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Three-Component Spiro Heterocyclization of Pyrrolediones with Indan-1,3-dione and Acyclic Enamines

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Abstract—Ethyl 4,5-dioxo-2-phenyl-4,5-dihydro-1*H*-pyrrole-3-carboxylates reacted with indan-1,3-dione and 3-amino-1-phenylbut-2-en-1-one or 3-aminobut-2-enenitrile to give 3-benzoyl-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]pyridine-4,3′-pyrroles] and 2-methyl-2′,5-dioxo-5′-phenyl-1,1',2',5-tetrahydrospiro[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-3-carbonitriles, respectively.

Keywords: 1*H*-pyrrole-2,3-diones, three-component reactions, spiro heterocyclization, dihydropyridines, indenopyridines, enamines.

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Researchers' interest in compounds containing a 2-oxopyrrole fragment is not accidental. Natural oxopyrroles, e.g., clausenamide and tetramic acid, exhibit a broad spectrum of biological activity [1–3]. Spiro fusion of an oxopyrrole ring makes it possible to introduce a valuable pharmacophoric fragment into potentially biologically active heterocyclic systems. We previously described three-component spiro heterocyclization of 1*H*-pyrrole-2,3-diones with indan-1,3-dione and cyclic enamines (3-amino-5,5-dimethylcyclohex-2-en-1-ones), which led to the formation of spiro[indeno[1,2-*b*]quinoline-10,3′-pyrroles] [4]. Three-component spiro heterocyclization of 1*H*-pyrrole-2,3-diones with indan-1,3-dione and acyclic enamines was not reported previously.

By reacting ethyl 4,5-dioxo-2-phenyl-4,5-dihydro-1*H*-pyrrole-3-carboxylates **1a**–**1e** with indan-1,3-dione and 3-amino-1-phenylbut-2-en-1-one (**2a**) at a molar ratio of 1:1:1 on heating in boiling anhydrous *o*-xylene for 1–2 h in the presence of acetic acid we obtained ethyl 3-benzoyl-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylates **3a**–**3e** (Scheme 1). Analogous reaction of **1a**–**1e** with indan-1,3-dione and 3-aminobut-2-enenitrile (**2b**) in 1–3 h afforded ethyl 3-cyano-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylates **3f**–**3j** whose structure was proved by X-ray analysis of compound **3f**.

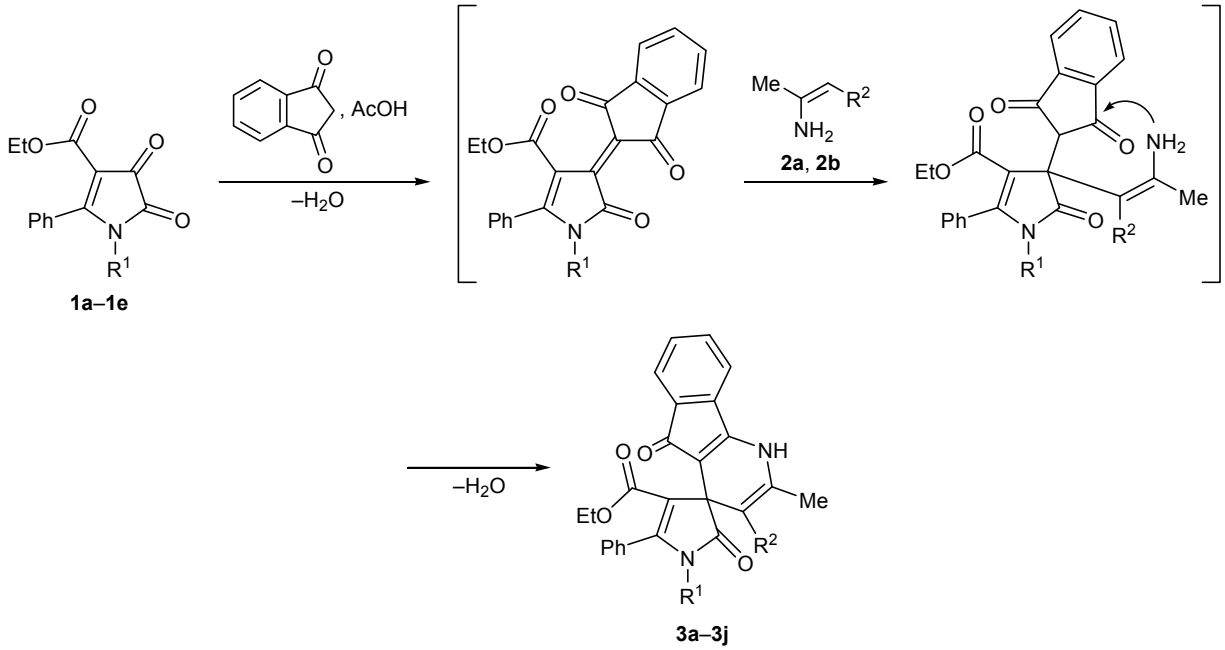
Compounds **3a**–**3j** are orange high-melting crystalline solids readily soluble in DMSO and haloalkanes, poorly soluble in acetone and ethanol, and insoluble in alkanes and water.

The IR spectra of **3a**–**3j** displayed absorption bands due to stretching vibrations of the NH (3165–3273 cm^{-1}) and lactam, ketone, and ester carbonyl groups (1622–1715 cm^{-1}). The spectra of **3f**–**3j** also contained a band at 2200–2208 cm^{-1} due to CN stretching vibrations.

In the ^{1}H NMR spectra of **3a**–**3j**, we observed signals from protons in the substituent on the pyrrole nitrogen atom, aromatic rings and substituents therein, and ester ethoxy group (δ 0.68–0.82 and 3.65–3.91 ppm), a singlet of the 2-CH_3 group (δ 1.44–2.34 ppm), and a singlet of the NH group (δ 10.11–11.01 ppm). In the ^{13}C NMR spectra of **3a**–**3d** and **3g**–**3j**, the carbonyl carbon nuclei resonated in the region δ_C 161.4–189.2 ppm, and the spiro carbon signal was located at δ_C 50.2–52.9 ppm.

According to the X-ray diffraction data (Fig. 1), compound **3f** crystallizes as a 2:1 solvate with *o*-xylene in the centrosymmetric space group belonging to the triclinic crystal system. The indenopyridine and pyrrole fragments are planar within 0.04 and 0.01 Å, respectively. The phenyl and benzyl substituents are turned through large angles with respect to the pyrrole ring plane, while the ester fragment lies in

Scheme 1.



1, R^1 = $PhCH_2$ (**a**), cyclohexyl (**b**), Ph (**c**), C_6H_4Me-4 (**d**), C_6H_4OMe-4 (**e**); **2**, R^2 = COPh (**a**), CN (**b**); **3**, R^2 = COPh, R^1 = $PhCH_2$ (**a**), cyclohexyl (**b**), Ph (**c**), C_6H_4Me-4 (**d**), C_6H_4OMe-4 (**e**); R^2 = CN, R^1 = $PhCH_2$ (**f**), cyclohexyl (**g**), Ph (**h**), C_6H_4Me-4 (**i**), C_6H_4OMe-4 (**j**).

that plane. The benzene ring of the benzyl substituent is disordered by two positions with different populations. Molecules **3f** in crystal are linked to form centrosymmetric dimers through the intermolecular hydrogen bond $N^2–H^2\cdots O^1$ [$1-x$, $1-y$, $-z$].

Presumably, compounds **3** are formed as a result of initial condensation of the ketone carbonyl group (C^4=O) of pyrroledione **1** at the methylene group of indan-1,3-dione, followed by successive nucleophilic additions of the β-CH and NH_2 groups of the enamino

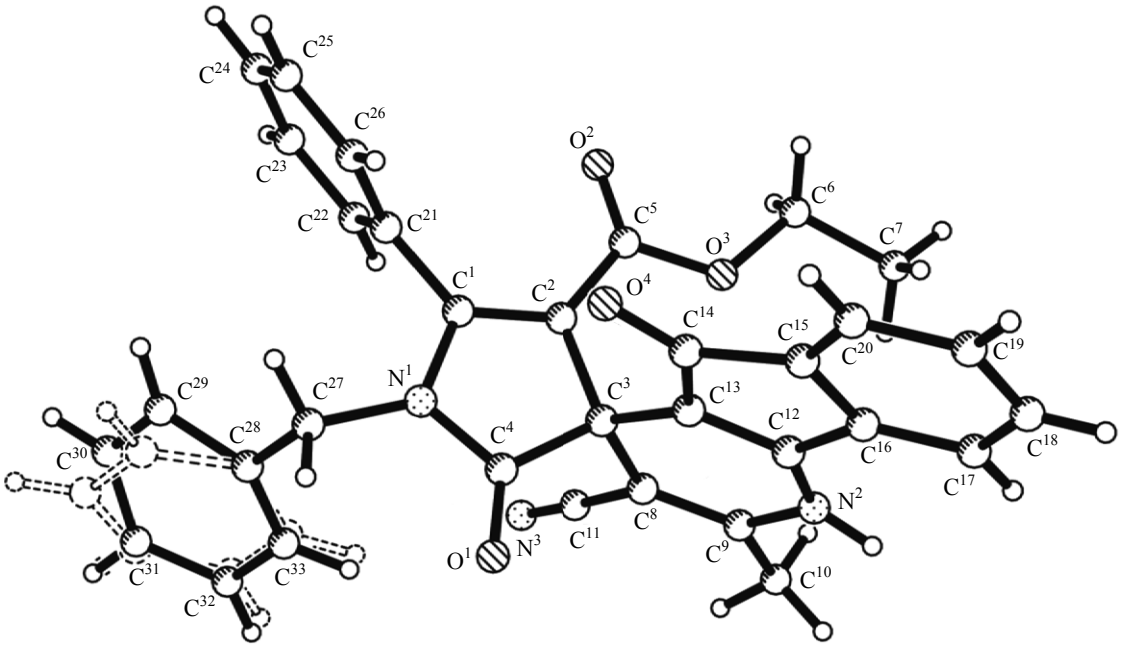


Fig. 1. Structure of the molecule of ethyl 1′-benzyl-3-cyano-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]-pyridine-4,3′-pyrrole]-4′-carboxylate (**3f**) according to the X-ray diffraction data.

fragment of **2** to C^4 of the pyrrole fragment and ketone carbonyl carbon of the indandione fragment, respectively (Scheme 1). The described reaction is the first example of three-component spiro heterocyclization of 1*H*-pyrrole-2,3-diones with indan-1,3-dione and acyclic enamines, leading to the difficultly accessible spiro[indeno[1,2-*b*]pyridine-4,3′-pyrrole] heterocyclic system. It should be noted that the indenopyridine fragment is the base structural unit of many alkaloids and that compounds containing this fragment exhibit anti-inflammatory [5] and cytotoxic properties [6].

EXPERIMENTAL

The IR spectra were recorded in mineral oil on a Perkin Elmer Spectrum Two spectrometer. The ^{1}H and ^{13}C NMR spectra were measured on a Bruker Avance III HD 400 spectrometer at 400 and 100 MHz, respectively, using tetramethylsilane as internal standard. The elemental analyses were obtained on a Vario MICRO cube analyzer. The progress of reactions was monitored by HPLC/MS on a Waters Acquity UPLC I-Class instrument equipped with an Acquity UPLC BEH C18 column (grain size 1.7 μm; eluent acetonitrile–water, flow rate 0.6 mL/min), Acquity UPLC PDA eλ detector, and Xevo TQD mass detector. The purity of the isolated compounds was checked by TLC on Silufol plates using benzene–ethyl acetate (5:1) and ethyl acetate as eluents; spots were visualized by treatment with iodine vapor. Initial pyrrolediones **1a**–**1e** were synthesized by reaction of the corresponding enamines with oxalyl chloride according to the procedure described in [7].

Ethyl 3-benzoyl-1′-benzyl-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]-pyridine-4,3′-pyrrole]-4′-carboxylate (3a). A solution of 335 mg (1.0 mmol) of pyrroledione **1a**, 146 mg (1.0 mmol) of indan-1,3-dione, and 161 mg (1.0 mmol) of 3-amino-1-phenylbut-2-en-1-one (**2a**) in 10 mL of anhydrous *o*-xylene containing 57 μL (1.0 mmol) of acetic acid was refluxed for 2 h (TLC, HPLC/MS). The mixture was cooled, and the precipitate was filtered off. Yield 398 mg (62%), mp 303–305°C (from acetone). IR spectrum, ν, cm^{-1}: 3183 (NH), 1692, 1645, 1632, 1622 (C=O). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 0.70 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 1.77 s (3H, 2-CH$_3$), 3.65–3.75 m (2H, CH$_3$C**H**$_2$), 4.41 d and 4.51 d (1H each, C**H**$_2$Ph, J = 16.4 Hz), 6.97–7.44 m (12H, H$_{arom}$), 7.46–7.55 m (3H, H$_{arom}$), 7.58–7.68 m (2H, H$_{arom}$), 7.75–7.81 m (2H, H$_{arom}$), 10.38 s (1H, NH). ^{13}C NMR spectrum (DMSO-d_6), δ_C, ppm: 13.4 (**C**H$_3$CH$_2$), 19.7 (2-CH$_3$), 44.2 (**C**H$_2$Ph), 51.5 (C^4), 58.5 (CH$_3$**C**H$_2$), 104.2, 111.2, 113.5, 119.4, 120.6, 126.5 (2C), 126.7, 127.7 (2C), 128.0 (2C), 128.2 (2C), 128.5 (2C), 128.7 (2C), 129.1, 130.1, 130.5, 131.8, 132.6, 133.5, 135.7, 137.0, 139.9, 141.3, 154.7, 155.5, 162.3 (4′-C=O), 179.5 ($C^{2'}$=O), 189.4 (C^5=O), 195.2 (Ph**C**O). Found, %: C 77.04; H 4.95; N 4.53. $C_{39}H_{30}N_2O_5$. Calculated, %: C 77.21; H 4.98; N 4.62.

Compounds **3b**–**3f** were synthesized in a similar way.

Ethyl 3-benzoyl-1′-cyclohexyl-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro[indeno-[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylate (3b). Yield 60%, mp 312–313°C (from 1,2-dichloroethane). IR spectrum, ν, cm^{-1}: 3165 (NH), 1690, 1677, 1650, 1633 (C=O). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 0.68 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 0.78–1.01 m (3H, C$_6$H$_{11}$), 1.39–1.51 m (1H, C$_6$H$_{11}$), 1.59–1.77 m (7H, C$_6$H$_{11}$, 2-CH$_3$), 1.89–2.07 m (2H, C$_6$H$_{11}$), 3.05 t.t (1H, 1′-CH, J = 15.4, 4.7 Hz), 3.66 q (2H, CH$_3$C**H**$_2$, J = 7.1 Hz), 7.01 d (1H, H$_{arom}$, J = 6.7 Hz), 7.28–7.54 m (9H, H$_{arom}$), 7.55–7.65 m (2H, H$_{arom}$), 7.69–7.74 m (2H, H$_{arom}$), 10.25 s (1H, NH). ^{13}C NMR spectrum (DMSO-d_6), δ_C, ppm: 13.4 (**C**H$_3$CH$_2$), 19.7 (2-CH$_3$), 24.8 (C$_6$H$_{11}$), 25.4 (2C, C$_6$H$_{11}$), 28.8 (2C, C$_6$H$_{11}$), 51.7 (C^4), 54.3 (1′-CH), 58.3 (CH$_3$**C**H$_2$), 104.8, 110.7, 113.8, 119.2, 120.4, 127.9 (2C), 128.1 (2C), 128.1, 128.3 (2C), 128.7 (2C), 129.1, 130.3, 131.3, 131.7, 132.3, 133.5, 140.2, 141.4, 155.2, 155.6, 162.2 (4′-C=O), 179.3 ($C^{2'}$=O), 189.2, 195.1 (PhCO, C^5=O). Found, %: C 76.01; H 5.90; N 4.62. $C_{38}H_{34}N_2O_5$. Calculated, %: C 76.23; H 5.72; N 4.68.

Ethyl 3-benzoyl-2-methyl-2′,5-dioxo-1′,5′-diphenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylate (3c). Yield 47%, mp 314–317°C (from acetone). IR spectrum, ν, cm^{-1}: 3184 (NH), 1706, 1688, 1649, 1645, 1633 (C=O). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 0.78 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 1.79 s (3H, 2-CH$_3$), 3.78 q (2H, CH$_3$C**H**$_2$, J = 7.1 Hz), 6.99–7.79 m (19H, H$_{arom}$), 10.43 s (1H, NH). ^{13}C NMR spectrum (DMSO-d_6), δ_C, ppm: 13.5 (**C**H$_3$CH$_2$), 20.0 (2-CH$_3$), 51.7 (C^4), 58.7 (CH$_3$**C**H$_2$), 104.8, 110.9, 113.8, 119.5, 120.6, 127.4 (2C), 127.7, 128.3 (4C), 128.6 (2C), 128.8 (2C), 128.9 (3C), 130.2, 130.5, 131.9, 132.4, 133.5, 134.9, 135.7, 140.4, 142.9, 154.0, 155.3, 162.5 (4′-C=O), 178.6, 189.5, 195.5. Found, %: C 77.11; H 4.68; N 4.71. $C_{38}H_{28}N_2O_5$. Calculated, %: C 77.01; H 4.76; N 4.73.

Ethyl 3-benzoyl-2-methyl-1′-(4-methylphenyl)-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro-[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylate (3d). Yield 52%, mp 305–308°C (from acetone). IR spectrum, ν, cm^{-1}: 3194 (NH), 1712, 1689, 1649, 1636, 1624 (C=O). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.77 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 1.44 br.s (3H, 2-CH$_3$), 2.30 s (3H, C$_6$H$_4$C**H**$_3$), 3.71–3.91 m (2H, CH$_3$C**H**$_2$), 6.93–7.06 m (1H, H$_{arom}$), 7.10–7.24 m (9H, H$_{arom}$), 7.27–7.37 m (5H, H$_{arom}$), 7.38–7.49 m (1H, H$_{arom}$), 7.54–7.67 m (2H, H$_{arom}$), 10.11 s (1H, NH). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 13.8 (**C**H$_3$CH$_2$), 20.6, 21.4, 52.9 (C^4), 59.4 (CH$_3$**C**H$_2$), 105.0, 112.1, 114.5, 120.1, 120.7, 127.5 (2C), 128.6 (2C), 128.7 (2C), 128.7 (2C), 128.9, 129.5 (2C), 129.8 (2C), 130.1, 130.5, 131.7, 132.3, 132.5, 133.5, 135.6, 138.3, 140.6, 143.3, 155.5, 156.3, 163.1, 182.2, 190.8, 195.7. Found, %: C 77.33; H 4.97; N 4.76. $C_{39}H_{30}N_2O_5$. Calculated, %: C 77.21; H 4.98; N 4.62.

Ethyl 3-benzoyl-1′-(4-methoxyphenyl)-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro-[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylate (3e). Yield 56%, mp 280–283°C (from CH_2Cl_2). IR spectrum, ν, cm^{-1}: 3185 (NH), 1712, 1689, 1649, 1636, 1623 (C=O). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.77 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 1.44 br.s (3H, 2-CH$_3$), 3.72–3.87 m (5H, OCH$_3$, CH$_3$C**H**$_2$), 6.79–6.87 m (2H, H$_{arom}$), 6.96–7.06 m (1H, H$_{arom}$), 7.10–7.26 m (7H, H$_{arom}$), 7.27–7.50 m (6H, H$_{arom}$), 7.56–7.63 m (2H, H$_{arom}$), 10.11 s (1H, NH). Found, %: C 75.28; H 4.72; N 4.38. $C_{39}H_{30}N_2O_6$. Calculated, %: C 75.23; H 4.86; N 4.50.

Ethyl 1′-benzyl-3-cyano-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]-pyridine-4,3′-pyrrole]-4′-carboxylate (3f). A solution of 335 mg (1.0 mmol) of pyrroledione **1a**, 146 mg (1.0 mmol) of indan-1,3-dione, and 82 mg (1.0 mmol) of 3-aminobut-2-enenitrile (**2b**) in 10 mL of anhydrous *o*-xylene containing 57 μL (1.0 mmol) of acetic acid was refluxed for 1 h (TLC, HPLC/MS). The mixture was cooled, and the precipitate was filtered off. Yield 358 mg (68%), mp 274–275°C (from acetone). IR spectrum, ν, cm^{-1}: 3195 (NH), 2208 (CN), 1693, 1682, 1652 (C=O). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 0.74 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 2.32 s (3H, 2-CH$_3$), 3.76 q (2H, CH$_3$C**H**$_2$, J = 7.0 Hz), 4.48–4.61 m (2H, C**H**$_2$Ph), 7.06–7.15 m (4H, H$_{arom}$), 7.16–7.27 m (3H, H$_{arom}$), 7.32–7.47 m (5H, H$_{arom}$), 7.53 t.d (1H, H$_{arom}$, J = 7.4, 1.2 Hz), 7.60–7.66 m (1H, H$_{arom}$), 11.01 s (1H, NH). Found, %: C 74.94; H 4.85; N 7.87. $C_{33}H_{25}N_3O_4$. Calculated, %: C 75.13; H 4.78; N 7.96.

The X-ray diffraction data for compound **3f** were obtained from a 0.35 × 0.30 × 0.20-mm fragment of an orange single crystal. Triclinic crystal system, space group P-1; $2(C_{33}H_{25}N_3O_4)\cdot C_8H_{10}$; unit cell parameters: a = 11.444(2), b = 12.461(2), c = 12.9795(17) Å; α = 91.911(13), β = 101.699(14), γ = 116.597(19)°; V = 1604.3(5) Å^3; Z = 1. Experimental reflection intensities were measured on an Xcalibur Ruby diffractometer with a CCD detector according to standard procedure [Mo K_α radiation, 295(2) K, ω-scanning through a step of 1°]. A correction for absorption was applied empirically by SCALE3 ABSPACK algorithm [8]. Total of 12733 reflection intensities were measured, including 7433 independent reflections and 4890 reflections with $I > 2\sigma(I)$. The structure was solved by the direct method using SHELXS-97 [9] and was refined against F^2 by the full-matrix least-squares method in anisotropic approximation for all non-hydrogen atoms using SHELXL-97 [9]. The NH hydrogen atom was localized from the difference Fourier maps, and its position was refined independently in isotropic approximation; the positions of the other hydrogens were refined according to the riding model. Soft restraints like DELU, SADI, DFIX, and SAME were applied to the thermal and positional parameters of some atoms of the disordered components. The aromatic ring of the *o*-xylene solvate molecule was idealized via AFIX 66 constraint. Final divergence factors: R_1 = 0.0629, wR_2 = 0.1619 [for reflections with $I > 2\sigma(I)$]; R_1 = 0.0963, wR_2 = 0.1898 (all independent reflections); goodness of fit S = 1.032. The set of X-ray diffraction data was deposited to the Cambridge Crystallographic Data Centre (CCDC entry no. 1864909) and is available at *www.ccdc.cam.ac.uk/data_request/cif.*

Compounds **3g**–**3j** were synthesized as described above for **3f**.

Ethyl 3-cyano-1′-cyclohexyl-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]-pyridine-4,3′-pyrrole]-4′-carboxylate (3g). Yield 66%, mp 310–312°C (from CH_2Cl_2). IR spectrum, ν, cm^{-1}: 3267 (NH), 2202 (CN), 1702, 1693, 1656 (C=O). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 0.73 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 0.82–1.06 m (3H, C$_6$H$_{11}$), 1.40–1.75 m (5H, C$_6$H$_{11}$), 1.92–2.14 m (2H, C$_6$H$_{11}$), 2.28 s (3H, 2-CH$_3$), 3.09 t.t (1H, 1′-CH, J = 12.8, 3.7 Hz), 3.66–3.78 m (2H, CH$_3$C**H**$_2$), 7.23–7.64 m (9H, H$_{arom}$), 10.85 s (1H, NH). ^{13}C NMR spectrum (DMSO-d_6), δ_C, ppm: 13.4 (**C**H$_3$CH$_2$), 18.3 (2-CH$_3$), 24.6, 25.3 (2C), 28.7, 28.8 (5C, C$_6$H$_{11}$), 50.2 (C^4), 54.6 (1′-CH), 58.7 (CH$_3$**C**H$_2$), 85.9, 95.4 (2C), 103.6, 111.2, 116.9, 119.6, 120.9, 128.4 (2C), 129.6, 130.2, 130.6,

132.2, 132.8, 135.7, 149.3, 155.0, 155.9, 161.4, 178.2, 189.7. Found, %: C 74.02; H 5.73; N 8.20. $C_{32}H_{29}N_3O_4$. Calculated, %: C 73.97; H 5.63; N 8.09.

Ethyl 3-cyano-2-methyl-2′,5-dioxo-1′,5′-diphenyl-1,1′,2′,5-tetrahydrospiro[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylate (3h). Yield 55%, mp 322–325°C (from CH_2Cl_2). IR spectrum, ν, cm^{-1}: 3273 (NH), 2202 (CN), 1715, 1693, 1653, 1629 (C=O). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 0.82 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 2.34 s (3H, 2-CH$_3$), 3.78–3.88 m (2H, CH$_3$C**H**$_2$), 7.03–7.12 m (2H, H$_{arom}$), 7.17–7.48 m (10H, H$_{arom}$), 7.53 t.d (1H, H$_{arom}$, J = 7.4, 1.3 Hz), 7.61–7.66 m (1H, H$_{arom}$), 10.97 s (1H, NH). ^{13}C NMR spectrum (DMSO-d_6), δ$_C$, ppm: 13.4 (**C**H$_3$CH$_2$), 18.1 (2-CH$_3$), 50.4 (C^4), 59.0 (CH$_3$**C**H$_2$), 85.4, 103.3, 111.4, 117.0, 119.7, 121.0, 127.6 (2C), 128.0 (2C), 128.2, 128.9 (4C), 129.2, 129.3, 130.7, 132.3, 132.7, 134.0, 135.6, 149.7, 154.1, 155.1, 161.6, 177.3, 189.9. Found, %: C 74.66; H 4.68; N 8.16. $C_{32}H_{23}N_3O_4$. Calculated, %: C 74.84; H 4.51; N 8.18.

Ethyl 3-cyano-2-methyl-1′-(4-methylphenyl)-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro-[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylate (3i). Yield 52%, mp 333–336°C (from DMSO–water, 2:1). IR spectrum, ν, cm^{-1}: 3270 (NH), 2200 (CN), 1714, 1692, 1653, 1627 (C=O). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 0.80 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 2.23 s and 2.33 s (6H, 2-CH$_3$, C$_6$H$_4$C**H**$_3$), 3.75–3.88 m (2H, CH$_3$C**H**$_2$), 6.89–7.01 m (2H, H$_{arom}$), 7.11–7.23 m (4H, H$_{arom}$), 7.27–7.46 m (5H, H$_{arom}$), 7.50–7.56 m (1H, H$_{arom}$), 7.61–7.66 m (1H, H$_{arom}$), 11.00 s (1H, NH). ^{13}C NMR spectrum (DMSO-d_6), δ$_C$, ppm: 13.5 (**C**H$_3$CH$_2$), 18.2 (2-CH$_3$), 20.6 (C$_6$H$_4$**C**H$_3$), 50.4 (C^4), 59.0 (CH$_3$**C**H$_2$), 85.4, 103.4, 111.3, 117.1, 119.8, 121.1, 127.7 (2C), 127.9 (2C), 129.0 (2C), 129.3, 129.4, 129.5 (2C), 130.8, 131.4, 132.4, 132.8, 135.7, 137.8, 149.8, 154.4, 155.2, 161.6, 177.5, 189.9. Found, %: C 75.36; H 4.73; N 7.84. $C_{33}H_{25}N_3O_4$. Calculated, %: C 75.13; H 4.78; N 7.96.

Ethyl 3-cyano-1′-(4-methoxyphenyl)-2-methyl-2′,5-dioxo-5′-phenyl-1,1′,2′,5-tetrahydrospiro-[indeno[1,2-*b*]pyridine-4,3′-pyrrole]-4′-carboxylate (3j). Yield 60%, mp 327–330°C (from acetone). IR spectrum, ν, cm^{-1}: 3261, 3225 (NH), 2202 (CN), 1712, 1693, 1654 (C=O). ^{1}H NMR spectrum (DMSO-d_6), δ, ppm: 0.80 t (3H, C**H**$_3$CH$_2$, J = 7.1 Hz), 2.33 s (3H, 2-CH$_3$), 3.69 s (3H, OCH$_3$), 3.76–3.89 m (2H, CH$_3$C**H**$_2$), 6.83–7.05 m (4H, H$_{arom}$), 7.13–7.48 m (7H, H$_{arom}$), 7.48–7.57 m (1H, H$_{arom}$), 7.60–7.67 m (1H, H$_{arom}$), 11.00 s (1H, NH). ^{13}C NMR spectrum (DMSO-d_6), δ$_C$, ppm: 13.5 (**C**H$_3$CH$_2$), 18.2 (2-CH$_3$), 50.3 (C^4), 55.3 (OCH$_3$), 59.0 (CH$_3$**C**H$_2$), 85.5, 103.5, 111.2, 114.3 (2C), 117.1, 119.8, 121.1, 126.6, 127.7 (2C), 129.0 (2C), 129.3 (4C), 130.8, 132.4, 132.8, 135.7, 149.8, 154.7, 155.2, 158.8, 161.7, 177.7, 190.0. Found, %: C 72.80; H 4.61; N 7.78. $C_{33}H_{25}N_3O_5$. Calculated, %: C 72.92; H 4.64; N 7.73.

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CONFLICT OF INTERESTS

The authors declare the absence of conflict of interests.

REFERENCES

1. Liu, G.T., Li, W.X., Chen, Y.Y., and Wei, H.L., *Drug Dev. Res*., 1996, vol. 39, p. 174. doi 10.1002/(SICI)1098-2299(199610)39:2<174::AID-DDR10>3.0.CO;2-C
2. Jiang, X.Y. and Zhang, J.T., *J. Asian Nat. Prod. Res*., 1998, vol. 1, p. 53. doi 10.1080/10286029808039843
3. Schobert, R. and Schlenk, A., *Bioorg. Med. Chem*., 2008, vol. 16, p. 4203. doi 10.1016/j.bmc.2008.02.069
4. Dmitriev, M.V., Salnikova, T.V., Silaichev, P.S., and Maslivets, A.N., *Tetrahedron Lett*., 2017, vol. 58, p. 67. doi 10.1016/j.tetlet.2016.11.100
5. Cooper, K., Fray, M.J., Cross, P.E., and Richardson, K., EP Patent no. 299727 A1, 1989.
6. Miri, R., Javidnia, K., Hemmateenejad, B., Azarpira, A., and Mirghofran, Z., *Bioorg. Med. Chem*., 2004, vol. 12, p. 2529. doi 10.1016/j.bmc.2004.03.032
7. Sano, T., Horiguchi, Y., Toda, J., Imafuku, K., and Tsuda, Y., *Chem. Pharm. Bull*., 1984, vol. 32, p. 497. doi 10.1248/cpb.32.497
8. CrysAlisPro, Version 1.171.37.33 (release 27-03-2014 CrysAlis171 .NET), Agilent Technologies.
9. Sheldrick, G.M., *Acta Crystallogr., Sect. A*, 2008, vol. 64, p. 112. doi 10.1107/S0108767307043930