Supporting Information for

Efficient Synthesis of Ureas by Direct Palladium-Catalyzed Oxidative Carbonylation of Amines

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General Experimental Methods

Melting points are uncorrected. ^1H NMR and ^{13}C NMR spectra were recorded at 300 MHz and 75 MHz, respectively, with Me_4Si as internal standard. Chemical shifts and coupling constants (J) are given in ppm (δ) and in Hz, respectively. IR spectra were taken on a FT-IR spectrometer. Mass spectra were obtained at 70 eV on a GC-MS apparatus. Microanalyses were performed at our analytical laboratory.

Characterization of products

1,3-Dibutylurea 2a. Colorless solid, mp 72–73 °C (lit.¹ 73 °C). IR (KBr) 3330 (s), 2959 (w), 2934 (w), 2871 (w), 1621 (s), 1578 (s), 1460 (w), 1233 (w) cm⁻¹; ¹H NMR (CDCl₃) δ 5.78 (t, br, J = 5.1, 2 H, 2 NH), 3.18–3.09 (m, 4 H, 2 NHCH₂), 1.51–1.26 (m, 8 H, 2 CH₂CH₂CH₃), 0.91 (t, J = 7.3, 6 H, 2 Me); ¹³C NMR (CDCl₃) δ 159.5, 40.0, 32.6, 20.2, 13.9; MS m/z 172 (M⁺, 100), 157 (17), 143 (17), 130 (39), 129 (33), 101 (45), 100 (33), 87 (31), 74 (69), 73 (27), 72 (33), 58 (16), 57 (67), 56 (33), 55 (17). Anal. Calcd for C₉H₂₀N₂O: C, 62.75; H, 11.70, N, 16.26. Found C, 62.81; H, 11.68, N, 16.28.

1,3-Dibenzylurea 2b. Colorless solid, mp 169–170 °C (lit.² 169–171 °C). IR (KBr) 3320 (m), 1627 (s), 1571 (s), 697 (m) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 7.34–7.18 (m, 10 H on phenyl rings), 6.48 (t, J = 5.9, 2 H, 2 NH), 4.24 (d, J = 5.9, 4 H, 2 CH₂); ¹³C NMR (DMSO-*d*₆) δ 158.1, 140.8, 128.1, 126.9, 126.5, 42.9; MS m/z 240 (M⁺, 27), 149 (16), 106 (100), 91 (43), 79 (15). Anal. Calcd for C₁₅H₁₆N₂O: C, 74.97; H, 6.71, N, 11.66. Found C, 75.11; H, 6.72, N, 11.62.

1,3-Di-*tert*-butylurea 2c. Whitish solid, mp 238–239 °C (lit.³ 238–240). IR (KBr) 3355 (m), 2964 (m), 1637 (s), 1560 (s) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 5.45 (s, 2 H, 2 NH), 1.19 (s, 18 H, 2 *t*-Bu); ¹³C NMR (DMSO-*d*₆) δ 157.0, 48.7, 29.3; MS m/z 172 (M⁺, 3), 157 (13), 71 (3), 61 (7), 59 (4), 58 (100), 57 (13), 56 (3). Anal. Calcd for C₉H₂₀N₂O: C, 62.75; H, 11.70, N, 16.26. Found C, 62.64; H, 11.72, N, 16.25.

¹ Nomura, R.; Hasegawa, Y.; Ishimoto, M.; Toyosaki, T.; Matsuda, H. *J. Org. Chem.* **1992**, *57*, 7339–7342.

² Franz, R. A.; Applegath, F.; Morriss, F. V.; Baiocchi, F. *J. Org. Chem.* **1961**, *26*, 3306–3308.

1,3-Diphenylurea 2d. Colorless solid, mp 240–241 °C (lit.⁴ 238–241 °C). IR (KBr) 1649 (s), 1595 (m), 1559 (s), 1448 (w), 1315 (w), 1234 (m), 754 (m), 698 (m) cm^{-1} ; ^1H NMR (DMSO- d_6) δ 8.69 (s, 2 H, 2 NH), 7.53–7.14 (m, 4 H on phenyl rings), 7.33–7.23 (m, 4 H on phenyl rings), 7.01–6.93 (m, 2 H on phenyl rings); ^{13}C NMR (DMSO- d_6) δ 152.5, 139.7, 128.7, 121.7, 118.1; MS m/z 212 (M^+ , 18), 119 (12), 94 (7), 93 (100), 92 (9), 91 (7), 77 (10), 66 (11), 65 (12). Anal. Calcd for $\text{C}_{13}\text{H}_{12}\text{N}_2\text{O}$: C, 73.56; H, 5.70, N, 13.20. Found C, 73.44; H, 5.71, N, 13.23.

1,3-Bis-(4-chlorophenyl)urea 2e. Pale yellow solid, mp 314–315 °C (lit.⁵ 315–319). IR (KBr) 3296 (m), 1633 (s), 1591 (s), 1557 (s), 1492 (s), 1397 (w), 1299 (w), 1237 (m), 1085 (m), 1013 (w), 823 (m), 639 (s), 507 (m) cm^{-1} ; ^1H NMR (DMSO- d_6) δ 8.88 (s, 2 H, 2 NH), 7.55–7.48 (m, 4 H on phenyl rings), 7.37–7.30 (m, 4 H on phenyl rings); ^{13}C NMR (DMSO- d_6) δ 152.3, 138.5, 128.6, 125.5, 119.8; MS m/z 282 ($\text{M}^+ + 2$, 8), 280 (M^+ , 11), 153 (13), 129 (32), 127 (100), 92 (8), 90 (7), 75 (5), 65 (10). Anal. Calcd for $\text{C}_{13}\text{H}_{10}\text{Cl}_2\text{N}_2\text{O}$: C, 55.54; H, 3.59; Cl, 25.22; N, 9.96. Found C, 55.63; H, 3.60; Cl, 25.20; N, 9.95.

1,3-Bis-(4-isopropylphenyl)urea 2f. Colorless solid, mp 207–208 °C (lit.⁶ 206–207). IR (KBr) 3311 (m), 2959 (m), 1651 (s), 1597 (m), 1555 (s), 1514 (m), 1417 (w), 1309 (m), 1285 (w), 1236 (m), 832 (m) cm^{-1} ; ^1H NMR (DMSO- d_6) δ 8.54 (s, 2 H, 2 NH), 7.41–7.34 (m, 4 H on phenyl rings), 7.18–7.10 (m, 4 H on phenyl rings), 2.82 (heptuplet, $J = 6.8$, 2 H, 2 CHMe_2), 1.18 (d, $J = 6.8$, 12 H, 4 Me); ^{13}C NMR (DMSO- d_6) δ 152.6, 141.6, 137.4, 126.4, 118.2, 32.7, 24.0; MS m/z 296 (M^+ , 23), 161 (4), 146 (12), 135 (34), 133 (9), 120 (100), 103 (4), 91 (7), 77 (5). Anal. Calcd for $\text{C}_{19}\text{H}_{24}\text{N}_2\text{O}$: C, 76.99; H, 8.16, N, 9.45. Found C, 76.85; H, 8.18, N, 9.46.

³ Izdebski, J.; Pawlak, D. *Synthesis* **1989**, 423–425.

⁴ Miller, R. E. *J. Org. Chem.* **1961**, 26, 2327–2330.

⁵ Beaver, D. J.; Roman, D. P.; Stoffel, P. J. *J. Org. Chem.* **1959**, 24, 1676–1678.

⁶ Atanassova, I. A.; Petrov, J. S.; Mollov, N. M. *Synthesis* **1987**, 734–736.

1,3-Bis-(4-methoxyphenyl)urea 2g. Whitish solid, mp 240–241 °C (lit.⁷ 240–241 °C). IR (KBr) 3302 (m), 1634 (s), 1607 (m), 1560 (s), 1511 (s), 1245 (s), 1170 (w), 1030 (w), 827 (m) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 8.40 (s, 2 H, 2 NH), 7.42–7.33 (m, 4 H on phenyl rings), 6.91–6.82 (m, 4 H on phenyl rings), 3.71 (s, 6 H, 2 OMe); ¹³C NMR (DMSO-*d*₆) δ 154.3, 153.0, 132.9, 119.9, 113.9, 55.1; MS *m/z* 272 (M⁺, 44), 149 (19), 134 (11), 123 (100), 108 (91), 95 (6), 80 (12). Anal. Calcd for C₁₅H₁₆N₂O₃: C, 66.16; H, 5.92, N, 10.29. Found C, 66.28; H, 5.91, N, 10.27.

1,3-Dihydrobenzoimidazol-2-one 2h. Pale pink solid, mp 320–321 °C (lit.⁸ 320 °C). IR (KBr) 3133 (m), 3027 (m), 2909 (m), 2809 (m), 1746 (s), 1485 (m), 737 (m), 705 (w), 599 (w) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 10.71 (s, 2 H, 2 NH), 7.04–6.93 (m, 4 H aromatic); ¹³C NMR (DMSO-*d*₆) δ 155.5, 129.8, 120.6, 108.7; MS *m/z* 134 (M⁺, 100), 106 (21), 105 (13), 79 (16), 67 (8), 52 (14). Anal. Calcd for C₇H₆N₂O: C, 62.68; H, 4.51, N, 20.88. Found C, 62.81; H, 4.50, N, 20.85.

1*H*,3*H*-Perimidin-2-one 2i. Pale pink solid, mp 302–303 °C (lit.⁹ 302–303 °C). IR (KBr) 3231 (m), 1735 (s), 1669 (w), 1647 (w), 1617 (w), 1383 (m), 815 (w), 773 (w), 755 (w) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 10.17 (s, 2 H, 2 NH), 7.25 (dd, *J* = 8.3, 7.3, 2 H aromatic), 7.14 (d, *J* = 8.3, 2 H aromatic), 6.60 (d, *J* = 7.3, 2 H aromatic); ¹³C NMR (DMSO-*d*₆) δ 150.2, 137.7, 134.2, 128.0, 117.7, 113.8, 104.1; MS *m/z* 184 (M⁺, 100), 166 (60), 155 (9), 139 (9), 92 (10), 83 (9). Anal. Calcd for C₁₁H₈N₂O: C, 71.73; H, 4.38, N, 15.21. Found C, 71.64; H, 4.39, N, 15.20.

Tributylurea 4aa. Pale yellow oil. IR (neat) 3344 (m, br), 2956 (m), 2929 (m), 2871 (m), 1625 (s), 1537 (s), 1464 (w), 1375 (w), 1292 (w), 1236 (w), 1111 (w) cm⁻¹; ¹H NMR (CDCl₃) δ 4.40 (t, *J* = 5.4, 1 H, NH), 3.26–3.13 (m, 6 H, CH₂NH + CH₂NCH₂), 1.58–1.42 (m, 6 H, 3 CH₂), 1.33 (heptuplet, *J* = 7.3, 6 H, 3 CH₂), 0.93 (t, *J*

⁷ Etter, M. C.; Urbanczyk-Lipkowska, Z.; Zia-Ebrahimi, M.; Panunto, T. W. *J. Am. Chem. Soc.* **1990**, *112*, 8415–8426.

⁸ Cairns, T. L.; Coffman, D. D.; Gilbert, W. W. *J. Am. Chem. Soc.* **1957**, *79*, 4405–4408.

= 7.3, 6 H, N(CH₂CH₂CH₂CH₃)₂], 0.92 (t, *J* = 7.3, NHCH₂CH₂CH₂CH₃); ¹³C NMR (CDCl₃) δ 157.8, 47.1, 40.6, 32.6, 30.9, 20.26, 20.22, 13.93, 13.87; MS *m/z* 228 (M⁺, 11), 185 (11), 156 (4), 129 (4), 100 (8), 87 (7), 86 (100), 57 (14), 56 (4). Anal. Calcd for C₁₃H₂₈N₂O: C, 68.37; H, 12.36, N, 12.27. Found C, 68.45; H, 12.34, N, 12.28.

Morpholine-4-carboxylic acid butylamide 4ab. Colorless solid, mp 75–76 °C (lit.¹⁰ 73 °C). IR (KBr) 3353 (m, br), 1622 (s), 1548 (s), 1405 (w), 1270 (m), 1111 (m) cm⁻¹; ¹H NMR (CDCl₃) δ 4.99 (t, *J* = 5.4, 1 H, NH), 3.70–3.64 (m, 4 H, CH₂OCH₂), 3.38–3.32 (m, 4 H, CH₂NCH₂), 3.21 (td, *J* = 7.1, 5.4, 2 H, NHCH₂), 1.55–1.42 (m, 2 H, NHCH₂CH₂), 1.42–1.27 (m, 2 H, CH₂CH₃), 0.92 (t, *J* = 7.3, 3 H, Me); ¹³C NMR (CDCl₃) δ 158.1, 66.6, 44.0, 40.7, 32.4, 20.1, 13.8; MS *m/z* 186 (M⁺, 14), 155 (13), 143 (8), 129 (9), 115 (5), 114 (49), 100 (7), 88 (9), 87 (50), 86 (39), 72 (9), 70 (31), 58 (8), 57 (100), 56 (33), 55 (6). Anal. Calcd for C₉H₁₈N₂O₂: C, 58.04; H, 9.74, N, 15.04. Found C, 58.22; H, 9.72, N, 15.05.

1-Benzyl-3-butyl-1-methylurea 4ac. Pale yellow solid, mp 46–47 °C. IR (KBr) 3357 (m, br), 2956 (m), 2930 (m), 2869 (w), 1615 (s), 1538 (s), 1451 (m), 1388 (w), 1363 (w), 1301 (m), 1236 (m), 1175 (w), 1024 (w), 943 (w), 725 (s), 695 (m), 591 (m) cm⁻¹; ¹H NMR (CDCl₃) δ 7.36–7.18 (m, 5 H, Ph), 4.63 (t, *J* = 5.4, 1 H, NH), 4.48 (s, 2 H, CH₂Ph), 3.23 (td, *J* = 7.3, 5.4, 2 H, HNCH₂), 2.85 (s, 3 H, NCH₃), 1.52–1.40 (m, 2 H, CH₂CH₂CH₃), 1.37–1.22 (m, 2 H, CH₂CH₂CH₃), 0.90 (t, *J* = 7.3, 3 H, CH₂CH₂CH₃); ¹³C NMR (CDCl₃) δ 158.5, 138.2, 128.6, 127.2, 52.1, 40.7, 34.3, 32.5, 20.1, 13.8; MS *m/z* 220 (M⁺, 56), 177 (5), 148 (11), 121 (8), 120 (61), 119 (12), 118 (15), 106 (21), 92 (12), 91 (100), 72 (8), 65 (10). Anal. Calcd for C₁₃H₂₀N₂O: C, 70.87; H, 9.15, N, 12.72. Found C, 71.02; H, 9.16, N, 12.70.

1,1-Dibutyl-3-*tert*-butylurea 4ca. Colorless solid, mp 63–64 °C. IR (KBr) 3378 (m), 2960 (m), 2930 (m), 1619 (s), 1533 (s), 1491 (w), 1401 (w), 1266 (w), 1213 (m)

⁹ Alper, H.; Lipschutz, B. H. *J. Org. Chem.* **1973**, *38*, 3742–3744.

¹⁰ Hackl, K. A.; Falk, H. *Monatsh. Chem.* **1992**, *123*, 599–606.

cm⁻¹; ¹H NMR (acetone-*d*₆) δ 4.77 (s, br, 1 H, NH), 3.18 (t, *J* = 7.3, 4 H, CH₂NCH₂), 1.56–1.43 (m, 4 H, 2 CH₂CH₂CH₃), 1.36–1.22 (m, 4 H, 2 CH₂CH₂CH₃), 1.30 (s, 9 H *t*-Bu), 0.91 (t, *J* = 7.3, 6 H, 2 CH₂CH₂CH₃); ¹³C NMR (acetone-*d*₆) δ 157.4, 50.8, 47.1, 31.5, 29.7, 20.7, 14.2; MS *m/z* 228 (M⁺, 6), 185 (5), 156 (6), 100 (5), 87 (7), 86 (100), 84 (5), 58 (5), 57 (21). Anal. Calcd for C₁₃H₂₈N₂O: C, 68.37; H, 12.36, N, 12.27. Found C, 68.45; H, 12.34, N, 12.29.

1,1-Dibutyl-3-phenylurea 4da. Colorless solid, mp 84–85 °C (lit.¹¹ 83–84 °C). IR (KBr) 3297 (m), 2958 (m), 1636 (s), 1533 (m), 1447 (m), 1408 (w), 1319 (w), 1243 (w), 1223 (w), 754 (m), 699 (w) cm⁻¹; ¹H NMR (acetone-*d*₆) δ 7.63 (s, br, 1 H, NH), 7.55–7.48 (m, 2 H on phenyl ring), 7.23–7.13 (m, 2 H on phenyl ring), 6.94–6.86 (m, 1 H on phenyl ring), 3.36 (t, *J* = 7.6, 4 H, CH₂NCH₂), 1.64–1.50 (m, 4 H, 2 CH₂CH₂CH₃), 1.32 (sextuplet, *J* = 7.3, 4 H, 2 CH₂CH₂CH₃), 0.92 (t, *J* = 7.3, 6 H, 2 Me); ¹³C NMR (acetone-*d*₆) δ 155.7, 141.7, 129.0, 122.4, 120.5, 47.4, 31.5, 20.7, 14.2; MS *m/z* 248 (M⁺, 31), 207 (6), 205 (9), 156 (36), 120 (7), 119 (32), 100 (23), 93 (16), 92 (8), 91 (14), 86 (60), 77 (12), 65 (7), 64 (8), 57 (100). Anal. Calcd for C₁₅H₂₄N₂O: C, 72.54; H, 9.74, N, 11.28. Found C, 72.65; H, 9.73, N, 11.26.

Morpholine-4-carboxylic acid phenylamide 4db. Colorless solid, mp 159–160 °C (lit.⁵ 159–160 °C). IR (KBr) 3269 (m, br), 1635 (s), 1538 (m), 1450 (m), 1415 (m), 1303 (w), 1251 (s), 1115 (m), 993 (w), 874 (w), 747 (m) cm⁻¹; ¹H NMR (CDCl₃) δ 7.35–7.28 (m, 2 H on phenyl ring), 7.27–7.19 (m, 2 H on phenyl ring), 7.15 (s, br, 1 H, NH), 7.06–6.98 (m, 1 H on phenyl ring), 3.61–3.54 (m, 4 H, CH₂OCH₂), 3.41–3.33 (m, 4 H, CH₂NCH₂); ¹³C NMR (CDCl₃) δ 155.6, 139.0, 128.7, 123.3, 120.7, 66.4, 44.2; MS *m/z* 206 (M⁺, 86), 205 (9), 120 (17), 119 (51), 115 (14), 114 (100), 93 (26), 92 (14), 91 (22), 87 (23), 86 (23), 77 (28), 70 (98), 65 (16), 64 (13), 57 (49), 56 (28). Anal. Calcd for C₁₁H₁₄N₂O₂: C, 64.06; H, 6.84, N, 13.58. Found C, 64.12; H, 6.82, N, 13.59.

¹¹ Yang, Y.; Lu, S. *Tetrahedron Lett.* **1999**, 40, 4845–4846.

Morpholine-4-carboxylic acid (4-methoxyphenyl)amide 4gb. Colorless solid, mp 126–127 °C (lit.⁵ 125 °C). IR (KBr) 3266 (m), 2961 (w), 1636 (s), 1540 (m), 1516 (s), 1421 (w), 1401 (w), 1297 (m), 1234 (s), 1109 (m), 1043 (w), 841 (w), 803 (m) cm⁻¹; ¹H NMR (CDCl₃) δ 7.22–7.15 (m, 2 H on phenyl ring), 6.99 (s, br, 1 H, NH), 6.82–6.74 (m, 2 H on phenyl ring), 3.75 (s, 3 H, OMe), 3.62–3.56 (m, 4 H, CH₂OCH₂), 3.38–3.32 (m, 4 H, CH₂NCH₂); ¹³C NMR (CDCl₃) δ 156.05, 155.99, 131.9, 123.1, 113.9, 66.5, 55.4, 44.1; MS *m/z* 236 (M⁺, 70), 207 (13), 149 (100), 134 (24), 122 (16), 114 (52), 106 (11), 87 (17), 78 (10), 70 (72), 57 (27), 56 (12). Anal. Calcd for C₁₂H₁₆N₂O₃: C, 61.00; H, 6.83, N, 11.86. Found C, 61.14; H, 6.82, N, 11.85.

Morpholine-4-carboxylic acid (9-isopropyl-4-methyl-9H-carbazol-3-yl)amide 4jb. Colorless solid, mp 208–210 °C. IR (KBr) 3295 (m), 1629 (s), 1522 (s), 1490 (w), 1459 (w), 1264 (m), 1115 (m), 748 (w) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 8.26 (s, 1 H, NH), 8.19 (d, *J* = 8.3, 1 H, H-2), 7.70 (d, *J* = 8.3, 1 H, H-1), 7.52–7.37 (m, 2 H aromatic), 7.24–7.15 (m, 2 H aromatic), 5.10 (heptuplet, *J* = 6.8, 1 H, CHMe₂), 3.68–3.59 (m, 4 H, CH₂OCH₂), 3.49–3.41 (m, 4 H, CH₂NCH₂), 2.62 (s, 3 H, Me at C-4), 1.61 [d, *J* = 6.8, 6 H, CH(CH₃)₂]; ¹³C NMR (DMSO-*d*₆) δ 156.8, 139.3, 137.0, 129.3, 128.7, 125.6, 124.6, 123.2, 122.3, 121.0, 118.3, 110.1, 107.3, 66.0, 45.8, 44.2, 20.3, 15.4; MS *m/z* 351 (M⁺, absent), 265 (14), 264 (69), 250 (20), 249 (100), 222 (17), 221 (14), 193 (19), 192 (10), 167 (6), 166 (6). Anal. Calcd for C₂₁H₂₅N₃O₂: C, 71.77; H, 7.17, N, 11.96. Found C, 71.67; H, 7.18, N, 11.98.

2-[3-(1-Methoxycarbonyl-2-phenylethyl)ureido]-3-phenylpropionic acid methyl ester 7a. Colorless solid, mp 155–157 °C (lit.¹² 156–157 °C). IR (KBr) 3356 (m), 1742 (s), 1715 (s), 1635 (s), 1577 (s), 1440 (m), 1358 (w), 1303 (m), 1213 (m), 1177 (w), 699 (m) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 7.33–7.13 (m, 10 H on phenyl rings),

6.53 (d, $J = 7.8$, 2 H, 2 NH), 4.40 (td, $J = 7.8$, 5.4, 2 H, CHCH₂), 3.59 (s, 6 H, 2 CO₂Me), 2.98 (distorted dd, $J = 13.7$, 5.4, 2 H, 2 CHH), 2.89 (distorted dd, $J = 13.7$, 7.8, 2 H, 2 CHH); ¹³C NMR (DMSO-*d*₆) δ 172.6, 156.6, 136.9, 129.1, 128.2, 126.5, 53.9, 51.6, 37.4; MS m/z 384 (M⁺, absent), 353 (8), 352 (35), 293 (13), 292 (10), 207 (14), 190 (13), 163 (53), 162 (98), 161 (30), 131 (59), 128 (19), 120 (15), 104 (20), 103 (16), 92 (11), 91 (100), 77 (13), 65 (12). Anal. Calcd for C₂₁H₂₄N₂O₅: C, 65.61; H, 6.29, N, 7.29. Found C, 65.70; H, 6.30, N, 7.27.

2-[3-(1-Methoxycarbonyl)ureido]propionic acid methyl ester 7b. Colorless solid, mp 182–183 °C (lit.¹² 183–184 °C). IR (KBr) 3342 (s), 1750 (s), 1737 (s), 1629 (s), 1585 (s), 1451 (w), 1435 (w), 1355 (w), 1335 (w), 1224 (s), 1153 (s), 641 (m) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 6.43 (d, $J = 7.3$, 2 H, 2 NH), 4.15 (quintuplet, $J = 7.3$, 2 H, 2 CH), 3.62 (s, 6 H, 2 CO₂Me), 1.24 (d, $J = 7.3$, 6 H, 2 CHCH₃); ¹³C NMR (DMSO-*d*₆) δ 174.1, 156.7, 51.7, 48.1, 17.9; MS m/z 232 (M⁺, absent), 200 (6), 142 (8), 141 (100), 113 (36), 70 (29). Anal. Calcd for C₉H₁₆N₂O₅: C, 44.55; H, 6.94, N, 12.06. Found C, 44.61; H, 6.92, N, 12.05.

2-[3-(1-Methoxycarbonyl-3-methylbutyl)ureido]-4-methylpentanoic acid methyl ester 7c. Colorless solid, mp 85–87 °C (lit.¹³ 85 °C). IR (KBr) 3360 (m), 2961 (m), 1755 (s), 1749 (s), 1643 (s), 1574 (s), 1437 (w), 1375 (w), 1248 (w), 1199 (m), 1171 (m) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 6.34 (d, $J = 8.3$, 2 H, 2 NH), 4.21–4.10 (multiplet, 2 H, 2 NHCHCH₂), 3.61 (s, 6 H, 2 CO₂Me), 1.73–1.52 (m, 2 H, CHMe₂), 1.45 (t, $J = 7.3$, CHCH₂CH), 0.90 (d, $J = 6.8$, 6 H, 2 CHCH₃), 0.86 (d, $J = 6.8$, 2 CHCH₃); ¹³C NMR (DMSO-*d*₆) δ 173.9, 157.1, 51.6, 50.9, 40.9, 24.2, 22.7, 21.5; MS m/z 316 (M⁺, absent), 228 (28), 225 (47), 209 (15), 157 (100), 155 (12), 141 (12), 129 (13), 100 (21), 86 (27), 70 (18), 69 (20), 55 (17). Anal. Calcd for C₁₅H₂₈N₂O₅: C, 56.94; H, 8.92, N, 8.85. Found C, 58.01; H, 8.90, N, 8.86.

¹² Buntain, I. G.; Suckling, C. J.; Wood, H. C. *S. J. Chem. Soc. Perkin Trans.1* **1988**, 3175–3182.

¹³ Chang, Y.-G.; Lee, H.-S.; Kim, K. *Tetrahedron Lett.* **2001**, 42, 8197–8200.

2-[3-(1-Methoxycarbonyl-3-methylpropyl)ureido]-3-methylbutyric acid methyl ester 7d. Colorless solid, mp 151–152 °C. IR (KBr) 3335 (m), 2965 (m), 1745 (s), 1633 (s), 1573 (s), 1435 (w), 1372 (w), 1309 (w), 1206 (m), 1147 (m) cm^{-1} ; ^1H NMR ($\text{DMSO-}d_6$) δ 6.42 (d, $J = 8.8$, 2 H, 2 NH), 4.08 (dd, $J = 8.8$, 5.4, 2 H, 2 NHCH), 3.63 (s, 6 H, 2 CO_2Me), 2.08–1.91 (m, 2 H, 2 CHMe_2), 0.862 (t, $J = 7.8$, 6 H, 2 CH_3CHCH_3), 0.859 (t, $J = 7.8$, 6 H, 2 CH_3CHCH_3); ^{13}C NMR ($\text{DMSO-}d_6$) δ 173.0, 157.5, 57.6, 51.5, 30.5, 19.0, 17.7; MS m/z 288 (M^+ , <0.5%), 257 (1), 229 (31), 154 (3), 130 (7), 88 (37), 73 (6), 72 (100), 55 (11). Anal. Calcd for $\text{C}_{13}\text{H}_{24}\text{N}_2\text{O}_5$: C, 54.15; H, 8.39, N, 9.72. Found C, 54.23; H, 8.41, N, 9.71.

(S,S)-2-[3-(1,3-Bis-methoxycarbonylpropyl)ureido]pentanedioic acid dimethyl ester 7e. Colorless solid, mp 119–121 °C (lit.¹⁴ 118 °C). IR (KBr) 3355 (m), 1746 (s), 1731 (s), 1642 (m), 1633 (s), 1573 (m), 1567 (m), 1556 (m), 1455 (m), 1435 (m), 1206 (s), 1167 (m), 982 (w), 784 (w) cm^{-1} ; ^1H NMR ($\text{DMSO-}d_6$) δ 5.88 (d, $J = 8.3$, 2 H, 2 NH), 4.53 (td, $J = 8.3$, 5.4, 2 H, 2 CH), 3.75 (s, 6 H, 2 CO_2Me), 3.67 (s, 6 H, 2 CO_2Me), 2.52–2.33 (m, 4 H, 2 $\text{CH}_2\text{CO}_2\text{Me}$), 2.25–2.10 (m, 2 H, 2 CHCHH), 2.04–1.88 (m, 2 H, 2 CHCHH); ^{13}C NMR ($\text{DMSO-}d_6$) δ 173.6, 173.5, 157.1, 52.45, 52.37, 51.8, 30.1, 28.1; MS m/z 376 (M^+ , absent), 344 (2), 312 (43), 285 (27), 284 (38), 281 (19), 280 (19), 253 (66), 252 (46), 239 (11), 226 (18), 225 (100), 224 (31), 221 (40), 193 (67), 192 (11), 165 (16), 142 (35), 138 (17), 110 (25), 84 (52), 82 (54), 59 (15), 56 (17), 55 (17). Anal. Calcd for $\text{C}_{15}\text{H}_{24}\text{N}_2\text{O}_9$: C, 47.87; H, 6.43, N, 7.44. Found C, 47.99; H, 6.42, N, 7.45.

¹⁴ Humphlett, W. J.; Wilson, C.V. *J. Org. Chem.* **1961**, 26, 2507–2510.

(3-Methoxycarbonylmethylureido)acetic acid methyl ester 7f. Colorless solid, mp 154–156 °C (lit.¹⁵ 155–156 °C). IR (KBr) 3351 (m), 1754 (s), 1633 (s), 1593 (s), 1437 (w), 1419 (w), 1375 (w), 1218 (m), 1200 (m), 1171 (w), 970 (w), 609 (w) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 6.57 (t, *J* = 5.9, 2 H, 2 NH), 3.80 (d, *J* = 5.9, 4 H, 2 CH₂), 3.62 (s, 6 H, 2 CO₂Me); ¹³C NMR (DMSO-*d*₆) δ 171.5, 157.8, 51.5, 41.3; MS *m/z* 204 (M⁺, absent), 172 (10), 141 (15), 140 (55), 113 (100), 100 (17), 85 (64), 59 (9), 56 (57). Anal. Calcd for C₇H₁₂N₂O₅: C, 41.18; H, 5.92, N, 13.72. Found C, 41.03; H, 5.91, N, 13.73.

[(Morpholine-4-carbonyl)amino]acetic acid methyl ester 8fb. Colorless solid, mp 102–103 °C. IR (KBr) 3303 (m), 1732 (s), 1621 (s), 1548 (m), 1539 (m), 1417 (w), 1351 (w), 1315 (w), 1274 (w), 1249 (m), 1115 (m), 1004 (w), 960 (w), 852 (w) cm⁻¹; ¹H NMR (DMSO-*d*₆) δ 7.05 (t, *J* = 5.9, 1 H, NH), 3.74 (d, *J* = 5.9, 2 H, NHCH₂), 3.61 (s, 3 H, CO₂Me), 3.57–3.51 (m, 2 H, CH₂OCH₂), 3.30–3.24 (m, 4 H, CH₂NHCH₂); ¹³C NMR (DMSO-*d*₆) δ 171.5, 157.6, 65.9, 51.5, 43.8, 42.1; MS *m/z* 202 (M⁺, 19), 171 (14), 143 (22), 114 (81), 113 (14), 88 (39), 87 (54), 86 (46), 70 (46), 57 (100), 56 (84). Anal. Calcd for C₈H₁₄N₂O₄: C, 47.52; H, 6.98, N, 13.85. Found C, 47.65; H, 7.00, N, 13.84.

¹⁵ Kondo, K.; Murata, K.; Miyoshi, N.; Murai, S.; Sonoda, N. *Synthesis* **1979**, 735–736.