Synthesis of benzimidazoles by CuI-catalyzed three-component reaction of 2-haloaniline, ammonia and aldehyde in water

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Supplementary Information

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1. General information

All reagents were purchased from commercial suppliers and used without further purification. All experiments were carried out in hydrothermal reactor (100 mL). Column chromatography was carried out with silica gel (200-300 mesh). Thin layer chromatography was carried out using Merck silica gel GF254 plates. All products were characterized by NMR. $^1$H NMR spectra were recorded at 400 MHz and $^{13}$C NMR spectra were recorded at 100 MHz (Bruker DPX) with Acetonitrile-$d_3$, Acetone-$d_6$ and DMSO-$d_6$ as solvent. Chemical shifts are reported in ppm using TMS as internal standard. Gas chromatography-mass spectra (GC/MS) were recorded on an Agilent Technologies 6890 N instrument with an Agilent 5973N mass detector (EI) and a HP5-MS 30 m $\times$ 0.25 mm capillary apolar column (Stationary phase: 5% diphenylmethylpolysiloxane film, 0.25 μm). GC/MS method: Initial temperature: 150 °C; Initial time: 1 min; Ramp: about 15°C/min until 250 °C then 20 min.

2. General procedure for the catalytic reactions

In a 100 mL hydrothermal reactor 2-iodoanilines (0.5 mmol), aldehyde (0.6 mmol), CuI (0.05 mmol), L1 (0.05 mmol), ammonia (1.0 mL) and Na$_2$CO$_3$ (2.0 equiv) and 2.0 mL water were stirred at 100 °C for 10 h. The reaction mixture was cooled to room temperature, quenched with water (3 mL), and diluted with ethyl acetate (5 mL). The layers were separated and the aqueous layer was extracted with (3 × 10 mL) ethyl acetate. The combined organic extracts were dried over anhydrous magnesium sulfate, filtered, and concentrated in vacuo. The residue was purified by silica-gel (eluent: petroleum ether/EtOAc) column chromatography to afford the corresponding product. All the products were fully characterized by the usual spectroscopic techniques.

3. Synthesis of mebendazole

(1) synthesis of Intermediate (2-amino-1H-benzo[d]imidazol-6-yl)(phenyl)methanone.

In a 100 mL hydrothermal reactor 3-amino-4-bromo-benzophenone (1 mmol), formamide (1.2 mmol), CuI (0.1 mmol), L1 (0.1 mmol), ammonia (2.0 mL) and Na$_2$CO$_3$ (2.0 equiv) and 4.0 mL water were stirred at 100 °C for 10 h. The reaction mixture was cooled to room temperature, quenched with water (6 mL), and diluted with ethyl acetate (10 mL). The layers were separated and the aqueous layer was extracted with (3 × 10 mL) ethyl acetate. The combined organic extracts were dried over anhydrous magnesium sulfate, filtered, and concentrated in vacuo. The residue was purified by silica-gel (eluent: petroleum ether/EtOAc=2:1) column chromatography to afford the Intermediate (2-amino-1H-benzo[d]imidazol-6-yl)(phenyl)methanone, yield 83%.

(2) synthesis of mebendazole

In a 100 mL Flask (2-amino-1H-benzo[d]imidazol-6-yl)(phenyl)methanone (0.5 mmol), methyl carbonochloridate (0.5 mmol), CuI (0.05 mmol), 1,10-Phenanthroline (0.05 mmol), KOH (2.0 equiv) and 10.0 mL DMF were stirred at 120 °C for 24 h. The reaction mixture was cooled to room temperature, quenched with water (10 mL),
and diluted with ethyl acetate (20mL). The layers were separated and the aqueous layer was extracted with (3×10mL) ethyl acetate. The combined organic extracts were dried over anhydrous magnesium sulfate, filtered, and concentrated in vacuo. The residue was purified by silica-gel (eluent: petroleum ether/EtOAc=1:2) column chromatography to afford mebendazole, yield 88%.

4. Experimental procedures and characterization data

2-phenyl-1H-benzo[d]imidazole\(^1\) (Table 2, entry 1):

\[
\text{white solid; mp = 294–295 °C; } ^1\text{H NMR (400 MHz, Acetonitrile-}d_3\text{): } \delta 7.25 – 7.29 \text{ (m, 2H), 7.53 – 7.66 (m, 5H), 8.13 (d, } J = 4.0 \text{ Hz, 2H), 10.95 (s, 1H); } ^{13}\text{C NMR (100 MHz, DMSO-}d_6\text{): } \delta 151.70, 144.29, 135.48, 130.65, 130.30, 129.42, 126.91, 123.00, 122.14, 119.35, 111.79; \text{ IR (KBr): } 3047, 2966, 2846, 1537, 1462, 1441 \text{ cm}^{-1}; \text{ ESI-MS (m/z): 195.1 [M+H]}^+.
\]

5-methyl-2-phenyl-1H-benzo[d]imidazole\(^2\) (Table 2, entry 2):

\[
\text{white solid; mp = 251–252 °C; } ^1\text{H NMR (400 MHz, Acetonitrile-}d_3\text{): } \delta 2.49 \text{ (s, 3H), 7.11 (d, } J = 8.0 \text{ Hz, 1H), 7.40 – 7.62 (m, 5H), 8.11 (d, } J = 8.0 \text{ Hz, 2H), 12.03 (s, 1H); } ^{13}\text{C NMR (100 MHz, DMSO-}d_6\text{): } \delta 151.18, 135.73, 132.30, 130.77, 130.07, 129.34, 126.75, 124.42, 123.69, 118.90, 111.48, 21.83; \text{ IR (KBr): } 3045, 2965, 2863, 1541, 1449, 1402, 1309 \text{ cm}^{-1}; \text{ ESI-MS (m/z): 209.1 [M+H]}^+.
\]

2-(2,4-dimethylphenyl)-5-methyl-1H-benzo[d]imidazole (Table 2, entry 3):

\[
yellow solid; mp = 291–292 °C; \text{ } ^1\text{H NMR (400 MHz, Acetonitrile-}d_3\text{): } \delta 2.40 \text{ (s, 3H), 2.49 (s, 3H), 2.61 (s, 3H), 7.10 (d, } J = 8.0 \text{ Hz, 1H), 7.16 – 7.24 (m, 2H), 7.41 (s, 1H), 7.51 (d, } J = 8.0 \text{ Hz, 1H), 7.62 (d, } J = 8.0 \text{ Hz, 2H), 10.52 (s, 1H); } ^{13}\text{C NMR (100 MHz, DMSO-}d_6\text{): } \delta 151.94, 144.56, 142.37, 139.07, 137.21, 132.37, 129.69, 127.81, 126.97, 123.97, 123.23, 118.86, 111.28, 21.77, 21.49, 21.22; \text{ IR (KBr): } 3020, 2967, 2915, 2658, 1738, 1619, 1452, 1399, 1265, 980, 803 \text{ cm}^{-1}; \text{ ESI-MS (m/z): 237.1 [M+H]}^+.
\]
2-(2-fluorophenyl)-5-methyl-1H-benzo[d]imidazole (Table 2, entry 4):

![Chemical structure](image)

white solid; mp = 251–252 °C; \(^1\)H NMR (400 MHz, Acetone-\(d_6\)): \(\delta\) 2.47 (s, 3H), 7.10 (d, \(J = 8.0\) Hz, 1H), 7.32 – 7.42 (m, 2H), 7.47 (s, 1H), 7.54 (ddd, \(J = 4.0, 8.0, 3.5\) Hz, 2H), 8.45 (t, \(J = 8.0\) Hz, 1H), 11.57 (s, 1H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 161.10, 158.61, 146.42, 141.72, 135.76, 133.59, 131.99 (d, \(J_{C,F} = 8.0\) Hz), 130.58 (d, \(J_{C,F} = 3.0\) Hz), 125.43 (d, \(J_{C,F} = 3.0\) Hz), 123.51, 118.79 (d, \(J_{C,F} = 12.0\) Hz), 117.00 (d, \(J_{C,F} = 21.0\) Hz), 112.00, 21.80; IR (KBr): 3055, 2960, 2962, 2855, 1631, 1586, 1439, 1387, 1317, 1212 cm\(^{-1}\); ESI-MS (m/z): 227.2 [M+H]\(^+\).

5-methyl-2-(pyridin-3-yl)-1H-benzo[d]imidazole\(^1\) (Table 2, entry 5):

![Chemical structure](image)

white solid; mp = 256–257 °C; \(^1\)H NMR (400 MHz, Acetonitrile-\(d_3\)): \(\delta\) 2.50 (s, 3H), 7.14 (d, \(J = 8.0\) Hz, 1H), 7.46 (s, 1H), 7.50 – 7.57 (m, 2H), 8.40 (d, \(J = 8.0\) Hz, 1H), 8.68 (d, \(J = 8.0\) Hz, 1H), 9.28 (d, \(J = 1.8\) Hz, 1H), 11.10 (s, 1H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 150.73, 148.87, 147.87, 139.43, 138.44, 134.05, 130.76, 126.70, 124.38, 115.78, 114.90, 21.76; IR (KBr): 3045, 2960, 2888, 2878, 2795, 2795, 1636, 1579, 1455, 1465, 1317 cm\(^{-1}\); ESI-MS (m/z): 210.1 [M+H]\(^+\).

5-nitro-2-phenyl-1H-benzo[d]imidazole\(^3\) (Table 2, entry 6):

![Chemical structure](image)

yellow solid; mp = 201–203 °C; \(^1\)H NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) 7.60 (d, \(J = 8.0\) Hz, 4H), 8.18 (dd, \(J = 40.0, 8.0\) Hz, 3H), 8.50 (s, 1H), 13.61 (s, 1H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 155.99, 142.99, 133.12, 131.17, 129.67, 129.35, 128.85, 127.35, 118.19, 115.01, 112.00; IR (KBr): 3042, 2990, 2920, 2853, 1621, 1596, 1481, 1339, 1591, 1262; ESI-MS (m/z): 240.1 [M+H]\(^+\).

5-chloro-2-phenyl-1H-benzo[d]imidazole\(^4\) (Table 2, entry 7):

![Chemical structure](image)

white solid; mp = 294–295 °C; \(^1\)H NMR (400 MHz, DMSO-\(d_6\)): \(\delta\) 7.25 (t, \(J = 8.0\) Hz, 1H), 7.52 – 7.76 (m, 5H), 8.20 (d, \(J = 4.0\) Hz, 2H), 13.14 (s, 1H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 154.29, 143.95, 135.07, 130.98, 129.76, 129.50, 127.20, 125.20,
5-bromo-2-phenyl-1H-benzo[d]imidazole² (Table 2, entry 8):

![5-bromo-2-phenyl-1H-benzo[d]imidazole](image)

white solid; mp = 206–208 °C; ¹H NMR (400 MHz, Acetonitrile-d₃): δ 7.39 (d, J = 12.0 Hz, 1H), 7.54 – 7.83 (m, 5H), 8.12 (d, J = 8.0 Hz, 2H), 11.03 (s, 1H); ¹³C NMR (100 MHz, DMSO-d₆): δ 167.82, 152.95, 133.22, 130.62, 130.16, 129.74, 129.41, 128.95, 127.09, 125.41, 114.74; IR (KBr): 3067, 2997, 2952, 2910, 2860, 1683, 1584, 1469, 1399, 701 cm⁻¹; ESI-MS (m/z): 273.1 [M+H]⁺.

5,6-dichloro-2-phenyl-1H-benzo[d]imidazole⁴ (Table 2, entry 9):

![5,6-dichloro-2-phenyl-1H-benzo[d]imidazole](image)

white solid; mp = 223–225 °C; ¹H NMR (400 MHz, Acetonitrile-d₃): δ 7.56 – 7.62 (m, 3H), 7.82 (d, J = 56.0 Hz, 2H), 8.11 (d, J = 8.0 Hz, 2H), 11.10 (s, 1H); ¹³C NMR (100 MHz, DMSO-d₆): δ 154.29, 143.94, 135.03, 130.98, 129.76, 129.50, 127.20, 125.19, 124.70, 120.40, 113.14; IR (KBr): 3057, 2997, 2952, 2910, 2860, 1646, 1576, 1544, 1464, 1297, 858, 783, 694 cm⁻¹; ESI-MS (m/z): 264.1 [M+H]⁺.

2-(p-tolyl)-1H-benzo[d]imidazole¹ (Table 2, entry 10):

![2-(p-tolyl)-1H-benzo[d]imidazole](image)

white solid; mp = 279–280 °C; ¹H NMR (400 MHz, Acetonitrile-d₃): δ 2.45 (s, 3H), 7.26 (dd, J = 8.0, 4.0 Hz, 2H), 7.40 (d, J = 8.0 Hz, 2H), 7.62 (s, 2H), 8.02 (d, J = 8.0 Hz, 2H), 11.11 (s, 1H); ¹³C NMR (100 MHz, DMSO-d₆): δ 145.21, 143.07, 136.22, 134.30, 130.65, 130.16, 129.45, 127.04, 123.03, 120.56, 118.71, 113.08; IR (KBr): 3057, 2957, 2970, 2860, 1539, 1506, 1449, 1399 cm⁻¹; ESI-MS (m/z): 209.1 [M+H]⁺.

2-(4-methoxyphenyl)-1H-benzo[d]imidazole¹ (Table 2, entry 11):

![2-(4-methoxyphenyl)-1H-benzo[d]imidazole](image)

white solid; mp = 231–233 °C; ¹H NMR (400 MHz, Acetonitrile-d₃): δ 3.90 (s, 3H), 7.11 (d, J = 8.0 Hz, 2H), 7.25 (dd, J = 4.0, 3.0 Hz, 2H), 7.56 – 7.65 (m, 2H), 8.07 (d, J
= 8.0 Hz, 2H), 10.98 (s, 1H); $^{13}$C NMR (100 MHz, DMSO-$d_6$): δ 161.06, 151.81, 144.38, 135.44, 128.46, 123.19, 122.50, 121.88, 118.95, 114.82, 111.47, 55.79; IR (KBr): 3052, 2957, 2952, 2860, 1611, 1499, 1391, 1292 cm$^{-1}$; ESI-MS (m/z): 225.1 [M+H]$^+$.  

2-(4-chlorophenyl)-1H-benzo[d]imidazole$^1$ (Table 2, entry 12) :  

![2-(4-chlorophenyl)-1H-benzo[d]imidazole](image)

white solid; mp = 304–305 °C; $^1$H NMR (400 MHz, Acetonitrile-$d_3$): δ 7.30 (s, 2H), 7.51 – 7.72 (m, 4H), 8.12 (d, $J = 4.0$ Hz, 2H), 10.96 (s, 1H); $^{13}$C NMR (100 MHz, DMSO-$d_6$): δ 150.62, 134.94, 129.49, 128.59, 122.72, 118.95, 112.16, 99.99, 34.93, 31.59, 30.30; IR (KBr): 3055, 2992, 2987, 1541, 1447, 1404, 1317, 741 cm$^{-1}$; ESI-MS (m/z): 229.1 [M+H]$^+$.  

2-(4-nitrophenyl)-1H-benzo[d]imidazole$^5$ (Table 2, entry 13) :  

![2-(4-nitrophenyl)-1H-benzo[d]imidazole](image)

eyellow solid; mp = 264–268 °C; $^1$H NMR (400 MHz, DMSO-$d_6$): δ 7.30 (s, 2H), 7.69 (d, $J = 36.0$ Hz, 2H), 8.44 (s, 4H), 13.32 (s, 1H); $^{13}$C NMR (100 MHz, DMSO-$d_6$): δ 149.46, 148.28, 136.50, 135.71, 130.81, 127.86, 124.74, 123.91, 122.85, 119.87, 112.29; IR (KBr): 3430, 2658, 2115, 1658, 1610, 1520, 1435, 1343 cm$^{-1}$; ESI-MS (m/z): 240.1 [M+H]$^+$.  

5-(1H-benzo[d]imidazol-2-yl)-2-methoxyphenol$^{12}$ (Table 2, entry 14) :  

![5-(1H-benzo[d]imidazol-2-yl)-2-methoxyphenol](image)

white solid; mp = 249–251 °C; $^1$H NMR (400 MHz, Acetone-$d_6$): δ 3.94 (s, 3H), 7.11 (d, $J = 8.0$ Hz, 1H), 7.19 (dd, $J = 8.0$, 4.0 Hz, 2H), 7.57 (dd, $J = 8.0$, 4.0 Hz, 2H), 7.70 – 7.77 (m, 2H), 9.72 (s, 1H), 12.09 (s, 1H); $^{13}$C NMR (100 MHz, DMSO-$d_6$): δ 151.88, 149.85, 147.05, 139.59, 123.17, 122.27, 118.51, 115.13, 114.18, 112.63, 56.14; IR (KBr): 3309, 3060, 2965, 2930, 2838, 1596, 1429, 1314 cm$^{-1}$; ESI-MS (m/z): 241.1 [M+H]$^+$.  

2-(1H-benzo[d]imidazol-2-yl)phenol$^6$ (Table 2, entry 15) :
white solid; mp = 241–243 °C; \(^1\)H NMR (400 MHz, Acetonitrile-\(d_3\)): \(\delta\) 7.04 – 7.10 (m, 2H), 7.39 (d, \(J = 32.0\) Hz, 3H), 7.69 (d, \(J = 28.0\) Hz, 2H), 7.84 (d, \(J = 8.0\) Hz, 1H), 11.11 (s, 1H), 13.20 (s, 1H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 158.47, 152.15, 141.33, 133.63, 132.18, 126.66, 123.73, 122.85, 119.57, 118.41, 117.64, 113.06, 111.98; IR (KBr): 3326, 3055, 1591, 1530, 1488 cm\(^{-1}\); ESI-MS (m/z): 221.1 [M+H]\(^+\).

2-(2-chlorophenyl)-1H-benzo[d]imidazole\(^5\) (Table 2, entry 16):

white solid; mp = 231–233 °C; \(^1\)H NMR (400 MHz, Acetonitrile-\(d_3\)): \(\delta\) 7.29 – 7.35 (m, 2H), 7.50 – 7.76 (m, 5H), 8.14 – 8.18 (m, 1H), 10.93 (s, 1H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 149.55, 143.67, 135.10, 132.53, 132.10, 131.64, 130.79, 130.44, 127.87, 123.19, 122.14, 119.54, 112.15; IR (KBr): 3065, 2957, 2908, 1541, 1447, 1404, 1317, 741 cm\(^{-1}\); ESI-MS (m/z): 229.1 [M+H]\(^+\).

2-(2-fluorophenyl)-1H-benzo[d]imidazole\(^7\) (Table 2, entry 17):

white solid; mp = 181–183 °C; \(^1\)H NMR (400 MHz, Acetone-\(d_6\)): \(\delta\) 7.23 – 7.29 (m, 2H), 7.34 – 7.44 (m, 2H), 7.54 – 7.60 (m, 1H), 7.68 (d, \(J = 2.7\) Hz, 2H), 8.47 (d, \(J = 4.0\) Hz, 1H), 11.67 (s, 1H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 161.16, 158.68, 146.87, 146.85 (d, \(J_{C,F} = 2.0\) Hz), 132.33, 132.25 (d, \(J_{C,F} = 8.0\) Hz), 130.70, 130.67 (d, \(J_{C,F} = 3.0\) Hz), 125.54, 125.50 (d, \(J_{C,F} = 4.0\) Hz), 122.76, 118.62, 118.50 (d, \(J_{C,F} = 12.0\) Hz), 117.06, 116.85 (d, \(J_{C,F} = 21.0\) Hz); IR (KBr): 3061, 2967, 2932, 1624, 1600, 1494, 1460, 1412, 1350 cm\(^{-1}\); ESI-MS (m/z): 213.1 [M+H]\(^+\).

3-(1H-benzo[d]imidazol-2-yl)benzonitrile\(^11\) (Table 2, entry 18):

white solid; mp = 255–256 °C; \(^1\)H NMR (400 MHz, Acetonitrile-\(d_3\)): \(\delta\) 7.32 (dd, \(J = 8.0, 4.0\) Hz, 2H), 7.67 (dd, \(J = 8.0, 4.0\) Hz, 2H), 7.72 (t, \(J = 8.0\) Hz, 1H), 7.85 (d, \(J = 8.0\) Hz, 1H), 8.38 (d, \(J = 8.0\) Hz, 1H), 8.45 (s, 1H), 10.99 (s, 1H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\)): \(\delta\) 149.65, 143.81, 135.35, 133.47, 131.81, 131.32, 130.73, 130.18, 123.05, 118.84, 112.62, 60.19, 21.18, 14.51; IR (KBr): 3052, 2995, 2900, 2845, 2234, 1541, 1477, 1369 cm\(^{-1}\); ESI-MS (m/z): 220.1 [M+H]\(^+\).

2-(3-fluorophenyl)-1H-benzo[d]imidazole\(^11\) (Table 2, entry 19):
white solid; mp = 255–257 °C; ¹H NMR (400 MHz, Acetonitrile-d₃): δ 7.30 (dd, J = 8.0, 4.0 Hz, 3H), 7.55 – 7.68 (m, 3H), 7.86 – 7.96 (m, 2H); ¹³C NMR (100 MHz, DMSO-d₆): δ 164.13, 161.71, 150.39, 150.36 (d, J_C,F = 3.0 Hz), 139.68, 132.95, 132.87 (d, J_C,F = 8.0 Hz), 131.60, 131.51 (d, J_C,F = 9.0 Hz), 122.99, 122.97, 122.89 (d, J_C,F = 8.0 Hz), 117.14, 116.93 (d, J_C,F = 21.0 Hz), 115.71, 113.62, 113.38 (d, J_C,F = 24.0 Hz); IR(KBr): 3060, 2920, 2848, 1620, 1486, 1464, 1394, 1314, 1205 cm⁻¹; ESI-MS (m/z): 213.1 [M+H]+.

4-(1H-benzo[d]imidazol-2-yl)-2-methoxyphenol⁹ (Table 2, entry 20):

white solid; mp = 216–218 °C; ¹H NMR (400 MHz, Acetone-d₆): δ 3.97 (s, 3H), 6.98 (d, J = 8.0 Hz, 1H), 7.19 (dd, J = 8.0, 4.0 Hz, 2H), 7.57 (dd, J = 6.0, 3.2 Hz, 2H), 7.71 (d, J = 8.0 Hz, 1H), 8.12 (s, 1H), 11.07 (s, 1H); ¹³C NMR (100 MHz, DMSO-d₆): δ 152.20, 148.86, 148.29, 122.13, 121.86, 120.16, 116.12, 114.90, 110.89, 56.17, 30.30, 29.47, 22.51, 14.39; IR (KBr): 3506, 3336, 3057, 2970, 1601, 1544, 1500, 1404, 1312 cm⁻¹; ESI-MS (m/z): 241.1 [M+H]+.

2-(pyridin-2-yl)-1H-benzo[d]imidazole² (Table 2, entry 21):

yellow solid; mp = 216–219 °C; ¹H NMR (400 MHz, Acetone-d₆): δ 7.25 – 7.28 (m, 2H), 7.48 (d, J = 1.6 Hz, 1H), 7.70 (dd, J = 8.0, 4.0 Hz, 2H), 7.97 – 8.01 (m, 1H), 8.43 (d, J = 8.0 Hz, 1H), 8.69 (d, J = 4.0 Hz, 1H), 12.10 (s, 1H); ¹³C NMR (100 MHz, DMSO-d₆): δ 151.19, 149.81, 148.91, 139.84, 137.97, 125.16, 123.01, 121.88, 116.11; IR (KBr): 3057, 2970, 1601, 1544, 1500, 1404, 1312 cm⁻¹; ESI-MS (m/z): 196.1 [M+H]+.

2-(furan-2-yl)-1H-benzo[d]imidazole¹² (Table 2, entry 22):

brown solid; mp = 287–289 °C; ¹H NMR (400 MHz, CDCl₃) δ 9.95 (s, 1H), 7.57 (d, J = 1.6 Hz, 3H), 7.32 – 7.29 (m, 2H), 7.24 (d, J = 4.0 Hz, 1H), 6.61 (dd, J = 3.6, 2.0 Hz, 1H); ¹³C NMR (100 MHz, CD₃OD-d₄) δ 176.49, 149.03, 148.32, 147.93, 126.63, 121.41, 115.75, 114.37, 91.81, 56.65; IR (KBr): 3057, 1631, 1525, 1411, 1360, 1275, 1234 cm⁻¹; ESI-MS (m/z): 185.1 [M+H]+.

1H-benzo[d]imidazole¹³ (Table 2, entry 23):

\[ \text{1H-benzo[d]imidazole} \]
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white solid; mp = 168–170 °C; ¹H NMR (400 MHz, CDCl₃) δ 9.90 (s, 1H), 8.13 (s, 1H), 7.71 (dd, J = 6.0, 3.2 Hz, 2H), 7.33 (dt, J = 7.2, 3.6 Hz, 2H). ¹³C NMR (100 MHz, CD₃OD-d₄) δ 141.07, 137.41, 122.69, 122.41, 122.11, 114.83, 99.99; IR(KBr): 3113, 3052, 1770, 1580, 1458, 1406, 1243, 747 cm⁻¹; ESI-MS (m/z): 185.1 [M+H]+.

2-isopropyl-1H-benzo[d]imidazole⁹ (Table 2, entry 24):

yellow solid; mp = 232–234 °C; ¹H NMR (400 MHz, Acetonitrile-d₃): δ 1.41 (d, J = 7.0 Hz, 6H), 3.21 (m, 1H), 7.18 (dd, J = 6.0, 4.0 Hz, 2H), 7.51 (dd, J = 8.0, 4.0 Hz, 2H); ¹³C NMR (100 MHz, Acetone-d₆): δ 205.44, 205.05, 159.75, 121.21, 114.31, 30.79, 28.86, 28.79, 20.88; IR (KBr): 3051, 2971, 2883, 1534, 1455, 1415, 1273 cm⁻¹; ESI-MS (m/z): 161.1 [M+H]+.

Mebendazole¹⁰

white solid; mp = 288–289 °C; ¹H NMR (400 MHz, Acetonitrile-d₃): δ 3.84 (s, 3H), 7.54 – 7.60 (m, 4H), 7.68 (dd, J = 16.0, 4.0 Hz, 3H), 7.80 (d, J = 4.0 Hz, 2H), 7.94 (s, 1H); ¹³C NMR (100 MHz, DMSO-d₆): δ 196.02, 154.88, 149.93, 138.89, 132.27, 130.28, 129.77, 128.80, 124.15, 53.11; IR(KBr): 3400, 2750, 1718, 1648 cm⁻¹; ESI-MS (m/z): 119.1 [M+H]+.

5. References
6. $^1$H NMR and $^{13}$C NMR spectra for the products

2-phenyl-1H-benzo[d]imidazole$^1$ (Table 2, entry 1)
5-methyl-2-phenyl-1H-benzo[d]imidazole (Table 2, entry 2)
2-(2,4-dimethylphenyl)-5-methyl-1H-benzo[d]imidazole (Table 2, entry 3)
HRMS:

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Sample Name: kf
Comment

Acquisition Date: 10/05/2018 11:15:33 AM
Operator: BDALi@CN
Instrument / Ser#: micTOF-Q II 10429

Acquisition Parameter
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Focus: Active
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Scan End: 800 m/z

Ion Polarity: Positive
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Set End Plate Offset: -500 V
Set Collision Cell RF: 300 V Vpp
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Intens x10^5

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2-(2-fluorophenyl)-5-methyl-1H-benzo[d]imidazole (Table 2, entry 4)
HRMS:

Mass Spectrum SmartFormula Report

Analysis Info
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Sample Name: k2
Comment:

Acquisition Parameter
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Operator: BDAL@CN
Instrument: microTOF-Q II 10429

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5-methyl-2-(pyridin-3-yl)-1H-benzo[d]imidazole¹ (Table 2, entry 5)
5-nitro-2-phenyl-1H-benzo[d]imidazole® (Table 2, entry 6)
5-chloro-2-phenyl-1H-benzo[d]imidazole (Table 2, entry 7)
5-bromo-2-phenyl-1H-benzo[d]imidazole (Table 2, entry 8)
5,6-dichloro-2-phenyl-1H-benzo[d]imidazole (Table 2, entry 9)
2-(p-tolyl)-1H-benzo[d]imidazole\textsuperscript{1} (Table 2, entry 10)
2-(4-methoxyphenyl)-1H-benzo[d]imidazole\(^1\) (Table 2, entry 11)
2-(4-chlorophenyl)-1H-benzo[d]imidazole (Table 2, entry 12)
2-(4-nitrophenyl)-1H-benzo[d]imidazole\textsuperscript{7} (Table 2, entry 13)
5-(1H-benzo[d]imidazol-2-yl)-2-methoxyphenol (Table 2, entry 14)
2-(1H-benzo[d]imidazol-2-yl)phenol\textsuperscript{5} (Table 2, entry 15)
2-(2-chlorophenyl)-1H-benzo[d]imidazole\textsuperscript{7} (Table 2, entry 16)
2-(2-fluorophenyl)-1H-benzo[d]imidazole\textsuperscript{2} (Table 2, entry 17)
3-(1H-benzo[d]imidazol-2-yl)benzonitrile (Table 2, entry 18)
2-(3-fluorophenyl)-1H-benzo[d]imidazole (Table 2, entry 19)
4-(1H-benzo[d]imidazol-2-yl)-2-methoxyphenol (Table 2, entry 20)
2-(pyridin-2-yl)-1H-benzo[d]imidazole² (Table 2, entry 21)
2-(furan-2-yl)-1H-benzo[d]imidazole\textsuperscript{12} (Table 2, entry 22):
1H-benzo[d]imidazole\textsuperscript{14} (Table 2, entry 23):
2-isopropyl-1H-benzo[d]imidazole\(^4\) (Table 2, entry 24)
Mebendazole: