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ORIGINAL PAPER

Tandem synthesis of thiazolidine derivatives from primary amines, isothiocyanates, and bis(imidoyl) chlorides

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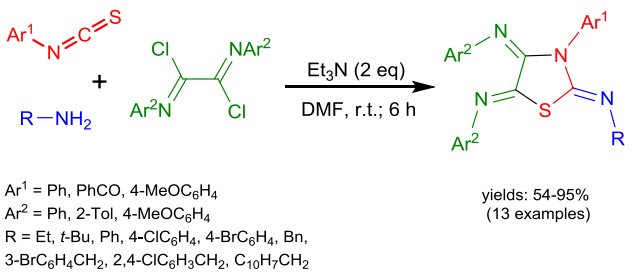
Abstract A series of thiazolidine derivatives have been synthesized *via* tandem reaction of primary amines, isothiocyanates, and bis(imidoyl) chlorides in DMF at room temperature.

Graphical Abstract



Keywords Primary amines · Thiazolidine · Bis(imidoyl) chloride · Heterocycles

Introduction

Heterocycles are key classes of compounds with diverse roles in many branches of chemistry, due to their use as building blocks in organic synthesis and medicinal chemistry [1]. Accordingly, the construction and functionalization of heterocyclic systems have become key objectives for organic chemists. Thiazolidines represent a significant group of compounds among nitrogen and sulfur containing heterocycles that cover the mainstream of pharmacologically active molecules and natural products [2, 3]. The thiazolidine ring system represents an important structural unit in antimicrobial [4], antitubercular [5], and anti-inflammatory [6] drugs.

Previously, the reaction between thioureas and imidoyl chlorides of oxalic acid have been reported [7]. There are several methods for the synthesis of thiazolidine derivatives [8–11]. As part of our current studies on the synthesis of sulfur-containing organic compounds [12–15], we describe a facile one-pot method for the direct synthesis of functionalized thiazolidines from the reaction of primary amines (**1**), isothiocyanates (**2**), and bis(imidoyl) chlorides (**3**) at room temperature. The reaction of dianionic compounds with oxaldiimidoyl dichlorides has been reviewed [16].

Experimental

Primary amines, isothiocyanates, and diethyl oxalate were obtained from *Merck* and used without further purification. Bis(imidoyl) chloride (**3**) was synthesized according to the reported procedure [17]. M.p.: Electrothermal-9100 apparatus. IR spectra: Shimadzu IR-460 spectrometer; band positions in cm^{-1}. ^1H and ^{13}C NMR spectra: Bruker DRX-300 Avance instrument at 300 and 75 MHz, respectively; δ in ppm, J in Hz. MS: Finnigan-MAT-8430EI-MS mass spectrometer, at 70 eV; in m/z (rel.%). Elemental analyses: Vario EL III CHNOS elemental analyzer.

General procedure

To a stirred mixture of primary amine (1 mmol), isothiocyanate (1 mmol), and Et_3N (0.202 g, 2 mmol) was added

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a solution of bis(imidoyl) chloride (1 mmol) in DMF (3 mL) at room temperature. After completion of the reaction [about 6 h; TLC (AcOEt/hexane 1:4) monitoring], the mixture was diluted with AcOEt and aq NH_4Cl (3 mL) and stirred for 10 min. The layers were separated, and the aqueous layer was extracted with AcOEt (3 × 3 mL). The organic fractions were combined and concentrated under reduced pressure, and the crude residue was purified by recrystallization from EtOH/AcOEt (1:1) to give the product. The spectroscopic and analytical data of compound **4a** have been reported [7]. Complete spectroscopic and analytical data for products **4b**–**4m** are given below.

(E)-N-((2Z,5Z)-3-phenyl-2,5-bis(phenylimino)thiazolidin-4-ylidene)benzenamine (4a)

Yellow crystals, mp: 198–200 °C {Lit [7]: 195 °C}; yield: 0.32 g (75%). IR (KBr) (ν_{max}, cm^{-1}): 3050, 1627 (C=N), 1588 (C=N), 1486 (C=N), 1363, 1160 (C–S), 757, 688.

(Z)-N-((2Z,4E)-2-(benzylimino)-3-phenyl-4-(phenylimino)thiazolidin-5-ylidene)benzenamine (4b)

Yellow crystals, mp: 202–204 °C; yield 0.30 g (68%). IR (KBr) (ν_{max}, cm^{-1}): 3060, 2925, 1631 (C=N), 1582 (C=N), 1489 (C=N), 1359, 1192 (C–S), 1065, 746, 691. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 4.57 (2 H, s, CH_2), 6.83–6.92 (6 H, m, 6 CH), 7.21 (2 H, d, ^3J = 6.1 Hz, 2 CH), 7.27 (2 H, t, ^3J = 6.1 Hz, 2 CH), 7.30 (2 H, t, ^3J = 8.2 Hz, 2 CH), 7.36–7.42 (4 H, br. m, 4 CH), 7.51–7.59 (2 H, br. m, 2 CH), 7.62 (2 H, d, ^3J = 8.2 Hz, 2 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 57.0 (CH_2), 119.3 (2 CH), 119.5 (2 CH), 120.0 (CH), 122.5 (2 CH), 126.5 (CH), 126.7 (CH), 126.9 (2 CH), 127.2 (2 CH), 128.0 (CH), 128.2 (C), 128.5 (2 CH), 129.0 (2 CH), 129.2 (C), 129.5 (2 CH), 139.1 (C), 149.1 (C), 149.4 (C), 151.1 (C), 158.0 (C). EI-MS: *m*/*z* (%) = 446 (M^+, 45), 355 (3), 296 (7), 194 (85), 135 (16), 91 (32), 77 (15). Anal. Calcd for $C_{28}H_{22}N_4S$ (446.57): C, 75.31; H, 4.97; N, 12.55%. Found: C, 75.72; H, 4.94; N, 12.61%.

(Z)-N-((2Z,4E)-2-(3-bromobenzylimino)-3-phenyl-4-(phenylimino)thiazolidin-5-ylidene)benzenamine (4c)

Yellow crystals, mp: 211–213 °C; yield 0.45 g (85%). IR (KBr) (ν_{max}, cm^{-1}): 3050, 2931, 1625 (C=N), 1578 (C=N), 1483 (C=N), 1355, 1186 (C–S), 1056, 755, 688. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 4.53 (2 H, s, CH_2), 6.21–6.85 (5 H, br. m, 5 CH), 7.13–7.22 (5 H, br. m, 5 CH), 7.25 (1 H, s, CH), 7.35–7.40 (5 H, br. m, 5 CH), 7.42–7.53 (3 H, br. m, 3 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 56.2 (CH_2), 119.4 (CH), 119.5 (CH), 120.0 (2 CH), 122.6 (2 CH), 125.7 (2 CH), 126.8 (CH), 128.2 (CH), 128.3 (C), 128.6 (C), 129.0 (2 CH), 129.2 (CH), 129.4 (CH), 129.5 (2 CH), 130.1 (CH), 130.3 (2 CH), 136.8 (C), 141.5 (C), 142.9 (C), 148.7 (C), 148.8 (C), 150.0 (C). EI-MS: *m*/*z* (%) = 525 (M^+, 40), 355 (7), 296 (10), 194 (90), 169 (31), 135 (38), 77 (46). Anal. Calcd for $C_{28}H_{21}BrN_4S$ (525.46): C, 64.00; H, 4.03; N, 10.66%. Found: C, 63.76; H, 4.07; N, 10.73%.

X-ray crystal-structure determination of 4c

Structure determination and refinement data: formula, $C_{28}H_{21}N_4SBr$: Mr 525.46; Monoclinic, space group *P*21, a = 17.423(3), *b* = 5.803(1), *c* = 24.264(4) Å; β = 90.29(1), *Z* = 4, *V* = 2453.2(7) $Å^3$, D_{calc} = 1.423 Mg/m^3, MoK_a radiation (0.71073 Å), *T* = 293(2) K; 5782 reflections collected on a Bruker P4 diffractometer, 5596 unique (Rint = 0.0601), 2736 unique reflections with $I > 2\sigma(I)$. The structure was solved by direct methods and refined by full-matrix least-squares techniques using the SHELXL-97 package. There are two molecules in the asymmetric unit. All non-hydrogen atoms have been refined anisotropically. The hydrogen atoms have been placed on calculated positions and refined isotropically by using the riding model. Refinement of racemic twinning has been done. Final indices [$I > 2\sigma(I)$]: R_1 = 0.0714, wR_2 = 0.1471, GOF = 0.993. The crystallographic data of **4c** have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication number CCDC-1486384. Copies of the data can be obtained, free of charge, *via* the internet (http://www.ccdc.cam.ac.uk/data_request/cif), e-mail (data_request@ccdc.cam.ac.uk), or fax (+44-1223-336033).

(Z)-N-((2Z,4E)-2-(2,4-dichlorobenzylimino)-3-phenyl-4-(phenylimino)thiazolidin-5-ylidene)benzenamine (4d)

Yellow crystals, mp: 217–218 °C; yield 0.45 g (87%). IR (KBr) (ν_{max}, cm^{-1}): 3050, 2858, 1633 (C=N), 1592 (C=N), 1486 (C=N), 1363, 1194 (C–S), 1064, 746, 688. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 4.51 (2 H, s, CH_2), 6.61–6.91 (4 H, br. m, 4 CH), 7.08–7.16 (4 H, br. m, 4 CH), 7.23 (1 H, t, ^3J = 6.4 Hz, CH), 7.32 (1 H, s, CH), 7.42 (4 H, t, ^3J = 8.4 Hz, 4 CH), 7.47–7.60 (2 H, br. m, 2 CH), 7.69 (2 H, d,^3J = 8.4 Hz, 2 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 53.7 (CH_2), 119.6 (CH), 119.9 (2 CH), 120.0 (2 CH), 122.7 (CH), 125.7 (2 CH), 126.8 (C), 127.2 (CH), 128.3 (C), 128.6 (C), 128.9 (CH), 129.0 (2 CH), 129.3 (CH), 129.4 (2 CH), 129.5 (2 CH), 133.1 (CH), 136.3 (C), 141.5 (C), 143.2 (C), 148.9 (C), 149.8 (C), 157.6 (C). EI-MS: *m*/*z* (%) = 514 (M^+, 30), 296 (10), 194 (100), 159 (31), 135 (28), 77 (29). Anal. Calcd for $C_{28}H_{20}Cl_2N_4S$ (515.46): C, 65.24; H, 3.91; N, 10.87%. Found: C, 65.53; H, 3.87; N, 10.96%.

(Z)-N-((2Z,4E)-2-(naphthalen-1-ylmethylimino)-3-phenyl-4-(phenylimino)thiazolidin-5-ylidene)benzenamine (4e)

Yellow crystals, mp: 186–187 °C; yield 0.47 g (95%). IR (KBr) (ν_{max}, cm^{-1}): 3053, 2878, 1633 (C=N), 1598 (C=N), 1486 (C=N), 1363, 1194 (C–S), 1068, 791, 759, 688. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 5.02 (2 H, s, CH_2), 6.81–7.22 (9 H, br. m, 9 CH), 7.42 (4 H, d, ^3J = 7.7 Hz, 4 CH), 7.49–7.55 (5 H, br. m, 5 CH), 7.77 (1 H, d, ^3J = 8.1 Hz, CH), 7.87 (1 H, d, ^3J = 9.4 Hz, CH), 7.91–7.97 (2 H, br. m, 2 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 55.0 (CH_2), 119.5 (CH), 120.0 (2 CH), 122.6 (CH), 123.7 (2 CH), 124.7 (2 CH), 125.6 (CH), 125.8 (CH), 126.1 (CH), 126.8 (CH), 127.8 (CH), 128.3 (CH), 128.5 (C), 128.8 (2 CH), 129.0 (2 CH), 129.3 (C), 129.5 (2 CH), 131.2 (CH), 133.7 (CH), 134.7 (C), 143.1 (C), 145.8 (C), 148.1 (C), 149.0 (C), 149.7 (C), 152.4 (C). EI-MS: *m/z* (%) = 496 (M^+, 35), 355 (4), 296 (10), 194 (95), 141 (68), 115 (25), 77 (17). Anal. Calcd for $C_{32}H_{24}N_4S$ (496.62): C, 77.39; H, 4.87; N, 11.28%. Found: C, 77.01; H, 4.83; N, 11.37%.

(E)-N-((2Z,5Z)-2-(ethylimino)-3-phenyl-5-(phenylimino)thiazolidin-4-ylidene)benzenamine (4f)

Yellow crystals, mp: 193–194 °C; yield 0.32 g (82%). IR (KBr) (ν_{max}, cm^{-1}): 3298, 2963, 1629 (C=N), 1591 (C=N), 1486 (C=N), 1362, 1291, 1194 (C–S), 1054, 754, 685. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 1.17 (3 H, t, ^3J = 6.7 Hz, Me), 3.36 (2 H, q, ^3J = 6.4 Hz, CH_2), 6.62–7.02 (5 H, br. m, 5 CH), 7.15–7.23 (4 H, br. m, 4 CH), 7.38–7.47 (6 H, br. m, 6 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 15.6 (CH_3), 48.4 (CH_2), 119.5 (CH), 119.7 (2 CH), 122.3 (2 CH), 125.6 (CH), 126.4 (CH), 128.2 (2 CH), 128.9 (2 CH), 129.1 (2 CH), 129.9 (2 CH), 136.2 (C), 136.9 (C), 146.1 (C), 147.5 (C), 149.1 (C), 157.5 (C). EI-MS: *m/z* (%) = 384 (M^+, 42), 369 (6), 355 (10), 297 (34), 194 (87), 141 (68), 87 (25), 77 (12). Anal. Calcd for $C_{23}H_{20}N_4S$ (384.14): C, 77.85; H, 5.24; N, 14.57%. Found: C, 77.42; H, 5.20; N, 14.65%.

((2Z,4E,5Z)-2-(benzylimino)-4,5-bis(phenylimino) thiazolidin-3-yl)(phenyl)methanone (4g)

Red crystals, mp: 140–142 °C; yield 0.26 g (54%). IR (KBr) (ν_{max}, cm^{-1}): 3054, 2919, 1670 (C=O), 1636 (C=N), 1517 (C=N), 1382 (C=N), 1274, 1163 (C–S), 1093, 871, 754, 689. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 5.57 (2 H, s, CH_2), 6.84 (2 H, d, ^3J = 8.4 Hz, 2 CH), 6.91 (2 H, d, ^3J = 8.4 Hz, 2 CH), 7.08 (1 H, t, ^3J = 7.5 Hz, CH), 7.20 (1 H, t, ^3J = 7.5 Hz, CH), 7.30 (2 H, t, ^3J = 7.5 Hz, 2 CH), 7.32 (2 H, t, ^3J = 7.4 Hz, 2 CH), 7.39 (2 H, t, ^3J = 7.3 Hz, 2 CH), 7.42 (1 H, t, ^3J = 6.4 Hz, CH), 7.54 (2 H, t, ^3J = 7.0 Hz, 2 CH), 7.60 (1 H, t, ^3J =7.3 Hz, CH), 7.67 (2 H, d, ^3J = 6.4 Hz, 2 CH), 8.31 (2 H, d, ^3J = 7.0 Hz, 2 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 48.1 (CH_2), 119.2 (2 CH), 120.5 (2 CH), 123.5 (CH), 127.2 (CH), 128.1 (CH), 128.5 (CH), 128.6 (2 CH), 128.7 (2 CH), 128.8 (2 CH), 129.2 (2 CH), 129.5 (2 CH), 130.3 (2 CH), 133.4 (C), 135.5 (C), 136.1 (C), 143.7 (C), 148.1 (C), 148.2 (C), 164.6 (C), 176.7 (C). EI-MS: *m/z* (%) = 473 (M^+, 85), 368 (12), 265 (15), 207 (50), 135 (39), 105 (90), 91 (89), 77 (82). Anal. Calcd for $C_{29}H_{22}N_4OS$ (474.58): C, 73.39; H, 4.67; N, 11.81%. Found: C, 73.66; H, 4.62; N, 11.92%.

(E)-N-((2Z,5Z)-3-(4-methoxyphenyl)-2,5-bis(phenylimino)thiazolidin-4-ylidene)benzenamine (4h)

Yellow crystals, mp: 223–226 °C; yield 0.36 g (92%). IR (KBr) (ν_{max}, cm^{-1}): 3427, 3050, 1628 (C=N), 1496 (C=N), 1365 (C=N), 1243, 1173 (C–S), 750, 688. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 3.76 (3 H, s, MeO), 6.71–6.91 (9 H, br. m, 9 CH), 7.01–7.16 (4 H, br. m, 4 CH), 7.22–7.29 (2 H, br. m, 2 CH), 7.40–7.42 (2 H, br. m, 2 CH), 7.51–7.56 (2 H, br. m, 2 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 55.5 (MeO), 114.4 (2 CH), 119.2 (CH), 119.3 (CH), 119.9 (2 CH), 122.3 (2 CH), 122.7 (2 CH), 126.4 (C), 126.6 (C), 128.1 (2 CH), 128.3 (2 CH), 128.5 (C), 128.7 (CH), 128.9 (2 CH), 129.5 (2 CH), 142.0 (C), 149.9 (C), 150.3 (C), 154.2 (C), 156.9 (C). EI-MS: *m/z* (%) = 462 (M^+, 45), 296 (8), 224 (11), 194 (92), 135 (22), 91 (10), 77 (35). Anal. Calcd for $C_{28}H_{22}N_4OS$ (462.57): C, 72.70; H, 4.79; N, 12.11%. Found: C, 72.39; H, 4.75; N, 12.19%.

(E)-N-((2Z,5Z)-2-(4-bromophenylimino)-3-(4-methoxyphenyl)-5-(phenylimino)thiazolidin-4-ylidene)benzenamine (4i)

Yellow crystals, mp: 230–233 °C; yield 0.49 g (91%). IR (KBr) (ν_{max}, cm^{-1}): 3055, 2928, 1622 (C=N), 1587 (C=N), 1489 (C=N), 1360, 1166 (C–S), 1019, 831, 753, 686. ^{1}H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 3.73 (3 H, s, MeO), 6.77–6.85 (6 H, br. m, 6 CH), 6.86–6.95 (2 H, br. m, 2 CH), 7.15–7.21 (4 H, br. m, 4 CH), 7.26–7.30 (2 H, br. m, 2 CH), 7.40–7.47 (2 H, br. m, 2 CH), 7.62–7.68 (2 H, br. m, 2 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 55.8 (MeO), 114.5 (2 CH), 119.4 (CH), 119.8 (2 CH), 122.1 (2 CH), 122.7 (2 CH), 126.6 (CH), 127.6 (2 CH), 129.2 (2 CH), 130.5 (2 CH), 132.5 (2 CH), 135.4 (C), 141.6 (C), 145.5 (C), 145.9 (C), 147.1 (C), 148.4 (C), 149.9 (C), 156.9 (C), 159.5 (C). EI-MS: *m/z* (%) = 540 (M^+, 82), 510 (14), 375 (5), 274 (93), 224 (35), 165 (24), 135 (57), 77 (76). Anal. Calcd for $C_{28}H_{21}BrN_4OS$ (541.46): C, 62.11; H, 3.91; N, 10.35%. Found: C, 62.28; H, 3.89; N, 10.39%.

(E)-N-((2Z,5Z)-2-(4-chlorobenzylimino)-3-(4-methoxyphenyl)-5-(phenylimino) thiazolidin-4-ylidene)benzenamine (4j)

Red crystals, mp: 182–185 °C; yield 0.45 g (88%). IR (KBr) (ν_{max}, cm^{-1}): 3055, 2949, 2830, 1655 (C=N), 1587 (C=N), 1494 (C=N), 1385, 1298, 1170 (C–S), 1026, 746, 690. ^1H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 3.68 (3 H, s, MeO), 5.09 (2 H, s, CH_2), 6.43–6.46 (4 H, m, 4 CH), 6.88 (2 H, d, $^3J = 8.3$ Hz, 2 CH), 6.92–6.99 (2 H, br. m, 2 CH), 7.09 (2 H, t, $^3J = 8.1$ Hz, 2 CH), 7.15–7.21 (3 H, br. m, 3 CH), 7.29 (2 H, t, $^3J = 8.0$ Hz, 2 CH), 7.34 (1 H, d, $^3J = 7.9$ Hz, CH), 7.41–7.65 (2 H, m, 2 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 44.0 (CH_2), 55.6 (MeO), 113.8 (2 CH), 119.9 (2 CH), 120.7 (C), 122.3 (2 CH), 123.4 (2 CH), 127.4 (C), 128.3 (C), 128.6 (2 CH), 128.7 (2 CH), 128.9 (2 CH), 129.0 (2 CH), 129.4 (C), 133.7 (CH), 135.0 (C), 135.1 (CH), 138.0 (C), 140.5 (C), 147.8 (C), 155.5 (C). EI-MS: *m/z* (%) = 510 (M^+, 75), 479 (5), 385 (20), 231 (90), 206 (3), 165 (10), 125 (57), 77 (12). Anal. Calcd for $C_{29}H_{23}ClN_4OS$ (511.04): C, 68.16; H, 4.54; N, 10.96%. Found: C, 67.91; H, 4.51; N, 10.99%.

(E)-N-((2Z,5Z)-2-(tert-butylimino)-3-(4-methoxyphenyl)-5-(phenylimino)thiazolidin-4-ylidene)benzenamine (4k)

Yellow crystals, mp: 206–208 °C; yield 0.41 g (93%). IR (KBr) (ν_{max}, cm^{-1}): 3305, 2972, 1632 (C=N), 1514 (C=N), 1368 (C=N), 1298, 1252, 1178 (C–S), 1036, 753, 690. ^1H NMR (500 MHz, $CDCl_3$): δ_H (ppm) 1.21 (9 H, s, CMe_3), 3.82 (3 H, s, MeO), 6.38–6.44 (2 H, br. m, 2 CH), 6.46–6.58 (6 H, br. m, 6 CH), 7.02–7.17 (2 H, br. m, 2 CH), 7.32–7.39 (2 H, br. m, 2 CH), 7.42–7.51 (2 H, br. m, 2 CH). ^{13}C NMR (125 MHz, $CDCl_3$): δ_C (ppm) 30.3 (CMe_3), 55.3 (CMe_3), 55.8 (MeO), 114.1 (CH), 114.3 (CH), 119.9 (2 CH), 120.0 (2 CH), 120.3 (2 CH), 122.4 (2 CH), 126.3 (C), 126.6 (C), 128.3 (C), 128.5 (C), 129.7 (2 CH), 130.5 (2 CH), 138.1 (C), 140.6 (C), 158.9 (C). EI-MS: *m/z* (%) = 442 (M^+, 63), 427 (47), 385 (15), 327 (9), 115 (22), 77 (12). Anal. Calcd for $C_{26}H_{26}N_4OS$ (442.58): C, 70.56; H, 5.92; N, 12.66%. Found: C, 70.31; H, 5.89; N, 12.69%.

(E)-2-methyl-N-((2Z,5Z)-3-phenyl-2-(phenylimino)-5-(o-tolylimino)thiazolidin-4-ylidene) benzenamine (4l)

Yellow crystals, mp: 175–176 °C; yield 0.33 g (71%). IR (KBr) (ν_{max}, cm^{-1}): 3013, 2921, 1627 (C=N), 1591 (C=N), 1484 (C=N), 1358, 1161 (C–S), 751, 688. ^1H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 1.79 (3 H, s, Me), 2.16 (3 H, s, Me), 6.72 (1 H, d, $^3J = 7.9$ Hz, CH), 6.77 (1 H, br. m, CH), 6.84 (1 H, t, $^3J = 7.1$ Hz, CH), 6.89 (2 H, d, $^3J = 7.6$ Hz, 2 CH), 7.04 (3 H, d, $^3J = 7.2$ Hz, 3 CH), 7.10 (3 H, d, $^3J = 7.6$ Hz, 3 CH), 7.28 (2 H, t, $^3J = 7.6$ Hz, 2 CH), 7.45 (1 H, br. m, CH), 7.53–7.63 (4 H, br. m, 4 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 18.5 (Me), 18.8 (Me), 115.4 (CH), 116.8 (CH), 117.6 (C), 118.9 (CH), 121.8 (2 CH), 124.0 (C), 125.3 (2 CH), 126.0 (CH), 126.6 (2 CH), 127.9 (2 CH), 128.2 (CH), 128.5 (CH), 128.7 (CH), 129.5 (CH), 130.0 (CH), 131.7 (CH), 136.4 (C), 145.2 (C), 145.4 (C), 145.9 (C), 147.6 (C), 148.5 (C), 150.5 (C). EI-MS: *m/z* (%) = 460 (M^+, 38), 383 (5), 325 (10), 234 (43), 135 (52), 91 (4), 77 (17). Anal. Calcd for $C_{29}H_{24}N_4S$ (460.59): C, 75.62; H, 5.25; N, 12.16%. Found: C, 75.31; H, 5.23; N, 12.22%.

(Z)-N-((2Z,4E)-2-(benzylimino)-3-(4-methoxyphenyl)-4-(4-methoxyphenylimino)thiazolidin-5-ylidene)-4-methoxybenzenamine (4m)

Red crystals, mp: 179–181 °C; yield: 0.35 g (65%). IR (KBr) (ν_{max}, cm^{-1}): 3010, 2930, 2833, 1620 (C=N), 1503 (C=N), 1455 (C=N), 1370, 1295, 1191 (C–S), 1027, 829, 737, 536. ^1H NMR (300 MHz, $CDCl_3$): δ_H (ppm) 3.64 (2 H, s, CH_2), 3.75 (3 H, s, MeO), 3.82 (3 H, s, MeO), 4.60 (3 H, s, MeO), 6.83–6.74 (3 H, br. m, 3 CH), 6.92–6.89 (4 H, br. m, 4 CH), 6.98–7.03 (2 H, br. m, 2 CH), 7.22 (2 H, t, $^3J = 7.1$ Hz, 2 CH), 7.31 (2 H, t, $^3J = 6.7$ Hz, 2 CH), 7.33 (2 H, t, $^3J = 7.3$ Hz, 2 CH), 7.36–7.40 (2 H, br. m, 2 CH). ^{13}C NMR (75 MHz, $CDCl_3$): δ_C (ppm) 49.4 (CH_2), 55.0 (MeO), 55.5 (MeO), 56.8 (MeO), 113.4 (2 CH), 114.5 (2 CH), 115.3 (CH), 120.8 (2 CH), 122.6 (C), 126.9 (2 CH), 127.1 (2 CH), 127.8 (2 CH), 128.3 (2 CH), 128.7 (C), 129.8 (2 CH), 139.1 (C), 141.1 (C), 142.4 (C), 145.2 (C), 150.2 (C), 155.3 (C), 158.6 (C), 158.9 (C). EI-MS: *m/z* (%) = 536 (M^+, 75), 445 (7), 387 (20), 266 (85), 149 (30), 107 (10), 91 (23), 77 (12). Anal. Calcd for $C_{31}H_{28}N_4O_3S$ (536.65): C, 69.38; H, 5.26; N, 10.44%. Found: C, 69.74; H, 5.22; N, 10.54%.

Results and discussion

We began our investigation with desired bis(imidoyl) chlorides (**3**), which was synthesized according to the reported procedure [17]. The three-component reaction of primary amines (**1**) with isothiocyanates (**2**) in the presence of bis(imidoyl) chlorides proceeds smoothly in DMF at room temperature to produce 2-imino-3-aryl-4,5-bis(arylimino)thiazolidines **4**, in good yields (Table 1).

The structures of compounds **4b**–**4m** were deduced from their IR, ^{1}H NMR, and ^{13}C NMR, mass spectral data and single-crystal X-ray analyses. The mass spectrum of **4c** displayed the molecular ion peak at $m/z = 525$. The ^{1}H NMR spectrum of **4c** showed a signal singlet at 4.53 ppm for the CH_2 and characteristic multiplets for the phenyl protons, and the ^{1}H-decoupled ^{13}C NMR spectrum of **4c** exhibited 22 signals in agreement with the proposed structure.

Unequivocal evidences for the structure of **4c** were obtained from single-crystal X-ray analyses. The ORTEP [18] diagram of **4c** is shown in Fig. 1. The structure was deduced from the crystallographic data, and the same were assumed for the other derivatives on account of their NMR spectroscopic similarities.

A plausible mechanism for the formation of compounds **4** is given in Scheme 1. The initial event may be the formation of dianione **5** from primary amines **1** and isothiocyanates. Dianione **5** is a heteroanalogue of guanidinium cation with noticeable resonance stabilization energy of Y-shaped species with $4n + 2$ π-electrons, which suggest potential Y-aromaticity in these structures [19, 20]. Formation of a Y-delocalized intermediate, such as the thiourea dianione **5**, may act as a driving force for chemical transformations. Thus, intermediate **5** is attacked by bis(imidoyl) chlorides to form product **4** by elimination of two equivalents of $Et_3NH^+Cl^-$.

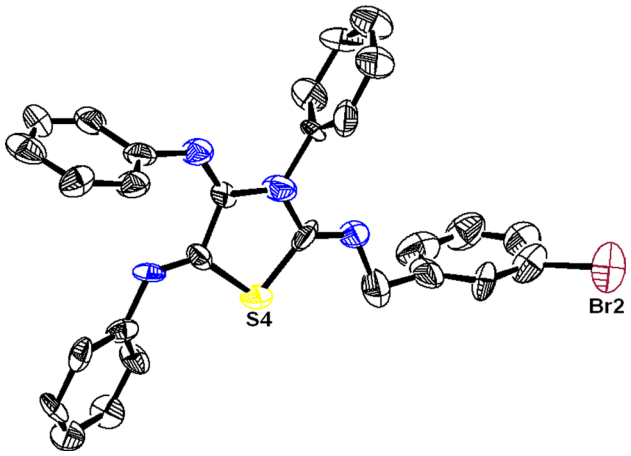
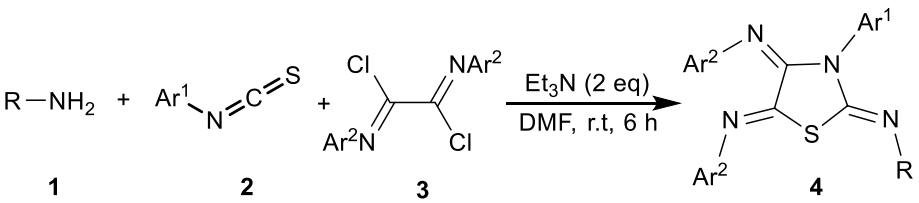


Fig. 1 X-ray crystal structure (ORTEP) of **4c**

In conclusion, we report a three-component synthesis of thiazolidine derivatives from primary amine, isothiocyanates, and bis(imidoyl) chlorides. The present procedure has the advantage that the reactants can be mixed without any prior activation or modification and this procedure has advantages of good yields. The products were crystallized out from the

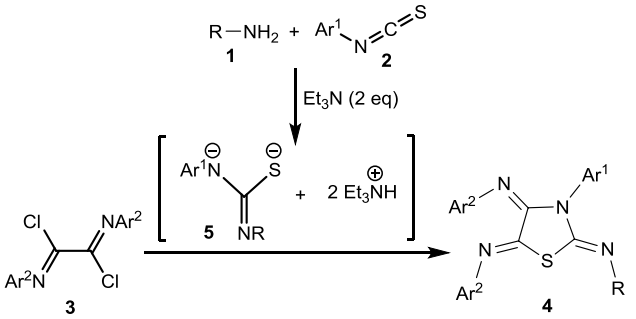
Table 1 Synthesis of 4,5-bis(arylimino)thiazolidine derivatives



1 2 3 4

Entry	*R*	Ar^1	Ar^2	Product	Yield (%)
1	Ph	Ph	Ph	**4a**	75
2	Bn[a]	Ph	Ph	**4b**	68
3	3-$BrC_6H_4CH_2$	Ph	Ph	**4c**	85
4	2,4-$ClC_6H_3CH_2$	Ph	Ph	**4d**	87
5	$C_{10}H_7CH_2$	Ph	Ph	**4e**	95
6	Et	Ph	Ph	**4f**	82
7	Bn	PhCO	Ph	**4g**	54
8	Ph	4-$MeOC_6H_4$	Ph	**4h**	92
9	4-BrC_6H_4	4-$MeOC_6H_4$	Ph	**4i**	91
10	4-$ClC_6H_4CH_2$	4-$MeOC_6H_4$	Ph	**4j**	88
11	*t*-Bu[b]	4-$MeOC_6H_4$	Ph	**4k**	93
12	Ph	Ph	2-Tol[c]	**4l**	71

[a] Benzyl, [b] *tert*-Butyl, [c] 2-Tolidine



Scheme 1 Proposed mechanism for the synthesis of thiazolidine derivatives

reaction mixture in pure form. The simplicity of the experimental procedure and the ready accessibility of primary amines and isothiocyanates render this experimentally attractive method for the synthesis of thiazolidine derivatives.

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