Supporting Information

Oxidation of Active $sp^3$ C-H Bond Initiated Consecutive Intermolecular/intramolecular Cyclization between Glycine Derivatives and $o$-Vinylphenols: Construction of Polycyclic Benzofuroquinoline Skeleton

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Supporting Information

<table>
<thead>
<tr>
<th>Content</th>
<th>page</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>S2</td>
</tr>
<tr>
<td>General experimental procedure</td>
<td>S2</td>
</tr>
<tr>
<td>Analytical data for compounds</td>
<td>S2</td>
</tr>
<tr>
<td>$^1$H and $^{13}$C spectra</td>
<td>S13</td>
</tr>
</tbody>
</table>
General

Solvents are anhydrous. TBPA\(^{+}\) was purchased from commercial sources and used without treatment. Flash chromatography was carried out with silica gel (200-300 mesh). Analytical TLC was performed with silica gel GF254 plates, and the products were visualized by UV detection. \(^1\)H NMR (400 MHz) and \(^{13}\)C NMR (100 MHz) spectra were recorded in CDCl\(_3\). Chemical shifts (\(\delta\)) are reported in ppm using TMS as internal standard and spin-spin coupling constants (J) are given in Hz. The high resolution mass spectra (HRMS) were measured on an electrospray ionization (ESI) apparatus using time of flight (TOF) mass spectrometry.

General Experimental Procedure

A solution of 1a (1 mmol), 2a (1.5 mmol) and CuI (10 mol %) in MeCN (10 ml) was mixed fully, then TBPA\(^{+}\) (10 mol %) was added dropwise. The reaction solution was stirred at 60\(^\circ\)C under O\(_2\) atmosphere. After completion monitored by TLC (by UV visualization), the reaction was quenched by addition of NEt\(_3\) (1 ml). The mixture was poured into a separator funnel with the addition of excess DCM (10 ml), and then the crude organic solution was extracted three times with water to remove inorganic salts. The organic phase was then dried over anhydrous magnesium sulfate, filtered, and the solvent was removed under reduced pressure. The products were separated by silica gel column chromatography eluted with petroleum ether/acetone (v/v 15:1) to afford the products.

Analytical data for compounds

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.63 (d, \(J = 8.7\) Hz, 0.3H), 7.58 (d, \(J = 8.7\) Hz, 1H), 7.44 (d, \(J = 7.4\) Hz, 1.3H), 7.20 – 7.09 (m, 1.4H), 7.03 – 6.95 (m, 1.5H), 6.93 (d, \(J = 2.7\) Hz, 1H), 6.87 – 6.79 (m, 1.5H), 6.77 (dd, \(J = 8.6\), 2.6 Hz, 1.2H), 6.54 (s, 1H), 5.31 (s, 0.3H), 4.02 (s, 3H), 4.00 (s, 0.7H), 3.78 (s, 3H), 1.64 (s, 3H), 1.60 (s, 0.8H); \(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta\) 166.2, 165.1, 162.0, 161.8, 158.1, 156.2, 148.7, 147.0, 136.0, 133.8, 133.5, 132.9, 132.8, 132.7, 128.6 (two \(^{13}\)C), 123.7 (two \(^{13}\)C), 122.1, 121.7, 113.7, 113.2, 112.1, 111.9, 110.6, 110.2, 103.4, 79.6, 55.5, 53.6, 53.3, 50.5, 45.5, 26.8, 21.8; HRMS (ESI) m/z calculated for C\(_{19}\)H\(_{17}\)NO\(_3\) + Na\(^{+}\) (3a), 362.1004, found: 362.1005; C\(_{19}\)H\(_{17}\)NO\(_4\) + Na\(^{+}\), 346.1055 (4a), found: 346.1058.
1H NMR (400 MHz, CDCl$_3$) $\delta$ 7.59 (d, $J = 8.7$ Hz, 1H), 7.49 – 7.38 (m, 1H), 7.17 (td, $J = 7.9$, 1.2 Hz, 1H), 7.01 (td, $J = 7.5$, 0.8 Hz, 1H), 6.94 (d, $J = 2.7$ Hz, 1H), 6.85 (d, $J = 7.9$ Hz, 1H), 6.78 (dd, $J = 8.7$, 2.7 Hz, 1H), 6.62 (s, $OH$, 1H), 4.51 (q, $J = 7.2$ Hz, 2H), 3.79 (s, 3H), 1.64 (s, 3H), 1.47 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 165.8, 161.9, 156.3, 147.3, 135.9, 132.8, 132.6, 128.6, 123.7, 122.1, 113.6, 112.0, 110.6, 103.6, 63.0, 55.5, 50.5, 21.7, 14.2; HRMS (ESI) m/z calculated for C$_{20}$H$_{19}$NO$_5$ + Na$^+$, 376.1161, found: 376.1155.

1H NMR (400 MHz, CDCl$_3$) $\delta$ 7.52 (d, $J = 7.9$ Hz, 1H), 7.46 (d, $J = 7.4$ Hz, 1H), 7.23 (s, 1H), 7.17 (td, $J = 7.8$, 1.3 Hz, 1H), 7.09 (dd, $J = 7.9$, 1.1 Hz, 1H), 7.03 (td, $J = 7.5$, 0.9 Hz, 1H), 6.86 (d, $J = 7.9$ Hz, 1H), 6.55 (s, $OH$, 1H), 4.52 (q, $J = 7.2$ Hz, 2H), 2.34 (s, 3H), 1.66 (s, 3H), 1.48 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 165.7, 156.3, 149.3, 142.1, 136.4, 133.4, 133.0, 130.9, 128.7, 128.5, 127.6, 124.0, 122.1, 110.6, 103.6, 63.4, 50.1, 21.8, 21.8, 14.2; HRMS (ESI) m/z calculated for C$_{20}$H$_{19}$NO$_4$ + Na$^+$, 360.1212, found: 360.1198.

1H NMR (400 MHz, CDCl$_3$) $\delta$ 7.57 (d, $J = 8.7$ Hz, 1H), 7.45 (d, $J = 7.4$ Hz, 1H), 7.17 (t, $J = 7.7$ Hz, 1H), 7.02 (t, $J = 7.5$ Hz, 1H), 6.93 (d, $J = 2.5$ Hz, 1H), 6.85 (d, $J = 7.9$ Hz, 1H), 6.76 (dd, $J = 8.7$, 2.6 Hz, 1H), 6.63 (s, $OH$, 1H), 4.51 (q, $J = 7.1$ Hz, 2H), 4.01 (q, $J = 7.0$ Hz, 2H), 1.64 (s, 3H), 1.47 (t, $J = 7.1$ Hz, 3H), 1.39 (t, $J = 7.0$ Hz, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 165.9, 161.3, 156.3, 147.2, 135.9, 132.9, 132.8, 132.5, 128.6, 123.8, 122.1, 114.0, 112.4, 110.6, 103.6, 63.6, 63.0, 50.5, 21.8, 14.6, 14.2; HRMS (ESI) m/z calculated for C$_{21}$H$_{21}$NO$_5$ + Na$^+$, 390.1317; found: 390.1306.
$^1$H NMR (400 MHz, CDCl$_3$) δ 7.43 (d, $J = 7.4$ Hz, 1H), 7.15 (t, $J = 7.7$ Hz, 1H), 6.99 (t, $J = 7.5$ Hz, 1H), 6.84 (d, $J = 7.9$ Hz, 1H), 6.72 (s, 1H), 6.52 (d, $J = 2.4$ Hz, 1H), 6.30 (d, $J = 2.2$ Hz, 1H), 4.47 (q, $J = 7.1$ Hz, 2H), 3.89 (s, 3H), 3.78 (s, 3H), 1.61 (s, 3H), 1.46 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) δ 166.1, 163.1, 157.9, 156.4, 145.1, 137.3, 132.8, 128.6, 123.7, 122.5, 122.0, 110.6, 104.4, 103.7, 96.7, 62.9, 56.3, 55.4, 50.7, 21.4, 14.1; HRMS (ESI) m/z calculated for C$_{21}$H$_{21}$NO$_6$ + Na$^+$, 406.1267; found: 406.1277.

NCO$_2$Et
MeO
OH
and
NCO$_2$Et
Me
OH

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.44 (d, $J = 7.4$ Hz, 1H), 7.35 (d, $J = 8.9$ Hz, 1H), 7.17 – 7.08 (m, 2H), 7.00 – 6.90 (m, 3H), 6.83 (d, $J = 7.9$ Hz, 1H), 6.55 (s, $OH$, 0.3H), 5.30 (s, 1H), 4.54 – 4.39 (m, 2.5H), 2.54 (s, 3H), 2.51 (s, 1H), 2.30 (s, 4H), 2.29 (s, 1H), 1.63 (s, 1H), 1.60 (s, 3H), 1.45 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) δ 166.0, 164.9, 158.2, 149.3, 146.0, 141.0, 139.0, 139.0, 135.8, 133.5, 132.5, 131.3, 130.5 (two $^{13}$C), 128.4, 128.3, 125.6, 125.3, 124.7, 124.0, 123.9, 122.0, 121.5, 116.0, 110.5, 110.1, 79.9, 62.7, 62.1, 45.5, 31.5, 30.1, 26.7, 21.7, 21.6, 17.7, 14.2, 14.1; HRMS (ESI) m/z calculated for C$_{21}$H$_{21}$NO$_4$ + Na$^+$ (3f), 374.1368; found: 374.1358; C$_{21}$H$_{21}$NO$_3$ + Na$^+$, 358.1419; found: 358.1411 (4f).

NCO$_2$Pr
MeO
OH
and
NCO$_2$Pr
Me
OH

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.47 – 7.40 (m, 1H), 7.20 – 7.09 (m, 1H), 7.04 – 6.92 (m, 1H), 6.87 – 6.80 (m, 2H), 6.76 (d, $J = 2.7$ Hz, 1H), 6.69 – 6.61 (m, 1H), 5.28 (s, 1H), 4.57 – 4.35 (m, 2H), 3.78 (s, 3H), 3.77 (s, 1H), 2.56 (s, 3H), 2.54 (s, 1H), 1.62 (s, 1H), 1.58 (s, 3H), 1.49 – 1.40 (m, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) δ 166.1, 164.9, 161.3, 161.0, 158.2, 156.3, 147.2, 141.6, 141.4, 141.6, 136.1, 133.7, 133.3, 132.2, 131.2, 128.5, 128.4, 123.8, 123.7, 122.0, 121.5, 113.6, 113.6, 111.2, 110.6, 110.6, 110.1, 103.6, 79.7, 62.5, 62.0, 55.3, 50.6, 45.8, 26.5, 21.6, 18.1, 18.1, 14.2, 14.1; HRMS (ESI) m/z calculated for C$_{21}$H$_{21}$NO$_4$ + Na$^+$ (3g), 374.1368; found: 374.1381; C$_{21}$H$_{21}$NO$_3$ + Na$^+$, 390.1317; found: 390.1330 (4g).

NCO$_2$Pr
MeO
OH
and
NCO$_2$Pr
Me
OH

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.58 (d, $J = 8.7$ Hz, 1H), 7.43 (d, $J = 7.4$ Hz, 1H), 7.16 (t, $J = 7.7$ Hz, 1H), 7.01 (t, $J = 7.4$ Hz, 1H), 6.94 (s, 1H), 6.85 (d, $J = 8.0$ Hz, 1H), 6.78 (d, $J = 8.7$ Hz, 1H), 6.57 (s,
$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.61 – 7.49 (m, 1H), 7.42 (d, $J = 7.4$ Hz, 1H), 7.16 (t, $J = 7.7$ Hz, 1H), 7.00 (t, $J = 7.4$ Hz, 1H), 6.93 (s, 1H), 6.84 (d, $J = 8.1$ Hz, 1H), 6.77 (dd, $J = 8.6$, 1.7 Hz, 1H), 6.61 (s, $OH$, 1H), 5.53 – 5.39 (m, 1H), 3.80 (s, 3H), 2.10 – 1.99 (m, 2H), 1.99 – 1.89 (m, 2H), 1.89 – 1.78 (m, 2H), 1.74 – 1.57 (m, 5H); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 165.8, 161.7, 156.3, 147.8, 135.7, 132.9, 132.7, 129.6, 128.6, 123.7, 122.0, 115.3, 113.4, 112.0, 110.6, 103.7, 80.1, 55.5, 50.4, 32.6, 32.5, 23.9, 23.8, 21.7; HRMS (ESI) m/z calculated for C$_{23}$H$_{23}$NO$_5$ + Na$^+$, 416.1474; found: 416.1465.

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.66 (d, $J = 8.7$ Hz, 0.2H), 7.60 (d, $J = 8.7$ Hz, 1H), 7.44 (d, $J = 7.3$ Hz, 1H), 7.16 (t, $J = 7.7$ Hz, 1H), 7.01 (t, $J = 7.4$ Hz, 1H), 6.94 (d, $J = 2.7$ Hz, 1H), 6.85 (d, $J = 7.9$ Hz, 1H), 6.78 (dd, $J = 8.7$, 2.7 Hz, 1H), 6.59 (s, $OH$, 1H), 5.32 (s, 0.2H), 4.28 (d, $J = 7.3$ Hz, 2H), 3.80 (s, 0.6H), 3.79 (s, 3H), 1.65 (s, 3H), 1.62 (s, 0.6H), 1.36 (m, 0.6H), 0.91 – 0.82 (m, 0.6H), 0.66 (q, $J = 5.5$ Hz, 2H), 0.43 (q, $J = 5.1$ Hz, 2H); $^{13}$C NMR (151 MHz, CDCl$_3$) $\delta$ 165.9, 161.9, 156.3, 147.5, 135.9, 132.9, 132.7, 128.7, 123.8, 122.1, 113.6, 112.0, 110.7, 103.6, 71.9, 55.5, 50.5, 21.7, 9.8, 3.8 (two $^{13}$C); HRMS (ESI)
m/z calculated for C_{22}H_{21}NO_5 + Na^+ (3k), 402.1317; found: 402.1300; C_{22}H_{21}NO_4 + Na^+ (4k), 386.1368; found: 386.1347.

$\begin{align*}
\text{MeO} & \quad \text{CO}_2\text{Bu}^+ \\
\text{4l}
\end{align*}$

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.60 (d, $J = 8.7$ Hz, 1H), 7.41 (d, $J = 7.5$ Hz, 1H), 7.13 (t, $J = 7.7$ Hz, 1H), 7.01 – 6.92 (m, 2H), 6.83 (d, $J = 7.9$ Hz, 1H), 6.78 (dd, $J = 8.7$, 1.7 Hz, 1H), 5.25 (s, 1H), 3.80 (s, 3H), 1.64 (s, 9H), 1.61 (s, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 163.7, 161.4, 158.2, 150.6, 133.7, 133.5, 133.1, 132.6, 128.5, 123.7, 121.5, 112.9, 111.8, 110.1, 83.1, 80.0, 55.4, 45.6, 28.1, 26.8; HRMS (ESI) m/z calculated for C_{22}H_{23}NO_4 + H^+, 366.1705; found: 366.1695.

$\begin{align*}
\text{MeO} & \quad \text{CO}_2\text{Bn} \\
\text{3m}
\end{align*}$

$\begin{align*}
\text{and} \quad \text{MeO} & \quad \text{CO}_2\text{Bn} \\
\text{4m}
\end{align*}$

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.64 (d, $J = 8.7$ Hz, 1H), 7.58 (d, $J = 8.6$ Hz, 0.3H), 7.51 (d, $J = 7.4$ Hz, 2H), 7.44 – 7.32 (m, 4.5H), 7.18 – 7.12 (m, 1.4H), 7.06 – 6.92 (m, 2.5H), 6.87 – 6.73 (m, 2.4H), 6.46 (s, OH, 0.3H), 5.49 (d, $J = 12.5$ Hz, 1H), 5.44 (d, $J = 12.4$ Hz, 1H), 5.32 (s, 1H), 5.31 (s, 3H), 3.81 (s, 3H), 1.64 (s, 1H), 1.61 (s, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 164.5, 161.8, 158.1, 149.0, 135.5, 133.7, 133.0, 132.9, 128.7, 128.6, 128.5, 128.4, 123.7, 123.1, 121.1, 121.7, 113.5, 113.1, 111.9, 110.6, 110.2, 103.6, 79.9, 68.2, 67.7, 55.5, 45.6, 31.6, 26.9, 21.7, 14.1; HRMS (ESI) m/z calculated for C_{25}H_{21}NO_4 + Na^+ (3m), 422.1368; found: 422.1361; C_{25}H_{21}NO_5 + Na^+ (4m), 416.1493; found: 416.1484.

$\begin{align*}
\text{Me} & \quad \text{N} \quad \text{O} \\
\text{4n}
\end{align*}$

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.59 (d, $J = 3.4$ Hz, NH, 1H), 7.52 (d, $J = 7.4$ Hz, 1H), 7.37 (d, $J = 7.9$ Hz, 1H), 7.26 (s, 1H), 7.13 (t, $J = 7.7$ Hz, 1H), 7.07 (d, $J = 7.9$ Hz, 1H), 6.98 (t, $J = 7.4$ Hz, 1H), 6.83 (d, $J = 8.0$ Hz, 1H), 5.49 (s, 1H), 3.02 (d, $J = 5.1$ Hz, 3H), 2.33 (s, 3H), 1.59 (s, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 164.3, 158.5, 152.4, 141.1, 136.8, 133.2, 132.0, 129.7, 128.6, 128.3, 127.3, 123.9, 121.4, 110.2, 77.9, 45.1, 26.8, 26.2, 21.7; HRMS (ESI) m/z calculated for C_{19}H_{18}N_2O_2 + Na^+, 329.1266; found: 329.1248.

$\begin{align*}
\text{MeO} & \quad \text{N} \\
\text{3o}
\end{align*}$
$\text{H NMR (400 MHz, CDCl}_3 \delta 8.49 (s, OH, 1H), 7.84 (d, J = 4.2 Hz, NH, 1H), 7.50 (d, J = 7.4 Hz, 1H), 7.39 (d, J = 8.6 Hz, 1H), 7.16 (t, J = 7.7 Hz, 1H), 7.02 (t, J = 7.5 Hz, 1H), 6.92 (d, J = 2.6 Hz, 1H), 6.86 (d, J = 7.9 Hz, 1H), 6.75 (dd, J = 8.6, 2.6 Hz, 1H), 3.78 (s, 3H), 3.01 (d, J = 5.2 Hz, 3H), 1.63 (s, 3H);}$

$\text{13C NMR (101 MHz, CDCl}_3 \delta 166.0, 161.3, 156.5, 147.5, 136.7, 132.7, 131.9, 131.4, 128.5, 123.8, 121.9, 113.7, 112.1, 110.7, 104.5, 55.5, 50.4, 26.0, 21.9; HRMS (ESI) m/z calculated for } \text{C}_{19}\text{H}_{18}\text{N}_2\text{O}_4^+ \text{ Na}^+, 361.1164; \text{found: 361.1156.}$

$\text{H NMR (400 MHz, CDCl}_3 \delta 8.59 (s, OH, 1H), 7.95 (d, J = 4.1 Hz, NH, 1H), 7.48 (d, J = 7.3 Hz, 1H), 7.16 (t, J = 7.7 Hz, 1H), 7.00 (t, J = 7.4 Hz, 1H), 6.85 (d, J = 7.9 Hz, 1H), 6.52 (d, J = 2.4 Hz, 1H), 6.30 (d, J = 2.3 Hz, 1H), 3.87 (s, 3H), 3.78 (s, 3H), 2.99 (d, J = 5.1 Hz, 3H), 1.61 (s, 3H);}$

$\text{13C NMR (101 MHz, CDCl}_3 \delta 166.3, 162.3, 157.0, 156.6, 145.6, 138.0, 132.8, 128.5, 123.8, 121.9, 110.7, 104.7, 104.5, 97.0, 56.1, 55.4, 50.6, 26.0, 21.6; HRMS (ESI) m/z calculated for } \text{C}_{20}\text{H}_{20}\text{N}_2\text{O}_5^+ \text{ Na}^+, 391.1270; \text{found: 391.1258.}$

$\text{H NMR (400 MHz, CDCl}_3 \delta 7.77 (s, NH, 1H), 7.34 – 7.22 (m, 2H), 7.09 – 7.02 (m, 2H), 6.98 (t, J = 7.4 Hz, 1H), 6.88 (d, J = 7.4 Hz, 1H), 6.61 (s, OH, 1H), 3.93 (s, 3H), 2.94 (d, J = 5.1 Hz, 3H), 2.78 (s, 3H), 2.31 (s, 3H);}$

$\text{13C NMR (101 MHz, CDCl}_3 \delta 167.9, 158.3, 154.0, 145.7, 144.8, 140.7, 139.7, 130.5, 130.2, 129.4, 129.2, 127.8, 122.5, 120.7, 117.9, 99.9, 55.4, 26.5, 18.1, 16.4; HRMS (ESI) m/z calculated for } \text{C}_{21}\text{H}_{20}\text{N}_2\text{O}_4^+ \text{ H}^+, 353.1496; \text{found: 353.1489.}$

$\text{H NMR (400 MHz, CDCl}_3 \delta 7.37 (d, J = 8.6 Hz, 1H), 7.23 (d, J = 7.5 Hz, 1H), 7.16 – 7.08 (m, 2H), 6.91 (t, J = 7.4 Hz, 1H), 6.83 (d, J = 8.0 Hz, 1H), 6.80 (d, J = 8.6, 2.7 Hz, 1H), 5.46 (s, 1H), 3.85 (s, 3H), 3.10 (s, 3H), 3.01 (s, 3H), 1.68 (s, 3H);}$

$\text{13C NMR (101 MHz, CDCl}_3 \delta 167.8, 160.5, 157.6, 155.6, 133.5, 133.3, 131.9, 130.8, 128.6, 123.6, 121.7, 112.9, 111.7, 110.0, 81.9, 55.5, 45.2, 38.2, 35.2, 27.6; HRMS (ESI) m/z calculated for } \text{C}_{20}\text{H}_{20}\text{N}_2\text{O}_4^+ \text{ H}^+, 337.1547; \text{found: 337.1533.}$
\[
\text{EtO} - \begin{array}{c}
\text{NMe}_2 \\
\text{3s}
\end{array} - \text{COMe}
\]

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.35\) (d, \(J = 8.6\) Hz, 1H), \(7.23\) (d, \(J = 7.5\) Hz, 1H), \(7.16 - 7.07\) (m, 2H), \(6.91\) (t, \(J = 7.4\) Hz, 1H), \(6.83\) (d, \(J = 8.0\) Hz, 1H), \(6.78\) (dd, \(J = 8.6, 2.6\) Hz, 1H), \(5.46\) (s, 1H), \(4.06\) (q, \(J = 7.0\) Hz, 2H), \(3.10\) (s, 3H), \(3.00\) (s, 3H), \(1.68\) (s, 3H), \(1.43\) (t, \(J = 7.0\) Hz, 3H); \(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta 167.8, 159.9, 157.6, 155.5, 133.6, 133.2, 131.9, 131.0, 128.6, 123.7, 121.7, 113.4, 112.2, 109.9, 81.9, 63.8, 45.2, 38.2, 35.2, 27.7, 14.8; HRMS (ESI) m/z calculated for C\(_{21}\)H\(_{22}\)N\(_2\)O\(_3\) + H\(^+\), 351.1709; found: 351.1716.

\[
\text{MeO} - \begin{array}{c}
\text{NMe}_2 \\
\text{3t}
\end{array} - \text{COMe}
\]

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.27\) (dd, \(J = 7.5, 0.8\) Hz, 1H), \(7.10\) (td, \(J = 8.0, 1.3\) Hz, 1H), \(6.95 - 6.87\) (m, 2H), \(6.82\) (d, \(J = 8.0\) Hz, 1H), \(6.66\) (d, \(J = 2.6\) Hz, 1H), \(5.44\) (s, 1H), \(3.81\) (s, 3H), \(3.12\) (s, 3H), \(3.09\) (s, 3H), \(2.43\) (s, 3H), \(1.64\) (s, 3H); \(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta 167.8, 159.8, 157.8, 153.0, 139.5, 133.8, 132.1, 128.4, 123.7, 121.6, 113.6, 110.4, 109.9, 81.3, 55.3, 45.4, 38.5, 35.6, 27.3, 18.2; HRMS (ESI) m/z calculated for C\(_{21}\)H\(_{22}\)N\(_2\)O\(_3\) + H\(^+\), 351.1703; found: 351.1692.

\[
\text{MeO} - \begin{array}{c}
\text{OH} \\
\text{3u}
\end{array} - \text{CO}_2\text{Me}
\]

and

\[
\text{MeO} - \begin{array}{c}
\text{4u}
\end{array} - \text{CO}_2\text{Me}
\]

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 7.64\) (d, \(J = 8.7\) Hz, 1H), \(7.58\) (d, \(J = 8.7\) Hz, 0.2H), \(7.22\) (s, 1.3H), \(7.01\) (d, \(J = 2.7\) Hz, 1.1H), \(6.98 - 6.89\) (m, 1.5H), \(6.81\) (dd, \(J = 8.7, 2.7\) Hz, 1.3H), \(6.75 - 6.69\) (m, 1.2H), \(6.43\) (s, \(OH\), 0.2H), \(5.28\) (s, 1H), \(4.03\) (s, 0.4H), \(4.00\) (s, 3H), \(3.82\) (s, 3H), \(3.81\) (s, 0.5H), \(2.34\) (s, 0.5H), \(2.33\) (s, 3H), \(1.62\) (s, 0.6H), \(1.59\) (s, 3H); \(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \(\delta 165.1, 161.7, 156.1, 149.0, 133.9, 133.6, 132.9, 132.7, 131.1, 128.9, 124.1, 113.4, 111.6, 109.7, 79.8, 55.5, 53.2, 45.6, 26.9, 21.0; HRMS (ESI) m/z calculated for C\(_{23}\)H\(_{19}\)NO\(_4\) + H\(^+\) (3u), 360.1211; found: 360.1199; C\(_{23}\)H\(_{19}\)NO\(_4\) + H\(^+\) (4u), 338.1387; found: 338.1377.
$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.64 (d, $J = 8.6$ Hz, 1H), 7.58 (d, $J = 8.7$ Hz, 0.4H), 7.22 (s, 1.4H), 7.00 (s, 1H), 6.98 – 6.88 (m, 1.8H), 6.84 – 6.76 (m, 1.5H), 6.73 (t, $J = 6.8$ Hz, 1.4H), 6.51 (s, 0.4H), 5.28 (s, 1H), 4.57 – 4.40 (m, 2.8H), 3.82 (s, 4H), 2.33 (s, 4H), 1.62 (s, 1H), 1.59 (s, 3H), 1.50 – 1.39 (m, 4H); $^1$C NMR (101 MHz, CDCl$_3$): $\delta$ 165.8, 164.7, 161.8, 161.6, 156.1, 154.2, 149.4, 147.6, 136.0, 133.8, 133.7, 132.9, 132.7, 132.7, 131.5, 131.0, 129.0, 128.9, 124.3, 124.2, 113.8, 113.3, 111.7, 111.6, 110.1, 109.7, 103.6, 79.9, 63.0, 62.3, 55.5, 50.5, 45.6, 26.8, 21.7, 21.1, 21.0, 14.3, 14.2; HRMS (ESI) m/z calculated for C$_{21}$H$_{21}$NO$_5$ + Na$^+$ (3v), 390.1317, found: 390.1315; C$_{21}$H$_{21}$NO$_4$ + Na$^+$, 374.1368 (4v), found: 374.1375.

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.68 – 7.61 (m, 1H), 7.58 (d, $J = 8.7$ Hz, 0.2H), 7.02 – 6.92 (m, 2.2H), 6.84 – 6.77 (m, 1.3H), 6.74 (m, 1.2H), 6.70 – 6.62 (m, 1.3H), 6.42 (s, 0H, 0.2H), 5.28 (s, 1H), 4.02 (s, 1H), 4.00 (s, 3H), 3.81 (s, 3H), 3.80 (s, 1H), 3.78 (s, 3.4H), 1.61 (s, 1H), 1.58 (s, 3H); $^1$C NMR (101 MHz, CDCl$_3$): $\delta$ 165.1, 161.8, 155.0, 152.3, 149.0, 134.0, 133.6, 133.5, 132.8, 113.7, 113.2, 112.7, 111.9, 110.9, 110.6, 109.7, 103.6, 79.9, 56.1, 55.5, 53.2, 45.9, 26.8, 21.7; HRMS (ESI) m/z calculated for C$_{20}$H$_{19}$NO$_5$ + Na$^+$ (3w), 376.1161, found: 376.1153; C$_{20}$H$_{19}$NO$_6$ + Na$^+$ (4w), 392.1110, found: 392.0999.

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 7.65 (d, $J = 8.7$ Hz, 1H), 7.59 (d, $J = 8.7$ Hz, 0.2H), 7.16 – 7.08 (m, 1.2H), 6.94 (d, $J = 2.7$ Hz, 1H), 6.89 (d, $J = 2.7$ Hz, 0.2H), 6.86 – 6.78 (m, 2.2H), 6.77 – 6.70 (m, 1.2H), 6.55 (s, OH, 0.2H), 5.33 (s, 1H), 4.03 (s, 0.5H), 4.00 (s, 3H), 3.82 (s, 3H), 3.81 (s, 0.6H), 1.61 (s, 0.6H), 1.59 (s, 3H); $^1$C NMR (101 MHz, CDCl$_3$): $\delta$ 165.0, 161.9, 159.2, 156.8, 154.1, 148.5, 134.4, 134.4, 133.5, 133.0, 132.9, 115.0, 114.7, 113.6, 113.1, 112.1, 111.1, 110.8, 110.5, 110.6, 104.0, 55.5, 53.6, 53.2, 45.9, 26.8, 26.6, 21.6; HRMS (ESI) m/z calculated for C$_{19}$H$_{16}$FNO$_5$ + Na$^+$ (3x), 380.0910, found: 380.0894; C$_{19}$H$_{16}$FNO$_4$ + Na$^+$ (4x), 364.0961, found: 364.0944.
$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.65 (d, $J = 8.7$ Hz, 1H), 7.11 (d, $J = 7.7$ Hz, 1H), 6.94 (s, 1H), 6.87 – 6.78 (m, 2H), 6.77 – 6.68 (m, 1H), 5.33 (s, 1H), 4.57 – 4.41 (m, 2H), 3.82 (s, 3H), 1.59 (s, 3H), 1.44 (t, $J = 7.1$ Hz, 3H); $^1$C NMR (101 MHz, CDCl$_3$) $\delta$ 164.5, 161.8, 159.2, 156.8, 154.1, 149.0, 134.4, 133.6, 132.9, 114.9, 114.7, 113.0, 112.0, 111.1, 110.8, 110.6, 110.5, 108.3, 62.4, 55.5, 45.9, 26.6, 14.3; HRMS (ESI) m/z calculated for C$_{20}$H$_{18}$FNO$_4$ + Na$^+$, 378.1118; found: 378.1116.

and

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.60 (d, $J = 8.7$ Hz, 1H), 7.60 (d, $J = 8.7$ Hz, 1H), 7.41 – 7.33 (m, 2H), 7.17 – 7.04 (m, 2H), 6.95 (s, 1H), 6.89 (s, 1H), 6.82 (t, $J = 8.0$ Hz, 2H), 6.76 (dd, $J = 8.4$, 3.9 Hz, 2H), 6.59 (s, $OH$, 1H), 5.34 (s, 1H), 4.04 (s, 3H), 4.01 (s, 3H), 3.84 (s, 3H), 3.83 (s, 3H), 1.62 (s, 3H), 1.60 (s, 3H); $^1$C NMR (101 MHz, CDCl$_3$) $\delta$ 166.1, 164.9, 162.1, 161.9, 156.8, 154.9, 148.4, 146.6, 135.2, 134.9, 134.8, 133.5, 132.9, 132.5, 128.6, 128.52 126.8, 126.4, 124.0, 123.9, 113.8, 113.2, 112.1, 112.0, 111.7, 111.2, 104.1, 80.3, 55.6, 53.7, 53.3, 50.7, 45.8, 26.8, 21.6; HRMS (ESI) m/z calculated for C$_{19}$H$_{16}$ClNO$_4$ + Na$^+$ (5a), 380.0666, found: 380.0653; C$_{19}$H$_{16}$ClNO$_4$ + Na$^+$ (6a), 396.0615, found: 396.0601.

$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.60 (d, $J = 8.7$ Hz, 1H), 7.37 (s, 1H), 7.12 (d, $J = 8.4$ Hz, 1H), 6.89 (s, 1H), 6.81 (d, $J = 8.7$ Hz, 1H), 6.76 (d, $J = 8.4$ Hz, 1H), 6.68 (s, $OH$, 1H), 4.51 (q, $J = 7.0$ Hz, 2H), 3.82 (s, 3H), 1.62 (s, 3H), 1.47 (t, $J = 7.1$ Hz, 3H); $^1$C NMR (101 MHz, CDCl$_3$) $\delta$ 165.8, 162.0, 155.0, 146.9, 135.1, 134.9, 133.0, 132.6, 128.5, 126.7, 124.0, 113.7, 112.0, 111.7, 104.2, 63.1, 55.6, 50.7, 26.9, 21.6, 14.1; HRMS (ESI) m/z calculated for C$_{20}$H$_{18}$ClNO$_3$ + Na$^+$, 410.0771; found: 410.0784.
$^1$H NMR (400 MHz, CDCl$_3$) δ 7.60 (d, $J = 8.7$ Hz, 1H), 7.52 (d, $J = 2.0$ Hz, 1H), 7.27 (dd, $J = 8.4$, 2.1 Hz, 1H), 6.89 (d, $J = 2.7$ Hz, 1H), 6.82 (dd, $J = 8.7$, 2.7 Hz, 1H), 6.72 (d, $J = 8.4$ Hz, 1H), 6.60 (s, OH, 1H), 4.03 (s, 3H), 3.82 (s, 3H), 1.62 (s, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) δ 166.1, 162.1, 155.5, 146.6, 135.3, 135.1, 133.0, 132.5, 131.5, 126.8, 113.9, 113.8, 112.3, 112.1, 104.1, 55.6, 53.6, 50.7, 21.6; HRMS (ESI) m/z calculated for C$_{19}$H$_{16}$BrNO$_5$ $^+ \text{Na}^+$, 440.0110; found: 440.0108.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.60 (d, $J = 8.7$ Hz, 1H), 7.51 (s, 1H), 7.26 (d, $J = 9.4$ Hz, 2H), 6.88 (s, 1H), 6.85 – 6.78 (m, 1H), 6.72 (d, $J = 8.4$ Hz, 1H), 6.69 (s, OH, 1H), 4.51 (q, $J = 7.1$ Hz, 2H), 3.82 (s, 3H), 1.61 (s, 3H), 1.47 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (101 MHz, CDCl$_3$) δ 165.8, 162.0, 155.5, 146.9, 135.4, 135.0, 133.0, 132.6, 131.5, 126.8, 113.8, 113.7, 112.3, 112.0, 104.2, 63.1, 55.6, 50.7, 21.6, 14.1; HRMS (ESI) m/z calculated for C$_{20}$H$_{18}$BrNO$_5$ $^+ \text{Na}^+$, 454.0266; found: 454.0255.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.76 (d, $J = 8.6$ Hz, 1H), 7.70 (d, $J = 8.7$ Hz, 0.3H), 7.46 (d, $J = 7.4$ Hz, 0.3H), 7.36 (d, $J = 7.4$ Hz, 1.2H), 7.22 (m, 5.6H), 7.11 – 6.86 (m, 6.4H), 6.82 (s, 1.4H), 6.73 (s, 0.4H), 6.63 (s, OH, 0.4H), 5.53 (s, 1H), 4.52 – 4.33 (m, 2.7H), 3.74 (s, 3H), 3.71 (s, 0.8H), 1.46 – 1.33 (m, 4H); $^{13}$C NMR (101 MHz, CDCl$_3$) δ 164.4, 161.9, 161.7, 159.6, 148.7, 143.0, 135.2, 132.6, 132.0, 131.9, 129.8, 128.9, 128.8, 128.7, 128.1, 127.9, 127.6, 127.5, 126.2, 125.8, 122.1, 122.0, 115.2, 114.9, 113.1, 112.9, 111.0, 110.3, 103.1, 81.7, 63.1, 62.4, 60.2, 55.6, 55.5, 14.2, 14.1; HRMS (ESI) m/z calculated for C$_{25}$H$_{22}$NO$_5$ $^+ \text{H}^+$ (5e), 416.1493, found: 416.1491; C$_{25}$H$_{22}$NO$_4$ $^+ \text{H}^+$ (6e), 400.1543, found: 400.1540.

$^1$H NMR (400 MHz, CDCl$_3$) δ 7.29 (dd, $J = 8.0$, 1.6 Hz, 1H), 7.05 – 6.97 (m, 1H), 6.92 (d, $J = 2.6$ Hz, 1H),
1H), 6.89 – 6.81 (m, 2H), 6.60 – 6.48 (m, 2H), 5.40 (s, NH, 1H), 3.91 (s, 3H), 3.73 (s, 3H), 2.47 (dd, \( J = 12.9, 1.7 \) Hz, 1H), 2.13 (d, \( J = 12.9 \) Hz, 1H), 1.85 (s, 3H); \(^{13}\)C NMR (101 MHz, CDCl\(_3\)) \( \delta \) 169.1, 153.1, 152.1, 133.6, 130.6, 129.5, 127.2, 125.4, 121.2, 117.0, 114.7, 111.9, 110.3, 83.2, 55.8, 53.2, 36.0, 33.3, 23.2; HRMS (ESI) m/z calculated for C\(_{19}\)H\(_{19}\)NO\(_4\) + Na\(^+\), 348.1206, found: 348.1218.
$^1$H and $^{13}$C spectra

![Chemical Structures](image)
The image contains a chemical structure labeled as 3c with chemical entities such as Me, N, CO₂Et, and OH. The structure is accompanied by a 1H NMR spectrum with various peaks indicating the presence of different chemical shifts. The spectrum includes peaks at different chemical shifts ranging from 0.0 to 7.5 parts per million (ppm).
EtO-3d

\[
\begin{align*}
\text{EtO} & \quad \text{N} \\
\text{OH} & \quad \text{CO}_2\text{Et}
\end{align*}
\]
and

**3u**

**4u**
\[ \text{MeO} \] 
\[ \text{\textbf{MeO}} \text{\textbf{N}} \text{\textbf{CO}_2\text{Me}} \] 
\[ \text{MeO} \text{\textbf{O}} \text{\textbf{OH}} \] 
\[ \text{MeO} \] 
\[ \text{\textbf{MeO}} \text{\textbf{N}} \text{\textbf{CO}_2\text{Me}} \] 

and

\[ \text{MeO} \] 
\[ \text{\textbf{MeO}} \text{\textbf{N}} \text{\textbf{CO}_2\text{Me}} \] 
\[ \text{MeO} \text{\textbf{O}} \text{\textbf{OH}} \] 
\[ \text{MeO} \] 
\[ \text{\textbf{MeO}} \text{\textbf{N}} \text{\textbf{CO}_2\text{Me}} \] 

3w

and

4w
and

$\text{5a}$

$\text{6a}$