4, C-4′), 146.5 (C-3, C-3′), 166.5 (C-10, C-10′). HRMS Calcd for $C_{34}H_{38}NO_8(M+NH_4^+)$: 588.2592. Found: 588.2597. . The data are consistent with the literature.[12] The data of **1** in the literature:[12jj] IR (KBr/cm^{-1}): 2923, 2853, 2360, 2338, 1714, 1603, 1514, 1454, 1374, 1270, 1115, 1031, 756, 712 cm-1; ^{1}H NMR ($CDCl_3$, 300MHz) δ: 2.36 (m, 2H, $ArCH_2CH$), 2.81(m, 4H, 2 × $ArCH_2CH$), 3.77 (s, 6H, 2 × OCH_3), 4.35 (dd, 2H, *J* = 11.2, 4.3 Hz, H-9b, H-9b′), 4.54 (2H, dd, *J* = 11.2, 5.9 Hz, H-9a, H-9a′), 5.45(s, 2H, OH), 6.53 (d, 2H, *J* = 1.8 Hz, H-2, H-2′), 6.61 (dd, 2H, *J* = 8.0, 1.8 Hz, H-6, H-6′), 6.79 (2H, dd, *J* = 8.0, 1.8 Hz, H-5, H-5′), 7.43 (t, 4H, *J* = 7.7 Hz, H-14, H-14′, H-16, H-16′), 7.57 (t, 2H, *J* = 6.5 Hz, H-15, H-15′), 8.01 (d, 4H, *J* = 8.0 Hz, H-13, H-13′, H-17, H-17′). ^{13}C NMR ($CDCl_3$, 75MHz) δ: 35.1 (t, C-7, C-7′), 40.4 (d, C-8, C-8′), 55.6 (c, C-10, C-10′), 65.0 (t, C-9, C-9′), 111.2 (d, C-2,C-2′), 114.2 (d, C-5, C-5′), 121.7 (d, C-6, C-6′), 128.4 (d, C-14, C-14′;C-16, C-16′), 129.5 (d, C-13, C-13′; C-17, C-17′), 130.1 (s, C-12,C-12′), 131.5 (s, C-1, C-1′), 133.0 (d, C-15, C-15′), 144.0 (s, C-4,C-4′), 146.5 (s, C-3, C-3′), 166.5 (s, C-11, C-11′).

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