Supplementary Material (ESI) for Chemical Communications
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Dynamic Kinetic Resolution of 2-Oxo-3-aryl-succinic Acid Esters by Organocatalyzed Aldolization

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General

Unless otherwise indicated, all commercially available compounds were used without further purification. Solvents were dried according to standard procedures. β-ketoesters were prepared according to the literature.[1-4] Column chromatography was carried out using silica gel (H60). Melting points were measured on an XRC-1 melting point apparatus and uncorrected. ^{1}H and ^{13}C NMR spectra were recorded on a Varian-Inova-400 or Bruker AV400 spectrometer at 400 MHz and 100 MHz, respectively, with TMS as internal standard. Infrared spectra were obtained on a Nicolet-Avatar-360 FT-IR spectrometer. Elemental analyses were carried out using Carlo-Erba-1110 Analyzer. Optical rotations were measured at 589 nm (Na D line) on a Autopol IV automatic polarimeter. The enantiomeric excess (ee) of the products were determined by HPLC analysis on a Chiralpak AS-H and AD-H column using 2-propanol/hexane as the eluent.

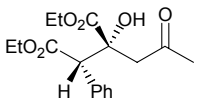
Experimental Procedures

1. dynamic kinetic resolutions (DKR) of β-ketoesters

General Procedure: To a stirred solution (or suspension) of *L*-proline (10 mol %) in a mixture of dry donor ketone (2.0 mL) and the desired solvent (8.0 mL) was added the β-ketoester (2 mmol). The reaction mixture was stirred at this temperature for the time as specified in Table 1 (monitored by TLC) and then was treated with saturated ammonium chloride solution. The mixture was extracted with ethyl acetate (3 × 15 mL), and the combined extracts were washed with brine (5 mL), and dried over anhydrous sodium sulfate. After removal of the solvent, the crude products were purified by column chromatography over silica gel (1:8 ethyl acetate/hexane) to furnish the two desired diastereomers, which were characterized by elemental analysis, IR, ^{1}H NMR and ^{13}C NMR spectroscopy.

Diethyl 2-hydroxy-2-(2-oxopropyl)-3-phenylsuccinate (2a)

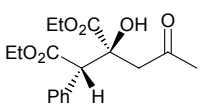
syn-isomer



syn-**2a**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.20 (t, J = 7.2 Hz, 3H, OCH_2CH_3), 1.28 (t, J = 7.2 Hz, 3H, OCH_2CH_3), 2.02 (s, 3H, $COCH_3$), 2.64 (d, J = 17.2 Hz, 1H, COC*H*H), 2.80 (d, J = 16.8 Hz, 1H, COCH*H*), 4.07–4.27 (m, 5H, PhC*H*, 2 × OCH_2CH_3), 4.79 (s, 1H, OH), 7.34–7.38 (m, 5H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 13.92, 13.98, 30.81, 48.99, 56.23, 61.36, 62.02, 76.70, 128.19, 128.54, 129.97, 133.55, 172.19, 173.49, 206.22; IR (film) ν_{max}: 3409.7, 2982.1, 1731.3, 1605.1, 1384.4, 779.0, 707.8cm^{-1}. Anal. calcd for $C_{17}H_{22}O_6$: C 63.34, H 6.88; found: C 63.69, H 6.98. HPLC: Chiralpak AS-H (*i*-PrOH/hexane, 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 6.7 min; t_{minor} = 7.9 min; $[\alpha]_D^{25}$ = – 71.1 (*c* 1.0, $CHCl_3$), ee > 99%.

anti-isomer

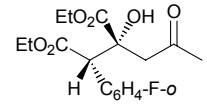


anti-**2a**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.16 (t, J = 7.4 Hz, 3H, OCH_2CH_3), 1.23 (t, J = 7.0 Hz, 3H, OCH_2CH_3), 2.16 (s, 3H, $COCH_3$), 2.99 (d, J =16.8 Hz, 1H, COC*H*H), 3.27 (d, J = 16.8 Hz, 1H, COCH*H*), 3.98 (s, 1H, PhC*H*), 4.06–4.22 (m, 4H, 2 × OCH_2CH_3), 4.33 (s, 1H, OH), 7.31–7.39 (m, 5H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.23, 14.40, 31.44, 49.14, 58.37, 61.59, 62.40, 77.19, 128.47, 128.54, 130.38, 133.59, 171.05, 173.19, 207.63; IR (film) ν_{max}: 3461.3, 3064.0, 2982.2, 1720.5, 1629.1, 1384.5, 777.1, 703.7cm^{-1}; Anal. calcd for $C_{17}H_{22}O_6$: C 63.34, H 6.88; found: C 63.29, H 6.79. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 6.3 min, t_{minor} = 6.9 min; $[\alpha]_D^{25}$ = +72.5 (*c* 1.0, $CHCl_3$), ee = 96%.

Diethyl 3-(2-fluorophenyl)-2-hydroxy-2-(2-oxopropyl)succinate (2b)

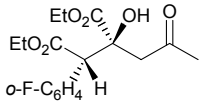
syn-isomer



syn-**2b**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.20 (t, J = 7.0 Hz, 3H, OCH_2CH_3), 1.31 (t, J = 7.2 Hz, 3H, OCH_2CH_3), 2.05 (s, 3H, $COCH_3$), 2.72 (d, J = 16.8 Hz, 1H, COC*H*H), 2.80 (d, J = 16.8 Hz, 1H, COCH*H*), 4.09–4.19 (m, 2H, OCH_2CH_3), 4.16-4.31 (q, J = 7.2 Hz, 2H, OCH_2CH_3), 4.41 (s, 1H, PhC*H*), 4.49 (s, 1H, OH), 7.10 (t, J = 9.2 Hz, 1H, ArH), 7.18 (t, J = 7.4 Hz, 1H, ArH), 7.31-7.37 (m, 1H, ArH), 7.65-7.68 (m, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.23, 14.29, 31.21, 48.59, 49.16, 61.82, 62.57, 76.59, 115.54 (d, $J_{F\text{-}C}$ =22.9 Hz), 121.01 (d, $J_{F\text{-}C}$ =13.8 Hz), 124.62 (d, $J_{F\text{-}C}$ = 3.8 Hz), 130.18 (d, $J_{F\text{-}C}$ = 8.4 Hz), 131.79 (d, $J_{F\text{-}C}$ =2.3 Hz), 161.20 (d, $J_{F\text{-}C}$ = 244.9 Hz), 171.16, 173.87, 206.06; IR (film) ν_{max}: 3503.9, 2986.8, 2940.5, 1736.5, 1620.7, 1582.1, 1381.5, 1196.2, 1126.8, 1095.9, 1026.5, 764.1 cm^{-1}. Anal. calcd for $C_{17}H_{21}FO_6$: C 59.99, H 6.22; found: C 59.53, H 6.39. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 220 nm): t_{major} = 6.5 min; t_{minor} =11.8 min; $[\alpha]^{21}_D$ = –10.1 (*c* 5.40, $CHCl_3$), ee = 97%.

anti-isomer

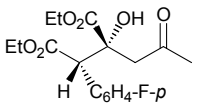


anti-**2b**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.16–1.30 (m, 6H, 2 × OCH_2CH_3), 2.19 (s, 3H, $COCH_3$), 3.12 (d, J = 17.2 Hz, 1H, COC*H*H), 3.24 (d, J = 17.2 Hz, 1H, COCH*H*), 4.06–4.22 (m, 4H, 2OCH_2CH_3), 4.37 (s, 1H, PhC*H*), 4.39 (s, 1H, OH), 7.02-7.18 (m, 2H, ArH), 7.27–7.33 (m, 1H, ArH), 7.63–7.69 (m, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.12, 14.30, 31.45, 48.93, 50.14, 61.80, 62.58, 76.98, 115.51 (d, $J_{F\text{-}C}$ =22.9 Hz), 121.13 (d, $J_{F\text{-}C}$ = 13.8 Hz), 124.26 (d, $J_{F\text{-}C}$ =3.0 Hz), 130.20 (d, $J_{F\text{-}C}$ = 8.4 Hz), 132.35 (d, $J_{F\text{-}C}$ = 2.3 Hz), 160.92 (d, $J_{F\text{-}C}$ =244.8 Hz), 170.34, 173.05, 207.62; IR (film) ν_{max}: 3496.1, 2986.8, 2940.5, 1736.5, 1620.7，1582.1, 1381.5, 1234.8, 1188.5, 1119.1, 1026.5, 764.1 cm^{-1}. Anal. calcd for $C_{17}H_{21}FO_6$: C 59.99, H 6.22; found: C 59.75, H 6.26. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 220 nm): t_{major} = 6.7 min; t_{minor} = 8.6 min; $[\alpha]^{21}_D$ = + 45.6 (*c* 1.17, $CHCl_3$); ee = 97%.

Diethyl 3-(4-fluorophenyl)-2-hydroxy-2-(2-oxopropyl)succinate (2c)

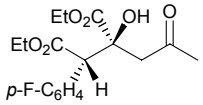
syn-isomer



syn-**2c**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.21 (t, J = 7.0 Hz, 3H, OCH_2CH_3), 1.30 (t, J = 7.0 Hz, 3H, OCH_2CH_3), 2.04 (s, 3H, $COCH_3$), 2.62 (d, J = 17.0 Hz, 1H, COC*H*H), 2.75 (d, J = 17.0 Hz, 1H, COCH*H*), 4.07 (s, 1H, PhC*H*), 4.11–4.17 (m, 2H, OCH_2CH_3), 4.25 (q, J = 7.0 Hz, 2H, OCH_2CH_3), 4.72 (s, 1H, OH), 7.04–7.40 (m, 4H, Ar-H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.29, 14.36, 31.21, 49.40, 55.85, 61.84, 62.51, 76.92, 115.83 ($J_{F\text{-}C}$ = 21.4 Hz), 129.70, 132.07 ($J_{F\text{-}C}$ =8.4 Hz), 163.03 ($J_{F\text{-}C}$ =245.7 Hz), 172.21, 173.79, 206.45; IR (film) ν_{max}: 3503.9, 3071.7, 2986.8, 2940.5, 1736.5, 1605.3, 1512.7, 1373.8, 1219.4, 1026.5, 849.0. Anal. calcd for $C_{17}H_{21}FO_6$: C 59.99, H 6.22; found: C 59.95, H 6.29. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 15/85, flow rate 1.0 mL/min, λ = 220 nm): t_{major} = 7.3 min, t_{minor} = 10. 9 min; $[\alpha]^{21}_D$ = –12.8 (*c* 12.83, $CHCl_3$); ee = 96%.

anti-isomer

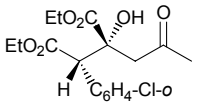


anti-**2c**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.17 (t, J = 7.0 Hz, 3H, OCH_2CH_3), 1.24 (t, J = 7.0 Hz, 3H, OCH_2CH_3), 2.18 (s, 3H, $COCH_3$), 3.01 (d, J = 17.4 Hz, 1H,COC*H*H), 3.26 (d, J = 17.4 Hz, 1H, COCH*H*), 3.94 (s, 1H, PhC*H*), 4.08–4.11 (m, 2H, OCH_2CH_3), 4.14–4.20 (m, 2H, OCH_2CH_3), 4.26 (s, 1H, OH), 6.99–7.39 (m, 4H, Ar-H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.27, 14.42, 31.40, 49.34, 57.44, 61.75, 62.53, 77.10, 115.44 ($J_{F\text{-}C}$ =21.4 Hz), 129.40, 132.11 ($J_{F\text{-}C}$ = 7.6 Hz), 163.00 ($J_{F\text{-}C}$ =245.7 Hz), 170.85, 173.16, 207.46; IR (film) ν_{max}: 3496.1, 3071.7, 2986.8, 2940.5, 1736.5, 1605.3, 1512.7, 1381.5, 1026.5, 849.0 cm^{-1}. Anal. calcd for $C_{17}H_{21}FO_6$: C 59.99, H 6.22; found: C, 59.87, H 6.32. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 15/85, flow rate 1.0 mL/min, λ = 220 nm): t_{major} = 8.6 min; t_{minor} = 9.4 min; $[\alpha]^{21}_D$ = +52.4 (*c* 2.88, $CHCl_3$); ee = 96%.

Diethyl 3-(2-chlorophenyl)-2-hydroxy-2-(2-oxopropyl)succinate (2d)

syn-isomer

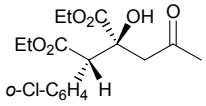


syn-**2d**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.19 (t, J = 7.2 Hz, 3H, OCH_2CH_3), 1.33 (t, J = 7.2 Hz, 3H, OCH_2CH_3), 2.04 (s, 3H, $COCH_3$), 2.59 (d, J = 16.8 Hz, 1H, COC*H*H), 2.87 (d, J = 16.8 Hz, 1H, COCH*H*), 4.07–4.19 (m, 2H, OCH_2CH_3), 4.31 (q, J = 7.2 Hz, 2H, OCH_2CH_3), 4.39 (s, 1H, PhC*H*), 4.79 (s, 1H, OH), 7.29–7.80 (m, 5H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 14.11, 14.46, 31.32, 50.20, 53.00, 61.91, 62.64, 76.92, 126.96, 129.69, 129.75, 131.72, 132.19, 134.95, 170.26, 173.02, 207.01; IR (film) ν_{max}: 3503.9, 3071.7, 2986.8, 2940.5, 1736.5, 1628.4, 1211.7, 1026.5, 756.3 cm^{-1}. Anal. calcd for $C_{17}H_{21}ClO_6$: C 57.23, H 5.93;

found: C 56.84, H 6.24. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 8.9 min; $[\alpha]^{25}_D$ = + 0.23 (*c* 7.96, $CHCl_3$); ee = 99%.

anti-isomer

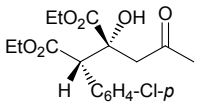


anti-**2d**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.12 (t, *J* = 7.2 Hz, 3H, OCH_2CH_3), 1.23 (t, *J* = 7.2 Hz, 3H, OCH_2CH_3), 2.18 (s, 3H, $COCH_3$), 3.24 (d, *J* = 17.4 Hz, 1H, COCHH), 3.39 (d, *J* = 17.4 Hz, 1H,COCHH), 3.98–4.22 (m, 5H, PhCH, 2 × OCH_2CH_3), 4.65 (s, 1H, OH), 7.23–7.84 (m, 5H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.36, 14.43, 31.45, 49.18, 52.51, 61.95, 62.81, 76.88, 127.44, 129.77, 129.87, 131.95, 132.13, 135.46, 171.10, 174.16, 206.15; IR (film) ν_{max}: 3488.4, 3071.7, 2986.8, 2940.5, 1736.5, 1366.0, 1242.6, 1173.1, 1119.1, 1026.5, 756.3 cm^{-1}. Anal. calcd for $C_{17}H_{21}ClO_6$: C 57.23, H 5.93; found: C 56.96, H 6.20. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 9.4 min; $[\alpha]^{25}_D$ = + 17.3 (*c* 1.43, $CHCl_3$); ee = 99%.

Diethyl 3-(4-chlorophenyl)-2-hydroxy-2-(2-oxopropyl)succinate (2e)

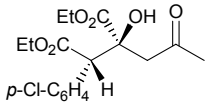
syn-isomer



syn-**2e**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.21 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 1.30 (t, *J* = 7.2 Hz, 3H, OCH_2CH_3), 2.04 (s, 3H, $COCH_3$), 2.62 (d, *J* = 17.2 Hz, 1H, COCHH), 2.75 (d, *J* = 17.2 Hz, 1H, COCHH), 4.06 (s, 1H, PhCH), 4.08–4.19 (m, 2H, OCH_2CH_3), 4.26 (q, *J* = 6.8 Hz, 2H, OCH_2CH_3), 4.71 (s, 1H, OH), 7.29–7.38 (m, 4H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.39, 14.46, 31.35, 49.51, 56.07, 62.03, 62.67, 76.96, 129.19, 131.83, 132.52, 134.76, 172.14, 173.80, 206.49; IR (film) ν_{max}: 3503.9, 2986.8, 2940.5, 1736.5, 1597.6, 1489.5, 1211.7, 1173.1, 1095.9, 841.2 cm^{-1}. Anal. calcd for $C_{17}H_{21}ClO_6$: C 57.23, H 5.93; found: C 57.26, H 6.06. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 10.8 min; $[\alpha]^{25}_D$ = – 23.9 (*c* 6.57, $CHCl_3$); ee = 99%.

anti-isomer

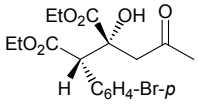


anti-**2e**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.17 (t, *J* = 7.2 Hz, 3H, OCH_2CH_3), 1.24 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 2.18 (s, 3H, $COCH_3$), 3.02 (d, *J* =17.2 Hz, 1H, COCHH), 3.26 (d, *J* = 17.2 Hz, 1H, COCHH), 3.93 (s, 1H, PhCH), 4.06–4.20 (m, 4H, 2 × OCH_2CH_3), 4.29 (s, 1H, OH), 7.29 (d, *J* = 8.4 Hz, 2H, ArH), 7.35 (d, *J* = 8.4 Hz, 2H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.27, 14.41, 31.41, 49.19, 57.54, 61.81, 62.57, 76.98, 128.68, 131.76, 132.05, 134.55, 170.62, 173.07, 207.48; IR (film) ν_{max}: 3488.4, 2986.8, 2932.7, 1736.5, 1489.5, 1366.0, 1242.6, 1204.0, 1173.1, 1119.1, 1095.9, 1018.7, 841.2 cm^{-1}. Anal. calcd for $C_{17}H_{21}ClO_6$: C 57.23, H 5.93; found: C 57.13, H 6.18. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 11.0 min; $[\alpha]^{25}_D$ = + 50.4 (*c* 1.729, $CHCl_3$); ee = 99%.

Diethyl 3-(4-bromophenyl)-2-hydroxy-2-(2-oxopropyl)succinate (2f)

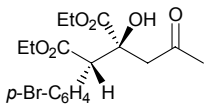
syn-isomer



syn-**2f**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.21 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 1.30 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 2.04 (s, 3H, $COCH_3$), 2.61 (d, *J* = 17.2 Hz, 1H, COCHH), 2.75 (d, *J* = 17.2 Hz, 1H, COCHH), 4.05 (s, 1H, PhCH), 4.08–4.19 (m, 2H, OCH_2CH_3), 4.26 (q, *J* = 7.2 Hz, 2H, OCH_2CH_3), 4.70 (s, 1H, OH), 7.30 (d, *J* = 7.6 Hz, 2H, ArH), 7.49 (d, *J* = 7.2 Hz, 2H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.10, 14.17, 31.03, 49.24, 55.95, 61.66, 62.29, 76.53, 122.60, 131.77, 131.99, 132.82, 171.55, 173.82, 206.06; IR (film) ν_{max}: 3503.9, 2986.8, 2909.6, 1736.5, 1589.9, 1489.5, 1381.5, 1211.7, 1173.1, 1119.1, 1018.7, 833.5 cm^{-1}. Anal. calcd for $C_{17}H_{21}BrO_6$: C 50.89, H 5.28; found: C 50.67, H 5.45. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 220 nm): t_{major} =7.2 min, t_{minor} = 9.6 min; $[\alpha]^{21}_D$ = – 20.4 (*c* 6.84, $CHCl_3$); ee = 97%.

anti-isomer



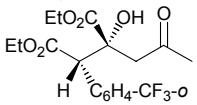
anti-**2f**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.17 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 1.24 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 2.18 (s, 3H, $COCH_3$), 3.00 (d, *J* = 17.2 Hz, 1H, COCHH), 3.26 (d, *J* = 17.2 Hz, 1H, COCHH), 3.92 (s, 1H, PhCH), 4.07–4.19 (m, 4H, 2 × OCH_2CH_3), 4.28 (s, 1H, OH), 7.28 (d, *J* = 7.2 Hz, 2H, ArH), 7.45 (d, *J* = 7.2 Hz, 2H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.29, 14.43, 31.43, 49.18, 57.64, 61.83, 62.59, 76.94, 122.83, 131.66, 132.11, 132.60, 170.56, 173.07, 207.49; IR (film) ν_{max}: 3488.4, 2986.8, 2932.7, 1713.3, 1589.9, 1481.8, 1412.3, 1018.7, 833.5 cm^{-1}. Anal. calcd for $C_{17}H_{21}BrO_6$: C 50.89, H 5.28; found: C

50.89, H 5.45. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 220 nm): t_{major} = 7.4 min; t_{minor} = 8.1 min; $[\alpha]^{21}_D$ = + 52.5 (*c* 1.77, $CHCl_3$); ee = 96%.

Diethyl 2-hydroxy-2-(2-oxopropyl)-3-(2-(trifluoromethyl)phenyl)succinate (2g)

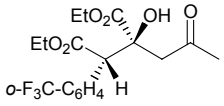
syn-isomer



syn-**2g**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.18 (t, *J* = 7.2 Hz, 3H, OCH_2CH_3), 1.37 (t, *J* = 7.2 Hz, 3H, OCH_2CH_3), 2.01 (s, 3H, $COCH_3$), 2.42 (d, *J* = 16.8 Hz, 1H, COC*H*H), 2.76 (d, *J* = 16.8 Hz, 1H, COCH*H*), 4.10–4.15 (m, 2H, OCH_2CH_3), 4.30–4.37 (m, 3H, OCH_2CH_3 and PhC*H*), 4.52 (s, 1H, OH), 7.47 (t, *J* = 7.6 Hz, 1H, ArH), 7.61 (t, *J* = 7.6 Hz, 1H, ArH), 7.71 (d, *J* = 7.6 Hz, 1H, ArH), 8.17 (d, *J* = 7.6 Hz, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.10, 14.18, 31.21, 49.83, 52.46, 61.83, 62.76, 77.00, 123.16, 125.95 (J_{F-C} = 4.9 Hz), 128.34, 129.78 (*J* = 28.2 Hz), 132.21, 132.85, 132.95, 169.77, 174.14, 205.75; IR (film) ν_{max}: 3480.7, 2986.8, 2940.5, 1744.2, 1605.3, 1582.1, 1450.9, 1381.5, 1312.0, 1173.1, 1034.2, 771.8 cm^{-1}; Anal. calcd for $C_{18}H_{21}F_3O_6$: C 55.38, H 5.42; found: C 55.37, H 5.36. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 220 nm): t_{major} = 4.7 min; t_{minor} = 7.1 min; $[\alpha]_D^{23}$ = + 36.1 (*c* 4.68, $CHCl_3$); ee = 95%.

anti-isomer

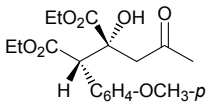


anti-**2g**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 0.92 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 1.23 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 2.18 (s, 3H, $COCH_3$), 3.26 (d, *J* = 17.8 Hz, 1H, COC*H*H), 3.61 (d, *J* = 17.8 Hz, 1H, COCH*H*), 3.82–3.95 (m, 2H, OCH_2CH_3), 4.19 (q, *J* = 7.0 Hz, 2H, OCH_2CH_3), 4.27 (s, 1H, PhC*H*), 4.33 (s, 1H, OH), 7.38 (t, *J* = 7.4 Hz, 1H, ArH), 7.54 (t, *J* = 7.4 Hz, 1H, ArH), 7.61 (d, *J* = 7.6 Hz, 1H, ArH), 8.17 (d, *J* = 8.0 Hz, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 13.78, 14.39, 31.14, 51.49, 52.75, 62.03, 62.45, 77.23, 123.19, 125.70 (q, J_{F-C} =5.3 Hz), 128.22, 129.10 (q, J_{F-C} = 29.7 Hz), 131.82, 132.59, 133.13, 169.53, 172.70, 207.33; IR (film) ν_{max}: 3488.4, 2986.8, 2940.5, 1744.2, 1605.3, 1582.1, 1450.9, 1381.5, 1312.0, 1173.1, 1026.5, 771.8 cm^{-1}. Anal. calcd for $C_{18}H_{21}F_3O_6$: C 55.38, H 5.42; found: C 55.39, H 5.43. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 4.8 min, t_{minor} = 6.8 min; $[\alpha]_D^{23}$ = + 2.57 (*c* 1.77, $CHCl_3$); ee = 93%.

Diethyl 2-hydroxy-3-(4-methoxyphenyl)-2-(2-oxopropyl)succinate (2h)

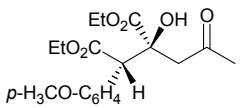
syn-isomer



syn-**2h**

white solid; m.p 80–82 °C. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.20 (t, *J* = 7.0 Hz,, 3H, OCH_2CH_3), 1.28 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 2.03 (s, 3H, $COCH_3$), 2.64 (d, *J* = 17.2 Hz, 1H, COC*H*H), 2.79 (d, *J* = 17.6 Hz, 1H, COCH*H*), 3.81 (s, 3H, OCH_3), 4.02 (s, 1H, PhC*H*), 4.06–4.25 (m, 4H, 2 × OCH_2CH_3), 4.77 (s, 1H, OH), 6.88 (d, *J* = 8.4 Hz, 2H, ArH), 7.31 (d, *J* = 8.4 Hz, 2H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.34, 14.40, 31.24, 49.34, 55.61, 55.68, 61.70, 62.39, 77.13, 114.28, 125.80, 131.39, 159.83, 172.82, 173.97, 206.76; IR (film) ν_{max}: 3465.3, 2986.8, 2948.2, 2840.1, 1736.5, 1613.0, 1520.4, 1466.4, 1373.8, 1250.3, 1180.8, 1119.1, 1026.5, 825.8 cm^{-1}. Anal. calcd for $C_{18}H_{24}O_7$: C 61.35, H 6.86; found: C 61.11, H 7.10. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 15.4 min; $[\alpha]^{25}_D$ = – 34.4 (*c* 9.83, $CHCl_3$); ee > 99%.

anti-isomer

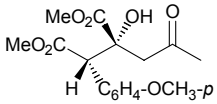


anti-**2h**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.11 (t, *J* = 7.0 Hz, 3H, OCH_2CH_3), 1.16 (t, *J* = 7.2 Hz, 3H, OCH_2CH_3), 2.09 (s, 3H, $COCH_3$), 2.90 (d, *J* = 17.2 Hz, 1H, COC*H*H), 3.18 (d, *J* = 17.2 Hz, 1H, COCH*H*), 3.71 (s, 3H, OCH_3), 3.85 (s, 1H, PhC*H*), 4.02–4.11 (m, 4H, 2 × OCH_2CH_3), 4.22 (s, 1H, OH), 6.77 (d, *J* = 8.0 Hz,, 2H, ArH), 7.23 (d, *J* = 8.0 Hz, 2H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 14.30, 14.44, 31.47, 49.18, 55.56, 57.56, 61.56, 62.42, 77.19, 113.93, 125.50, 131.45, 159.77, 171.28, 173.33, 207.67; IR (film) ν_{max}: 3488.4, 2986.8, 2948.2, 2840.1, 1736.5, 1613.0, 1512.7, 1458.7, 1366.0, 1250.3, 1180.8, 1119.1, 1026.5, 841.2 cm^{-1}. Anal. calcd for $C_{18}H_{24}O_7$: C 61.35, H 6.86; found: C 60.98, H 7.09. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate of 1.0 mL/min, λ = 250 nm): t_{major} = 16.5 min; $[\alpha]^{25}_D$ = + 62.0 (*c* 1.88, $CHCl_3$);ee > 99%.

Dimethyl 2-hydroxy-2-(2-oxopropyl)-3-phenylsuccinate (2i)

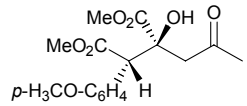
syn-isomer



syn-**2i**

White solid, m.p. 60–62 °C. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 2.02 (s, 3H, $COCH_3$), 2.66 (d,

J = 17.2 Hz, 1H, COC*H*H), 2.80 (d, *J* = 17.2 Hz, 1H, COCH*H*), 3.67 (s, 3H, OCH_3), 3.79 (s, 3H, OCH_3), 4.11 (s, 1H, PhC*H*), 4.79 (s, 1H, OH), 7.35–7.37 (m, 5H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 31.21, 49.31, 52.86, 53.38, 56.51, 77.21, 128.73, 129.03, 130.31, 133.67, 173.04, 174.46, 206.81; IR (KBr) ν_{max}: 3419.0, 2925.0, 2855.6, 1736.5, 1605.3, 1435.5, 1381.5, 1242.6, 1165.4, 1111.4, 1026.5, 802.6, 702.3 cm^{-1}. Anal. calcd for $C_{15}H_{18}O_6$: C 61.22, H 6.16; found: C 61.08, H 6.33. HPLC: AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} =11.4 min; t_{minor} = 16.7 min; $[\alpha]^{25}_D$ = – 53.8 (*c* 4.36, $CHCl_3$); ee = 95%.



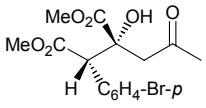
anti-**2i**

anti-isomer

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 2.16 (s, 3H, $COCH_3$), 3.03 (d, *J* = 17.2 Hz, 1H, COC*H*H), 3.25 (d, *J* = 17.2 Hz, 1H, COCH*H*), 3.63 (s, 3H, OCH_3), 3.70 (s, 3H, OCH_3), 3.99 (s, 1H, PhC*H*), 4.29 (s, 1H, OH), 7.32–7.37 (m, 5H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 31.37, 49.24, 52.70, 53.16, 58.28, 77.21, 128.61, 128.64, 130.25, 133.36, 171.46, 173.69, 207.54; IR (film) ν_{max}: 3488.4, 3000.2, 2955.9, 2855.6, 1736.5, 1628.4, 1435.5, 1381.5, 1242.6, 1211.7, 1165.4, 1126.8, 1.003.3, 748.6, 702.3 cm^{-1}. Anal. calcd for $C_{15}H_{18}O_6$: C 61.22, H 6.16; found: C 61.07, H 6.34. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 210 nm): t_{major} = 11.7 min; $[\alpha]^{25}_D$ = + 66.1 (*c* 1.58, $CHCl_3$); ee > 99%.

Dimethyl 3-(4-bromophenyl)-2-hydroxy-2-(2-oxopropyl)succinate (2j)

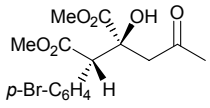
syn-isomer



syn-**2j**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 2.04 (s, 3H, $COCH_3$), 2.63 (d, *J* = 17.0 Hz, 1H, COC*H*H), 2.74 (d, *J* = 17.0 Hz, 1H, COCH*H*), 3.68 (s, 3H, OCH_3), 3.80 (s, 3H, OCH_3), 4.07 (s, 1H, PhC*H*), 4.66 (s, 1H, OH), 7.28 (d, *J* = 8.4 Hz, 2H, ArH), 7.49 (d, *J* = 8.4 Hz, 2H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 31.13, 49.33, 52.83, 53.36, 56.13, 76.83, 122.88, 132.00, 132.05, 132.70, 172.13, 174.19, 206.38; IR (film) ν_{max}: 3496.1, 3009.9, 2955.9, 2847.8, 1736.5, 1589.9, 1489.5, 1435.5, 1366.0, 1242.6, 1211.7, 1173.1, 1126.8, 1011.0, 818.1 cm^{-1}. Anal. calcd for $C_{15}H_{17}BrO_6$: C 48.28, H 4.59; found: C47.99, H4.91. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 9.1 min; t_{minor} = 12.3 min; $[\alpha]_D^{23}$ = – 32.2 (*c* 6.10, $CHCl_3$); ee = 96%.

anti-isomer

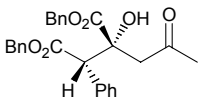


anti-**2j**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 2.17 (s, 3H, $COCH_3$), 3.03 (d, *J* = 17.4 Hz, 1H, COC*H*H), 3.23 (d, *J* = 17.4 Hz, 1H, COCH*H*), 3.64 (s, 3H, OCH_3), 3.71 (s, 3H, OCH_3), 3.93 (s, 1H, ArC*H*), 4.23 (s, 1H, OH), 7.27–7.44 (m, 4H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 31.32, 49.35, 52.84, 53.29, 57.63, 77.04, 122.95, 131.75, 132.01, 132.42, 170.95, 173.56, 207.33; IR (film) ν_{max}: 3488.4, 3002.2, 2955.9, 2855.6, 1744.2, 1589.9, 1489.5, 1435.5, 1366.0, 1242.6, 1211.7, 1165.4, 1126.8, 1011.0, 818.1 cm^{-1}. Anal. calcd for $C_{15}H_{17}BrO_6$: C 48.28, H 4.59; found: C 47.78, H 4.91. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 10/90, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 17.2 min; $[\alpha]_D^{25}$ = + 52.2 (*c* 1.48, $CHCl_3$); ee >99%.

Dibenzyl 2-hydroxy-2-(2-oxopropyl)-3-phenylsuccinate (2k)

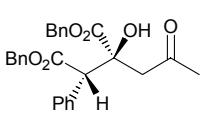
syn-isomer



syn-**2k**

Pale yellow oil. $[\alpha]_D^{22}$ = – 6.52 (*c* 9.50, $CHCl_3$);^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.97 (s, 3H, $COCH_3$), 2.65 (d, *J* = 17.2 Hz, 1H, COC*H*H), 2.80 (d, *J* = 17.2 Hz, 1H, COCH*H*), 4.15 (s, 1H, PhC*H*), 4.78 (s, 1H, OH), 5.03–5.29 (m, 4H, 2 × OCH_2Ph), 7.17–7.37 (m, 15H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 31.29, 49.34, 56.70, 67.43, 68.26, 128.51, 128.70, 128.90, 128.97, 129.02, 130.47, 133.56, 135.52, 135.64, 172.20, 173.78, 206.80; IR (film) ν_{max}: 3503.9, 3063.9, 3033.1, 2955.9, 1736.5, 1605.3, 1497.2, 1458.7, 1381.5, 1211.7, 1088.2, 972.4, 748.6, 702.3 cm^{-1}. Anal. calcd for $C_{27}H_{26}O_6$: C 72.63, H 6.16; found: C 72.21, H 6.12. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 10/90, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 15.7 min; t_{minor} = 26.9 min; ee = 88%.

anti-isomer



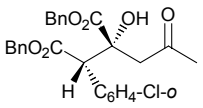
anti-**2k**

White solid, m.p 78–80 °C. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 2.08 (s, 3H, $COCH_3$), 2.91 (d, *J* = 17.2 Hz, 1H, COC*H*H), 3.22 (d, *J* = 16.8 Hz, 1H, COCH*H*), 4.03 (s, 1H, PhC*H*), 4.31 (s, 1H, OH), 4.96–5.14 (m, 4H, 2 × OCH_2Ph), 7.22–7.33 (m, 15H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 31.49, 49.07, 58.26, 67.32, 68.32, 77.40, 128.69, 128.77, 128.96, 129.13, 130.45, 133.24, 135.24, 135.81, 170.75, 173.09, 207.77; IR (KBr) ν_{max}: 3357.2, 3033.1, 2940.5, 2855.6, 1744.2, 1713.3, 1605.3, 1497.2, 1450.9, 1381.5, 1204.0, 1126.8, 972.4,

756.3, 702.3cm^{-1}. Anal. calcd for $C_{27}H_{26}O_6$: C 72.63, H 6.16; found: C 72.43, H 5.98. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 10/90, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 18.6 min; t_{minor} = 22.5 min; $[\alpha]_D^{22}$ = + 55.4 (*c* 1.85, $CHCl_3$); ee = 89%.

Dibenzyl 3-(2-chlorophenyl)-2-hydroxy-2-(2-oxopropyl)succinate (2l)

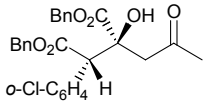
syn-isomer



syn-**2l**

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.96 (s, 3H, $COCH_3$), 2.59 (d, *J* = 16.4 Hz, 1H, COC*H*H), 2.86 (d, *J* = 16.8 Hz, 1H, COCH*H*), 4.39 (s, 1H, PhC*H*), 4.89 (s, 1H, OH), 5.01–5.15 (m, 4H, 2 × OCH_2Ph), 7.17–7.42 (m, 13H, ArH), 7.75–7.76 (m, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 30.99, 48.84, 52.31, 67.12, 68.04, 76.70, 127.02, 127.10, 128.11, 128.12, 128.27, 128.35, 128.37, 128.40, 128.42, 128.43, 128.44, 128.46, 128.47, 128.49, 128.50, 128.51, 128.52, 128.53, 129.43, 129.51, 131.36, 131.90, 135.14, 135.17, 135.18, 170.31, 173.56, 205.67; IR (film) ν_{max}: 3503.9, 3063.9, 3033.1, 2955.9, 1736.5, 1605.3, 1450.9, 1381.5, 1335.2, 1173.1, 1119.1, 1041.9, 748.6, 702.3 cm^{-1}. Anal. calcd for $C_{27}H_{25}ClO_6$: C 67.43, H 5.24; found: C 67.40, H 5.30. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 20/80, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 9.2 min; t_{minor} =16.4 min; $[\alpha]_D^{24}$ = + 4.51 (*c* 16.02, $CHCl_3$); ee = 87%.

anti-isomer



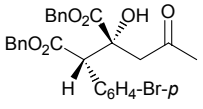
anti-**2l**

White solid, m.p 36–38°C;^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 2.00 (s, 3H, $COCH_3$), 3.17 (d, *J* = 17.6 Hz, 1H, COC*H*H), 3.27 (d, *J* = 17.6 Hz, 1H, COCH*H*), 4.21 (s, 1H, ClC_6H_4CH), 4.72 (s, 1H, OH), 4.88 (d, *J* = 12.0 Hz, 1H, OCH_2Ph), 5.06 (dd, *J* = 8.4, 4.0, Hz, 2H, OCH_2Ph), 5.17 (d, *J* = 12.4 Hz, 1H, O**C**H_2Ph), 7.17–7.36 (m, 13H, ArH), 7.80–7.82 (m, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 30.77, 49.78, 52.69, 67.02, 68.03, 76.73, 126.60, 128.05, 128.27, 128.46, 128.47, 128.49, 128.51, 128.52, 128.53, 128.72, 129.35, 129.43, 131.09, 131.91, 134.55, 134.76, 135.43, 169.54, 172.45, 206.59; IR (KBr) ν_{max}: 3503.9, 3063.9, 3033.1, 2955.9, 1736.5, 1613.0, 1450.9, 1381.5, 1335.2, 1165.4, 1119.1, 1041.9, 748.6, 702.3 cm^{-1}. Anal. calcd for $C_{27}H_{25}ClO_6$: C 67.43, H 5.24; found: C 67.35, H 5.16. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 25/75, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 8.6 min; t_{minor} = 11.1 min; $[\alpha]_D^{24}$ = + 51.5 (*c* 1.24, $CHCl_3$); ee =91%

Dibenzyl 3-(4-bromophenyl)-2-hydroxy-2-(2-oxopropyl)succinate (2m)

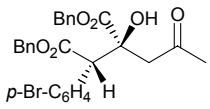
syn-isomer

Pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 1.96 (s, 3H, $COCH_3$), 2.62 (d, *J* = 17.2 Hz, 1H, COC*H*H), 2.75 (d, *J* = 16.8 Hz, 1H, COCH*H*), 4.11 (s, 1H, PhC*H*), 4.65 (s, 1H, OH), 5.02–5.11 (m, 4H, 2 × OCH_2Ph), 7.18–7.23 (m, 2H, ArH), 7.24–7.36 (m, 10H, ArH), 7.41–7.45 (m, 1H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 30.90, 48.97, 55.99, 67.24, 68.00, 76.65, 122.64, 128.25, 128.41, 128.52, 128.53, 128.55, 128.57, 128.59, 128.69, 128.70, 131.71, 131.84, 132.28, 135.01, 135.09, 171.09, 173.17, 206.06; IR (film) ν_{max}: 3503.9, 3063.9, 3033.1, 2955.9, 1736.5, 1589.9, 1489.5, 1450.9, 1381.5, 1335.2, 1211.7, 1173.1, 1080.5, 748.6, 702.3 cm^{-1}; Anal. calcd for $C_{27}H_{25}BrO_6$: C 61.72, H 4.80; found: C 61.57, H 4.80. HPLC: Chiralpak AS-H (*i*-PrOH/hexane = 25/75, flow rate 1.0 mL/min, λ = 250 nm): t_{major} = 8.1 min; t_{minor} = 12.8 min; $[\alpha]_D^{24}$ = + 9.13 (*c* 2.74, $CHCl_3$); ee = 89%.



syn-**2m**

anti-isomer



anti-**2m**

White solid, m.p 88–90 °C. ^{1}H NMR (400 MHz, $CDCl_3$), *δ*: 2.08 (s, 3H, $COCH_3$), 2.93 (d, *J* = 16.8 Hz, 1H, COC*H*H), 3.19 (d, *J* = 16.8 Hz, 1H, COCH*H*), 3.94 (s, 1H, BrC_6H_4CH), 4.23 (s, 1H, OH), 4.99–5.14 (m, 4H, 2 × OCH_2Ph), 7.14–7.35 (m, 14H, ArH); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 30.96, 48.94, 57.19, 67.09, 68.03, 76.70, 122.55, 128.32, 128.45, 128.57, 128.58, 128.60, 128.63, 128.81, 131.32, 131.72, 131.84, 134.67, 135.25, 169.82, 172.47, 206.98; IR (KBr) ν_{max}: 3480.7, 3063.9, 3033.1, 2955.9, 1744.2, 1659.3, 1605.3, 1489.5, 1450.9, 1381.5, 1327.5, 1250.3, 1227.1, 1180.8, 1072.8, 1011.0, 748.6, 694.6 cm^{-1}; Anal. calcd for $C_{27}H_{25}BrO_6$: C 61.72, H 4.80; found: C 61.59, H 4.73. HPLC: Chiralpak AD-H (*i*-PrOH/hexane = 20/80, flow rate of 1.0 mL/min, λ = 250 nm): t_{major} = 16.4 min; t_{minor} = 17.9 min; $[\alpha]_D^{24}$ = + 67.9 (*c* 1.50, $CHCl_3$); ee = 98%.

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