SYNTHESIS OF SOME THIOPHENE-FUSED AZEPINO[5,4,3-cd]INDOLES

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Abstract—Interaction of indolylzinc chloride with 2-chloro-3-nitrothiophene gave 3-(3-nitrothien-2-yl)indole (7) which was converted, via reduction followed by acylation, into 3-(3-acylaminothien-2-yl)indoles (9a-c). Cyclization of 9a-c induced by phosphorus oxychloride under Bischler-Napieralski reaction conditions, took place regioselectively at the indolic C-4 locus to furnish the respective thieno[2',3':6,7]azepino[5,4,3-cd]indoles (3a-c).

INTRODUCTION

Various types of azepine-fused heterocycles, such as thienoazepines 1 and azepinoindoles, 2 have been investigated. Amongst, few recent reports dealt with the synthesis and medicinal activities of compounds having the thieno[3,2-b]azepine skeleton (1), 3-5 bioisostere of benzo[b]azepine. Some derivatives of the latter system are known to display activities such as anticancerigen, 6 calcium antagonists 7 and central nervous system depressors. 8 Different thieno[3,2-b]azepines showed vasopressin V1, V2 and oxytocine antagonist activity, 4 as well as affinity towards dopamine D2, serotonin 2 and serotonin 1A receptors. 5 More recently, series of synthetic tricyclic heterocycles structurally based on the thieno[3,2-b]azepine skeleton, have revealed interesting biological activity. Examples include substituted pyrazolo[3,4-d] thieno[3,2-b]azepines, acting as potent orally active arginine vasopressin (AVP) receptor antagonist, 9 and pyrido[3,2-d]thieno[3,2-b]azepine derivatives, exhibiting a remarkable selectivity for renal tumor cell lines. 10

On the other hand, the azepino[5,4,3-cd]indole system constitutes the skeleton of the ergot alkaloid clavicipitic acid (2). 11 Some synthetic analogs of 2 were reported to exhibit potent activity on the central nervous system with potential against migraine attacks, 12 while others were described as dopamine D-1...
As part of our work concerning the synthesis of fused heterocycles with potential therapeutic interest, we have described some pyrazoloazepino[5,4,3-cd]indoles 16 and pyrazolo-β-carbolines.17 In continuation, we thought it is worthwhile to prepare the tetracyclic system (3) incorporating both thienoazepine (1) and azepinoindole (2) moieties. Herein, we report on the synthesis of thieno[2′,3′ : 3,2]azepino[5,4,3-cd]indoles (3) as outlined in Scheme 1.

RESULTS AND DISCUSSION

CHEMISTRY

The required 3-(3-nitrothien-2-yl)indole (7) is readily prepared via coupling of indolylzinc chloride (5) with 2-chloro-3-nitrothiophene (6) (Scheme 1), following similar procedure previously reported for 3-(4-nitropyrazol-3-yl) indoles 16 and related 3-(heteroaryl)indoles.18 Reduction of 7, using tin and hydrochloric acid in the conventional manner, yielded the respective 3-(3-aminothien-2-yl)indole (8) characterized as its monohydrochloride salt. Acylation of 8 with the appropriate acyl chloride gave 3-(3-acylaminothien-2-yl)indoles (9a-c) which were cyclized, using phosphorus oxychloride in acetonitrile under reflux, to furnish the desired thieno[2′,3′ : 6,7]azepino[5,4,3-cd]indoles (3a-c).

The formation of 3a-c via their precursors (9a-c) implies that cyclization under Bischler-Napieralski reaction conditions occurred regioselectively at the indolic C-4 locus instead of the usual C-2 position. In this respect, compounds (9a-c) behaved in a similar manner to their 3-(4-aminoacylpyrazol-3-yl)indole analogs which were reported to cyclize into pyrazoloazepino[5,4,3-cd]indoles.16

SPECTRAL DATA

The new compounds (7-9 and 3) were characterized by MS and NMR spectral data, and by elemental
analyses. These data, detailed in the EXPERIMENTAL, are consistent with the assigned structures. Thus, the measured HRMS data for M⁺ are in good agreement with the calculated values as suggested by their molecular formulas. DEPT and 2D (COSY, HMQC and HMBC) experiments showed different correlations that helped in the ¹H- and ¹³C- signal assignments to the various hydrogens and carbons. The indolic H-2 proton’s signal is characterized by a small coupling constant (J_{CH-NH} = 2.0 - 2.5 Hz) for its doublet that collapses to a singlet upon addition of D₂O. This doublet, collapsing to a singlet, prevails in the ¹H NMR spectra of the cyclized products (3a-c), indicating that annulation did not occur at the indolic C-2 locus. In addition, long range correlation between H-8 and the azomethine carbon (C-7) in HMBC experiments for 3a-c, provides supporting evidence that intramolecular cyclization occurred at the indolic C-4 locus. Protons of the methyl group appended at C-7 of 3c, also displayed long range correlation with C-7a. These and relevant spectral features are in accord with the azepino-indole structure of the cyclized products (3a-c).
EXPERIMENTAL

2-Chloro-3-nitrothiophene was purchased from Apollo Scientific Ltd., UK. The acyl chlorides, zinc chloride (1.0 M in ether) and methylmagnesium iodide (3.0 M in ether) were purchased from Aldrich. Phosphorous oxychloride was purchased from BDH. Melting points (uncorrected) were determined on an electrothermal Mel-Temp apparatus. $^1$H- and $^{13}$C NMR spectra were measured on a Bruker DPX-300 instrument with TMS as internal reference. Electron-impact MS spectra were obtained using a Finnigan MAT TSQ-70 spectrometer at 70 eV; ion source temperature = 200 °C. IR spectra were recorded as KBr discs on a Nicolet Impact-400 FT-IR spectrophotometer. Microanalyses were performed at the Microanalytical Laboratory-Inorganic Chemistry Department, Tübingen University, Germany.

3-(3-Nitrothien-2-yl)indole (7)

To a solution of indole (2.0 g; 17 mmol) in dry ether (20 mL), an ethereal solution of methylmagnesium iodide (3.0 M in ether, 5 mL) was added, and the mixture was stirred for 30 min at rt. An ethereal solution of ZnCl$_2$ (1.0 M, 15 mL) was then added, and the resultant mixture was further stirred at rt for 30 min. Later on, a solution of 2-chloro-3-nitrothiophene (6) (1.14 g; 7 mmol) in dry ether (20 mL) was added dropwise to the reaction mixture, and stirring was continued at rt for 6 h. Water (100 mL) was then added to the reaction mixture, the ether layer was separated and the aqueous layer was extracted with ether (3 x 50 mL). The combined ether portions were dried (anhydrous Na$_2$SO$_4$), and the solvent was evaporated. The crude product was purified by silica gel TLC chromatography, eluting with CH$_2$Cl$_2$, to afford an orange solid. Yield of pure 7 = 1.13 g (66 %), mp 95-96 °C. Anal. Calcd for C$_{12}$H$_8$N$_2$O$_2$S : C, 59.01; H, 3.30; N, 11.47; S, 13.13. Found: C, 58.86; H, 3.21; N, 11.42; S, 13.12. IR (KBr) : ν 3384, 3129, 3106, 3093, 1608, 1548, 1417, 1316, 1235 cm$^{-1}$; MS m/z (% rel. int.) : 244 (M$^+$,100), 227 (6), 214 (8), 196 (5), 187 (40), 171 (50), 160 (13), 132 (14), 117 (20), 99 (15), 89 (13); HRMS : Calcd for C$_{12}$H$_8$N$_2$O$_2$S : 244.030631. Found: 244.029378; $^1$H NMR (300 MHz, DMSO-d$_6$): δ 7.10 (dd, 1H, $J$ = 7.4, 7.6 Hz, H-5), 7.19 (dd, 1H, $J$ = 7.4, 7.9 Hz, H-6), 7.40 (d, 1H, $J$ = 7.6 Hz, H-4), 7.47 (d, 1H, $J$ = 7.9 Hz, H-7), 7.57 (d, 1H, $J$ = 5.8 Hz, H-5'), 7.70 (d, 1H, $J$ = 5.8 Hz, H-4'), 7.93 (br d, 1H, $J$ = 2.2 Hz, H-2), 11.57 (d, 1H, $J$ = 2.2 Hz, N$_1$-H); $^{13}$C NMR (75 MHz, DMSO-d$_6$): δ 105.6 (C-3), 112.8 (C-7), 119.8 (C-4), 120.9 (C-5), 122.7 (C-6), 124.3 (C-2'), 125.2 (C-3'), 125.9 (C-3a), 128.8 (C-2), 136.7 (C-7a), 140.8 (C-5'), 141.9 (C-4').

3-(3-Aminothien-2-yl)indole (8)

Tin granules (5 g; 4.2 g atom) were added to a solution of 3-(3-nitrothien-2-yl)indole (7) (1.27 g; 5.2 mmol) in conc. HCl (35 mL) and 95% ethanol (10 mL). The reaction mixture was refluxed for 2 h. The
resulting solution was cooled, basified with 40% aqueous NaOH solution, and extracted with CH₂Cl₂ (3 x 100 mL). The combined CH₂Cl₂ extracts were dried (anhysrous Na₂SO₄), and the solvent was evaporated to give a brown solid. Yield of crude product = 0.82 g (74%); A pure sample of 8, obtained by recrystallization from ether/n-hexane, had mp 65–66°C. MS m/z (% rel. int.) : 214 (M⁺, 100), 213 (46), 201 (8), 186 (17), 181 (7), 160 (12), 140 (3), 130 (16), 118 (7), 117 (11), 106 (8). Due to the instability of the title amino compound (8) as a free base, it was immediately used in the next N-acylation step.

Compound (8) was characterized as its stable monohydrochloride salt, 3-(3-aminothien-2-yl)indole monohydrochloride, white tiny granules (methanol–ether). Yield = 0.52 g (83%), mp > 250°C. Anal. Calcd for C₁₂H₁₁N₂ClS: C, 57.48; H, 4.42; N, 11.17; Cl, 14.14; S, 12.79. Found: C, 57.21; H, 4.26; N, 11.02; Cl, 14.05; S, 12.57. IR (KBr): ν 3276, 2981, 2783, 2583, 1607, 1560, 1525, 1429, 1249, 1122 cm⁻¹; ¹H NMR (300 MHz, DMSO-d₆): 7.10 (dd, 1H, J = 7.8, 7.5 Hz, H-5), 7.15 (dd, 1H, J = 7.9 Hz, H-7), 7.25 (d, 1H, J = 5.4 Hz, H-5'), 7.42 (d, 1H, J = 7.4 Hz, H-7), 7.45 (d, 2H, J = 8.2 Hz, H-3"/H-5"), 7.60 (d, 1H, J = 7.9 Hz, H-6), 7.70 (d, 2H, J = 8.2 Hz, H-2"/H-6"), 10.40 (br s, 3H, -NH₃), 11.75 (br s, 1H, N₁-H). ¹³C NMR (75 MHz, DMSO-d₆): δ 105.1 (C-3), 112.6 (C-7), 119.5 (C-4), 120.1 (C-5), 121.9 (C-7), 124.9 (C-2), 126.1 (C-7), 126.2 (C-3a), 129.5 (C-3"), 136.7 (C-7a).

3-[3-(4'-Chlorobenzoyl)aminothien-2-yl]indole (9a)
p-Chlorobenzoyl chloride (0.55 g; 3.2 mmol) was added to a solution of 8 (0.64 g; 3.0 mmol) in dry benzene (30 mL), followed by addition of triethylamine (2 mL; 14.2 mmol). The resulting mixture was refluxed for 4 h. Water was added to the solution, and the resultant mixture was washed with saturated sodium bicarbonate. The aqueous layer was extracted with benzene (2 x 10 mL), and the combined organic layers were dried over anhydrous Na₂SO₄. The solvent was evaporated to give the desired amide as a white solid which was recrystallized from benzene/petroleum ether (bp 40–60°C). Yield of 9a = 0.68 g (64%); mp 204–205°C (decomp). Anal. Calcd for C₁₉H₁₃N₂OClS: C, 64.68; H, 3.71; N, 7.94; Cl, 10.05; S, 9.09. Found: C, 64.41; H, 3.55; N, 7.68; Cl, 9.92; S, 8.83. IR (KBr): ν 3407, 3298, 3099, 3058, 1665, 1590, 1538, 1473, 1420, 1269, 1092, 1012 cm⁻¹; MS m/z (% rel. int.): 352 (M⁺, 43), 335 (5), 244 (3), 212 (38), 185 (7), 160 (4), 139 (41), 111 (21), 89 (6), 78 (17); HRMS: Calcd for C₁₉H₁₃N₂OClS: 352.043713. Found: 352.04482; ¹H NMR (300 MHz, DMSO-d₆): δ 7.03 (dd, 1H, J = 7.4, 7.5 Hz, H-6), 7.15 (dd, 1H, J = 7.2, 7.5 Hz, H-5), 7.25 (d, 1H, J = 5.3 Hz, H-5'), 7.42 (d, 1H, J = 7.4 Hz, H-7), 7.45 (d, 1H, J = 5.3 Hz, H-4'), 7.55 (d, 2H, J = 8.2 Hz, H-3''/H-5''), 7.60 (d, 1H, J = 2.4 Hz, H-2), 7.70 (d, 1H, J = 7.2 Hz, H-4), 7.92 (d, 2H, J = 8.2 Hz, H-2''/H-6''), 9.94 (br s, 1H, -NO₂), 11.41 (br s, 1H, N₁-H); ¹³C NMR (75 MHz, DMSO-d₆): δ 107.6 (C-3), 112.4 (C-7), 119.5 (C-4), 120.1 (C-5), 121.9 (C-7), 124.9 (C-2), 126.0 (C-3a), 127.8 (C-5), 128.2 (C-2), 128.9 (C-3''/C-5"), 130.0 (C-2''/C-6''), 130.7 (C-3"), 133.5 (C-1''), 136.6 (C-7a), 136.8 (C-4''), 165.2 (-CONH).
3-[3-(2'-Thenoyl)aminothien-2-yl]indole (9b)
This compound was prepared from 8 (0.64 g; 3.0 mmol) and 2-thiophenecarbonyl chloride (0.55 g; 3.2 mmol) by following the same procedure and experimental conditions described above for 9a. The product was recrystallized from benzene / petroleum ether producing white minute prisms. Yield of 9b = 0.81 g (83 %), mp 130-131°C. Anal. Calcd for C_{17}H_{12}N_{2}O_{5}S_{2}: C, 62.94; H, 3.73; N, 8.63; S, 19.77. Found: C, 62.91; H, 3.66; N, 8.48; S, 19.53. IR (KBr) : \nu 3358, 3258, 3098, 1642, 1522, 1480, 1274 cm^{-1}; MS : m/z (% rel. int.): 324 (M^+, 84 ), 307 (8), 256 (5), 213 (100), 212 (48), 201 (15), 185 (8), 160 (7), 130 (4), 128 (5), 111 (61), 83 (6); HRMS : Calcd for C_{17}H_{12}N_{2}O_{5}S_{2} : 324.039092. Found : 324.041118; ^1H NMR (300 MHz, DMSO-d$_6$) : \delta 7.05 ( dd, 1H, J = 7.6, 7.7 Hz, H-5), 7.08 ( dd, 1H, J = 7.7 Hz, H-6), 7.10 ( dd, 1H, J = 5.1, 5.2 Hz, H-4'', overlapped with H-6 signal), 7.20 ( d, 1H, J = 7.7, 7.8 Hz, H-5'), 7.38 ( d, 1H, J = 5.1 Hz, H-5), 7.38 ( d, 1H, J = 7.8 Hz, H-7), 7.40 ( d, 1H, J = 5.1 Hz, H-5''), overlapped with H-7 signal), 7.58 ( d, 1H, J = 2.5 Hz, H-2), 7.70 ( d, 1H, J = 7.6 Hz, H-4), 7.80 ( d, 1H, J = 5.1 Hz, H-4'), 7.85 ( dd, 1H, J = 5.1, 5.2 Hz, H-4''), 9.95 (s, 1H, -NH), 11.40 ( br s, 1H, N 1-H); ^13C NMR (75 MHz, DMSO-d$_6$) : \delta 108.0 (C-3), 112.5 ( C-6), 119.5 (C-4), 120.2 (C-5), 122.2 (C-7), 124.8 (C-2), 126.0 (C-3a), 127.8 (C-2'), 127.9 (C-4'), 128.5 (C-5''), 130.3 (C-3''), 132.0 (C-5''), 136.5 (C-7a), 140.2 (C-2''), 161.0 (-CONH).

3-[3-(N-Acetyl)aminothien-2-yl]indole (9c)
This compound was prepared from 8 (0.64 g; 3.0 mmol) and acetyl chloride (0.26 g; 3.3 mmol), by following the same procedure and experimental conditions described above for 9a. The product was recrystallized from benzene / petroleum ether producing white flakes. Yield of 9c = 0.40 g (52 %), mp 65-66 °C. Anal. Calcd for C_{14}H_{12}N_{2}O_{5}S : C, 65.60; H, 4.72; N, 10.93; S, 12.51. Found: C, 65.42; H, 4.60; N, 10.73; S, 12.29. IR (KBr) : \nu 3352, 3204, 3112, 3063, 2924, 2858, 1693, 1592, 1487, 1401, 1252, 1091 cm^{-1}; MS m/z (% rel. int.): 256 (M^+,100), 214 (94), 213 (76), 201 (22), 186 (13), 160 (12), 130 (11), 115 (7); HRMS: Calcd for C_{14}H_{12}N_{2}O_{5}S : 256.067021. Found : 256.065956; ^1H NMR (300 MHz, DMSO-d$_6$) : \delta 2.10 (s, 3H, -CH$_3$), 7.10-7.20 (m, 3H, H-5, H-6, H-2), 7.29 (d, 1H, J = 5.3 Hz, H-5'), 7.45 ( d, 1H, J = 8.1 Hz, H-7), 7.65 ( d, 1H, J = 7.9 Hz, H-4), 7.90 ( d, 1H, J = 5.3 Hz, H-4''), 8.80 ( br s, 1H, -CONH), 11.40 ( br s, 1H, N$_1$-H); ^13C NMR (75 MHz, DMSO-d$_6$) : \delta 24.1 (-CH$_3$), 107.5 (C-3), 111.8 (C-7), 119.5 (C-4), 119.8 (C-2'), 120.8 (C-4'), 123.0 (C-5), 123.2 (C-2), 123.4 (C-6), 124.1 (C-5'), 126.2 (C-3a), 132.3 (C-3'), 136.2 (C-7a), 167.6 (-CONH).

7-(4-Chlorophenyl)-1H-thieno[2', 3': 6,7]azepino[5,4,3-cd]indole (3a)
To a stirred solution of 9a (0.74 g; 2.1 mmol) in acetonitrile (30 mL) was added phosphorous oxychloride (12 mL; 128 mmol). The resulting mixture was refluxed for 48 h under continuous stirring.
Excess acetonitrile and phosphorous oxychloride were removed under vacuum and the residue was treated with ice-cooled water (100 mL). The cold aqueous solution was basified with 10% NaOH solution, extracted with dichloromethane (3 x 100 mL) and the combined organic extracts were dried (anhdyrous MgSO4). Evaporation of the solvent, gave a crude red solid. The product was purified on silica gel TLC plates, eluting with CH2Cl2: MeOH (98 : 2, v/v) to afford the title compound in analytically pure form. Yield of pure 3a = 0.20 g (28%), mp 240-241°C. Anal. Calcd for C19H11N2ClS: C, 68.16; H, 3.31; N, 8.37; Cl, 10.59; S, 9.58. Found: C, 68.03; H, 3.22; N, 8.21; Cl, 10.46; S, 9.34. IR (KBr): ν 3406, 3216, 3114, 3095, 1575, 1487, 1422, 1331, 1264, 1184, 1116 cm⁻¹; MS m/z (% rel. int.): 334 (M⁺, 100), 333 (64), 299 (42), 298 (31), 271 (9), 227 (3), 196 (4), 167 (11), 149 (86), 136 (41), 122 (12), 85 (8), 83 (11); HRMS: Calcd for C19H11N2ClS: 334.03315. Found: 334.03374; ¹H NMR (300 MHz, DMSO-d6): δ 6.15 (d, 1H, J = 8.2 Hz, H-8), 6.63 (d, 1H, J = 6.2 Hz, H-4), 6.70 (dd, 1H, J = 8.2, 8.3 Hz, H-9), 7.00 (d, 1H, J = 6.2 Hz, H-5), 7.07 (d, 1H, J = 8.3 Hz, H-10), 7.18 (br d, 1H, J = 2.0 Hz, H-2), 7.38 (d, 2H, J = 8.5 Hz, H-3'/H-5''), 7.45 (d, 2H, J = 8.5 Hz, H-2'/H-6''), 11.20 (br s, 1H, N1-H); ¹³C NMR (75 MHz, DMSO-d6): δ 113.3 (C-2a), 115.7 (C-10), 117.9 (C-2), 120.5 (C-5), 122.5 (C-8), 123.4 (C-9), 128.2 (C-2'/C-6''), 129.8 (C-2b), 130.1 (C-10b), 130.1 (C-3'/C-5'', superimposed over the C-10b signal), 130.8 (C-7a), 133.1 (C-4''), 133.2 (C-4), 138.2 (C-10a), 141.8 (C-1''), 142.9 (C-5a), 163.4 (C-7).

7-(2-Thienyl)-1H-thieno[2', 3': 6,7]azepino[5,4,3-cd]indole (3b)

This compound was prepared from 9b (0.52 g; 1.6 mmol) and phosphorous oxychloride (10 mL; 107 mmol) in acetonitrile (30 mL). This reaction mixture was refluxed for 24 h under continuous stirring, and worked up as described above for 3a. The product was recrystallized from CH2Cl2/ n-hexane to afford dark red scales. Yield of pure 3b = 0.17 g (35%), mp 187-188°C. Anal. Calcd for C₁₇H₁₀N₂S₂: C, 66.64; H, 3.29; N, 9.14; S, 20.93. Found: C, 66.51; H, 3.18; N, 9.06; S, 20.78. IR (KBr): ν 3408, 3220, 3072, 1617, 1547, 1493, 1409, 1321, 1244 cm⁻¹; MS m/z (% rel. int.): 306 (M⁺, 100), 305 (67), 273 (5), 261 (16), 244 (6), 221 (3), 196 (4), 171 (3), 153 (27), 139 (11), 131 (22), 112 (10); HRMS: Calcd for C₁₇H₁₀N₂S₂: 306.028531. Found: 306.027193; ¹H NMR (300 MHz, DMSO-d6): δ 6.66 (d, 1H, J = 5.2 Hz, H-4), 6.85 (dd, 1H, J = 7.4, 8.1 Hz, H-9), 6.95 (d, 1H, J = 7.4 Hz, H-8), 7.05 (m, 2H, H-5, H-3'), 7.15 (d, 1H, J = 8.1 Hz, H-10), 7.18 (d, 1H, J = 2.0 Hz, H-2), 7.42 (dd, 1H, J = 5.1, 4.9 Hz, H-4'), 7.60 (d, 1H, J = 4.9 Hz, H-5'), 11.20 (br s, 1H, N1-H); ¹³C NMR (75 MHz, DMSO-d6): δ 113.2 (C-2a), 115.8 (C-10), 118.2 (C-2), 120.7 (C-5), 121.7 (C-8), 123.3 (C-9), 127.1 (C-5'), 127.7 (C-4'), 128.1 (C-3'), 129.1 (C-2b), 129.8 (C-7a), 130.4 (C-10b), 132.6 (C-4), 138.3 (C-10a), 142.5 (C-5a), 146.7 (C-2'), 157.4 (C-7).
7-Methyl-1H-thieno[2', 3' : 6,7]azepino[5,4,3-cd]indole (3c)

This compound was prepared from 9c (0.41 g; 1.6 mmol) and phosphorous oxychloride (10 mL; 107 mmol) in acetonitrile (40 mL). The resulting mixture was refluxed for 24 h under continuous stirring, and worked up as described above for 3a. The product was recrystallized from CH₂Cl₂ / n-hexane forming fine red needles. Yield of pure 3c = 0.13 g (34 %), mp 187-188 °C. Anal. Calcd for C₁₄H₁₀N₂S: C, 70.56; H, 4.23; N, 11.75; S, 13.45. Found: C, 70.23; H, 4.04; N, 11.52; S, 13.36. IR (KBr): ν 3400, 3240, 3096, 3061, 3042, 1583, 1422, 1349, 1265, 1187, 1146 cm⁻¹; MS m/z (% rel. int.): 238 (M⁺,100), 223 (11), 196 (6), 179 (4), 156 (9), 139 (14), 119 (13), 111 (8); HRMS: Calcd for C₁₄H₁₀N₂S : 238.056461. Found: 238.057707; ¹H NMR (300 MHz, DMSO-d₆): δ 2.20 (s, 3H, -CH₃), 6.65 (d, 1H, J = 5.2 Hz, H-4), 6.82 (d, 1H, J = 7.9 Hz, H-8), 6.85 (d, 1H, J = 5.2 Hz, H-5), 7.13 (d, 1H, J = 8.2 Hz, H-10), 7.15 (d, 1H, J = 2.5 Hz, H-2), 7.90 (dd, 1H, J = 7.9, 8.2 Hz, H-9), 11.20 (br s, 1H, N₁-H); ¹³C NMR (75 MHz, DMSO-d₆): δ 28.1 (-CH₃), 113.1 (C-2a), 115.3 (C-10), 117.1 (C-2), 119.9 (C-5), 120.0 (C-8), 123.6 (C-9), 128.7 (C-2b), 129.0 (C-10b), 131.0 (C-7a), 133.1 (C-4), 137.6 (C-10a), 142.7 (C-5a), 161.3 (C-7).

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REFERENCES AND NOTES

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