Supporting Information

Copper-Catalysed Aerobic Oxidative Esterification of N-Heteroaryl Methanes with Alcohols

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General information

All reactions were carried out in oven-dried Schlenk tubes under O₂ atmosphere. Dry solvents were obtained by purification according to standard methods. Reagents were used as received unless otherwise noted. ¹H NMR, ¹³C NMR and ³¹P NMR data were obtained on a Bruker-400 spectrometer (400 MHz for ¹H, 100 MHz for ¹³C, and 162 MHz for ³¹P NMR spectroscopy). Data are reported as follows: Chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), Coupling constants (J) are reported in hertz. Mass spectra were measured on a Shimadzu GCMS-QP2010 Plus spectrometer (EI).

A typical procedure for the synthesis of esters

Under O₂ atmosphere, 0.2 mmol 2-methylquinoline, 1mL EtOH, 10 mol% CuI, 20 mol% Ph₂P(O)OH, 1 mL dioxane, 1 atm O₂ were charged into a 10 mL schlenk tube, and then the mixture was stirred at 120 °C for 24 h. After removal of the volatiles, the residues were passed through a short silica chromatography (particle size 37–54 μm, petroleum ether/ethyl acetate as eluent) to
afford analytically pure product 3a.

**Preparation of 2-CD$_3$-quinolines**

\[
\begin{array}{c}
\text{3a} \\
+ \text{D}_2\text{O} \quad \text{KOBu-t} \\
\text{THF, N}_2, 120 \degree \text{C} \quad \text{3a-CD}_3 \\
95\% \text{ D}
\end{array}
\]

Under N$_2$ atmosphere, 4 mmol KOBu-t, 1 mmol 2-methylquinoline, 3 mL D$_2$O and 0.3 mL THF were charged into a 25 mL glass tube, the mixture was heated at 120 °C for 16 h. The solution was extracted by ethyl acetate (10 mL), dried by Na$_2$SO$_4$ and evaporated under high vacuum to give an oil mixture. Redeuteration of the resulting oil mixture produced the 2-CD$_3$-quinoline in 68% yield with ca. 95% D.

**Characterization data of product 3**
Following the general procedure, 3a was isolated as a yellow liquid. $^1$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.31 (d, $J = 8.8$ Hz, 1H), 8.29 (d, $J = 8.8$ Hz, 1H), 8.18 (d, $J = 8.4$ Hz, 1H), 7.86 (d, $J = 8.4$ Hz, 1H), 7.78 (t, $J = 8.0$ Hz, 1H), 7.63 (t, $J = 8.0$ Hz, 1H); 4.56 (q, $J = 7.2$ Hz, 2H); 1.49 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 165.4, 148.2, 147.6, 137.2, 130.7, 130.2, 129.3, 128.5, 127.5, 121.0, 62.2, 14.4.

Following the general procedure, 3b was isolated as a white solid. $^1$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.14-8.22 (m, 3H), 7.63 (s, 1H), 7.62 (d, $J = 8.4$ Hz, 1H), 4.56 (q, $J = 7.2$ Hz, 2H), 2.57 (s, 3H), 1.50 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 165.5, 147.4, 146.2, 138.9, 136.4, 132.6, 130.4, 129.4, 126.3, 121.1, 62.1, 21.8, 14.4.

Following the general procedure, 3c was isolated as a yellow solid. $^1$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.21 (d, $J = 9.2$ Hz, 1H), 8.17 (s, 1H), 7.44 (dd, $J = 2.8$ Hz, 9.2 Hz, 1H), 7.11 (d, $J = 2.8$ Hz, 1H), 4.56 (q, $J = 7.2$ Hz, 2H), 3.97 (s, 3H); 1.50 (t, $J = 7.2$ Hz, 3H) $^{13}$C NMR (CDCl$_3$, 100 MHz, TMS) $\delta$ 165.6, 159.4, 145.8, 143.8, 135.6, 132.3, 130.8, 123.4, 121.5, 104.6, 62.1, 55.6, 14.4.

Following the general procedure, 3d was isolated as a yellow solid. $^1$H NMR (CDCl$_3$, 400 MHz, TMS) $\delta$ 8.32 (dd, $J = 5.6$ Hz, 9.6 Hz, 1H), 8.22 (dd, $J = 8.4$ Hz, 20.0 Hz, 1H), 8.22 (d, $J = 11.6$ Hz, 1H), 7.56 (ddd, $J = 2.4$ Hz, 8.8 Hz, 11.2 Hz, 1H), 7.49 (dd, $J = 2.4$ Hz, 8.8 Hz, 1H), 4.57 (q, $J = 7.2$ Hz, 2H), 1.50 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR
(CDCl₃, 100 MHz, TMS) δ 165.2, 162.8 (d, J_F-C = 250.5 Hz), 147.7 (d, J_F-C = 2.9 Hz), 144.7, 136.5 (d, J_F-C = 5.7 Hz), 133.5 (d, J_F-C = 9.5 Hz), 130.1 (d, J_F-C = 10.4 Hz), 121.7, 120.8 (d, J_F-C = 25.9 Hz), 110.5 (d, J_F-C = 21.8 Hz), 62.3, 14.3.

Following the general procedure, 3h was isolated as a yellow solid. ¹H NMR(CDCl₃, 400 MHz) δ 8.25 (d, J = 8.8 Hz, 1H), 8.21 (s, 2H), 7.86 (d, J = 2.4 Hz, 1H), 7.72 (dd, J = 2.4 Hz, 8.8 Hz, 1H), 4.56 (q, J = 7.2 Hz, 2H), 1.50 (t, J = 7.2 Hz, 3H); ¹³C NMR (CDCl₃, 100 MHz) δ 165.1, 148.5, 146.0, 136.3, 134.6, 132.3, 131.3, 129.8, 126.2, 121.9, 62.4, 14.4.

Following the general procedure, 3f was isolated as a yellow solid. ¹H NMR(CDCl₃, 400 MHz) δ 8.19 (s, 2H), 8.17 (d, J = 9.2 Hz, 1H), 8.03 (d, J = 2.0 Hz, 1H), 7.84 (dd, J = 2.0 Hz, 9.2 Hz, 1H), 4.56 (q, J = 7.2 Hz, 2H), 1.49 (t, J = 7.2 Hz, 3H); ¹³C NMR (CDCl₃, 100 MHz, TMS) δ 165.1, 148.5, 146.1, 136.2, 133.8, 132.3, 130.2, 129.6, 122.9, 121.9, 62.4, 14.3.

Following the general procedure, 3g was isolated as a white solid. ¹H NMR(CDCl₃, 400 MHz) δ 8.63 (s, 1H), 8.41 (d, J = 8.8 Hz, 1H), 8.36 (s, 2H), 8.24 (d, J = 8.4 Hz, 1H), 4.58 (q, J = 7.2 Hz, 2H), 4.01 (s, 3H), 1.51 (t, J = 7.2 Hz, 3H); ¹³C NMR (CDCl₃, 100 MHz) δ 166.2, 165.0, 150.2, 149.3, 138.6, 131.0, 130.5, 129.8, 129.6, 128.4, 121.7, 62.5, 52.6, 14.3. HRMS Calcd. for C₁₄H₁₃O₄ (M⁺) 259.0845, found 259.0841, M.P. 96.1-98.3 °C.
Following the general procedure, **3h** was isolated as a yellow solid. $^1$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.86 (d, $J = 2.0$ Hz, 1H), 8.54 (d, $J = 8.0$ Hz, 2H), 8.46 (d, $J = 9.6$ Hz, 1H), 8.34 (d, $J = 8.8$ Hz, 1H), 4.60 (q, $J = 7.2$ Hz, 2H), 1.52 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 164.6, 151.4, 149.4, 146.7, 139.3, 132.6, 128.0, 124.2, 123.6, 122.7, 62.8, 14.3. HMS:246.0623, bp: 163.0-164.2

Following the general procedure, **3i** was isolated as a white solid. $^1$H NMR(CDCl$_3$, 400 MHz) $\delta$ 8.27 (d, $J = 7.6$ Hz, 1H), 7.99 (d, $J = 7.6$ Hz, 1H), 7.54-7.62 (m, 2H), 4.57 (q, $J = 7.2$ Hz, 2H), 1.51 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 160.7, 158.6, 153.2, 136.8, 127.5, 127.1, 125.5, 122.1, 63.1, 14.3.

Following the general procedure, **3j** was isolated as a yellow solid. $^1$H NMR (CDCl$_3$, 400 MHz, TMS) $\delta$ 8.28-8.32 (m, 2H), 8.20 (d, $J = 8.4$ Hz, 1H), 7.87 (d, $J = 8.4$ Hz, 1H), 7.79 (t, $J = 7.6$ Hz, 1H), 7.65 (t, $J = 7.6$ Hz, 1H), 4.09 (s, 3H); $^{13}$C NMR (CDCl$_3$, 100 MHz, TMS) $\delta$ 165.9, 147.9, 147.5, 137.3, 130.7, 130.3, 129.3, 128.6, 127.6, 121.0, 53.2.

Following the general procedure, **3k** was isolated as a yellow liquid. $^1$H NMR(CDCl$_3$, 400 MHz) $\delta$ 8.32 (d, $J = 8.4$ Hz, 1H), 8.28 (d, $J = 8.4$ Hz, 1H), 8.16 (d, $J = 8.4$ Hz, 1H), 7.86 (d, $J = 8.4$ Hz, 1H), 7.77 (dd, $J = 8.4$ Hz, 7.2 Hz, 1H), 7.63 (dd, $J = 8.0$ Hz, 6.8 Hz, 1H), 4.50 (t, $J = 6.8$ Hz, 2H), 1.82-1.89 (m, 2H), 1.46-1.55 (m, 2H), 1.00 (t, $J = 7.6$ Hz, 3H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 165.4, 148.3, 147.6, 137.2, 130.8,
Following the general procedure, 3l was isolated as a yellow liquid. $^{1}$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.32 (d, $J = 8.4$ Hz, 1H), 8.30 (d, $J = 8.4$ Hz, 1H), 8.18 (d, $J = 8.8$ Hz, 1H), 7.88 (d, $J = 8.0$ Hz, 1H), 7.79 (dd, $J = 7.6$ Hz, 7.6 Hz, 1H), 7.65 (t, $J = 7.2$ Hz, 7.6 Hz, 1H), 4.49 (t, $J = 6.8$ Hz, 2H), 1.84-1.91 (m, 2H), 1.29-1.50 (m, 10H), 0.88 (t, $J = 6.4$ Hz, 3H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 165.5, 148.3, 147.7, 137.2, 130.9, 130.2, 129.3, 128.5, 127.5, 121.0, 66.4, 31.8, 29.3, 29.2, 28.7, 25.9, 22.6, 14.1. HRMS Calcd. for C$_{18}$H$_{23}$O$_2$P (M+) 285.1729, found 285.1722

Following the general procedure (9 equiv alcohol, 25 mL glass tube), 3m was isolated as a yellow liquid. $^{1}$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.30-8.33 (m, 2H), 8.20 (d, $J = 8.8$ Hz, 1H), 7.88 (d, $J = 8.4$ Hz, 1H), 7.79 (dd, $J = 8.4$ Hz, 7.2 Hz, 1H), 7.65 (dd, $J = 7.2$ Hz, 7.6 Hz, 1H), 5.49 (dd, $J = 1.2$ Hz, 17.2 Hz, 1H), 5.35 (dd, $J = 0.8$ Hz, 10.4 Hz, 1H), 5.00 (d, $J = 6.0$ Hz, 2H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 165.1, 148.0, 147.6, 137.3, 131.8, 130.8, 130.3, 129.3, 128.6, 127.5, 121.1, 119.2, 66.8.

Following the general procedure, 3n was isolated as a yellow liquid. $^{1}$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.32 (d, $J = 8.8$ Hz, 1H), 8.28 (d, $J = 8.8$ Hz, 1H), 8.15 (d, $J = 8.4$ Hz, 1H), 7.86 (d, $J = 8.4$ Hz, 1H), 7.77 (dd, $J = 8.4$ Hz, 7.2 Hz, 1H), 7.62 (dd, $J = 8.0$ Hz, 6.8 Hz, 1H), 5.35-5.45 (m, 1H), 1.47 (d, $J = 6.4$ Hz, 6H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 164.8, 148.6, 147.7, 137.1, 130.9, 130.1, 129.2, 128.4, 127.4, 121.0, 69.9, 21.9.
Following the general procedure (9 equiv alcohol, 25 mL glass tube), **3o** was isolated as a yellow liquid. $^1$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.19-8.25 (m, 2H), 8.07 (d, $J = 8.4$ Hz, 1H), 7.79 (d, $J = 8.4$ Hz, 1H), 7.69 (dd, $J = 7.6$ Hz, 7.6 Hz, 1H), 7.55 (dd, $J = 7.6$ Hz, 7.6 Hz, 1H), 5.05-5.11 (m, 1H), 1.18-2.01 (m, 10H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 164.6, 148.7, 147.7, 137.1, 130.9, 130.1, 129.2, 128.4, 127.4, 121.0, 74.7, 31.6, 25.4, 23.9; HMQC: HRMS Calcd. for C$_{16}$H$_{17}$NO$_2$ (M$^+$) 255.1259, found 255.1262

Following the general procedure (9 equiv alcohol, 25 mL glass tube), **3p** was isolated as a yellow liquid. $^1$H NMR (CDCl$_3$, 400 MHz, TMS) $\delta$ 8.29-8.32 (m, 2H), 8.16 (d, $J = 8.8$ Hz, 1H), 7.85 (d, $J = 8$ Hz, 1H), 7.77 (t, $J = 7.6$ Hz, 1H), 7.63 (t, $J = 7.4$ Hz, 1H), 7.52 (d, $J = 7.2$ Hz, 2H), 7.34-7.41 (m, 3H), 5.53 (s, 2H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 165.2, 147.9, 147.6, 137.2, 135.7, 130.8, 130.2, 129.3, 128.6, 128.5, 127.5, 121.1, 67.7. HRMS Calcd. for C$_{17}$H$_{13}$NO$_2$ (M$^+$) 263.0946, found 263.0937

Following the general procedure (9 equiv alcohol, 25 mL glass tube), **3q** was isolated as a yellow liquid. $^1$H NMR (CDCl$_3$, 400 MHz) $\delta$ 8.26-8.32 (m, 2H), 8.15 (d, $J = 8.4$ Hz, 1H), 7.87 (d, $J = 8.0$ Hz, 1H), 7.78 (dd, $J = 8.0$ Hz, 8.4 Hz, 1H), 7.64 (dd, $J = 7.2$ Hz, 7.6 Hz, 1H), 7.50 (d, $J = 8.8$ Hz, 1H), 7.22-7.29 (m, 3H), 5.54 (s, 2H), 2.46 (s, 3H); $^{13}$C NMR (CDCl$_3$, 100 MHz) $\delta$ 165.1, 148.0, 147.7, 137.2, 137.1, 133.7, 130.9, 130.4, 130.3, 129.5, 129.3, 128.7, 128.6, 127.5, 126.1, 121.0, 66.1, 19.1; HRMS Calcd. for C$_{18}$H$_{18}$NO$_2$ (M$^+$) 277.1103, found 277.1105.
Following the general procedure (9 equiv alcohol, 25 mL glass tube), 3r was isolated as a white liquid. \( ^1 \)H NMR (CDCl\(_3\), 400 MHz) \( \delta \) 8.29-8.33 (m, 2H), 8.17 (d, \( J = 8.4 \) Hz, 1H), 7.88 (d, \( J = 8.0 \) Hz, 1H), 7.80 (dd, \( J = 7.2 \) Hz, 8.0 Hz, 1H), 7.66 (dd, \( J = 7.6 \) Hz, 7.6 Hz, 1H), 7.47 (d, \( J = 8.4 \) Hz, 2H), 7.37 (d, \( J = 8.0 \) Hz, 2H), 5.50 (s, 2H); \( ^{13} \)C NMR (CDCl\(_3\), 100 MHz) \( \delta \) 165.2, 147.8, 147.7, 137.3, 134.4, 134.2, 130.8, 130.3, 130.0, 129.4, 128.8, 128.7, 127.5, 121.1, 66.9; HRMS Calcd. for C\(_{17}\)H\(_{12}\)NO\(_2\) (M+) 297.0557, found 297.0561

Reference

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Copies of $^1$H NMR and $^{13}$C NMR spectra