ISSN 1070-4280, Russian Journal of Organic Chemistry, 2015, Vol. 51, No. 1, pp. 110–115. © Pleiades Publishing, Ltd., 2015.
Original Russian Text © V.L. Gein, M.A. Mar'yasov, 2015, published in Zhurnal Organicheskoi Khimii, 2015, Vol. 51, No. 1, pp. 112–117.

Reactions of 5-Aryl-4-(hetaren-2-ylcarbonyl)-3-hydroxy-1-(1,3-thiazol-2-yl)-2,5-dihydro-1*H*-pyrrol-2-ones with Hydrazine, Phenylhydrazine, and Hydroxylamine

V. L. Gein and M. A. Mar'yasov

Perm State Pharmaceutical Academy, ul. Polevaya 2, Perm, 614990 Russia
e-mail: geinvl48@mail.ru

Received February 7, 2014

Abstract—Three-component condensation of methyl 4-(furan-2-yl)- and 4-(thiophen-2-yl)-2,4-dioxobutanoates with aromatic aldehydes and 1,3-thiazol-2-amine afforded 5-aryl-4-(hetaren-2-ylcarbonyl)-3-hydroxy-1-(1,3-thiazol-2-yl)-2,5-dihydro-1*H*-pyrrol-2-ones. Reactions of the latter with hydrazine and phenylhydrazine gave pyrrolo[3,4-*c*]pyrazol-6-ones and 3-phenylhydrazones, while the corresponding oximes were obtained in reactions with hydroxylamine.

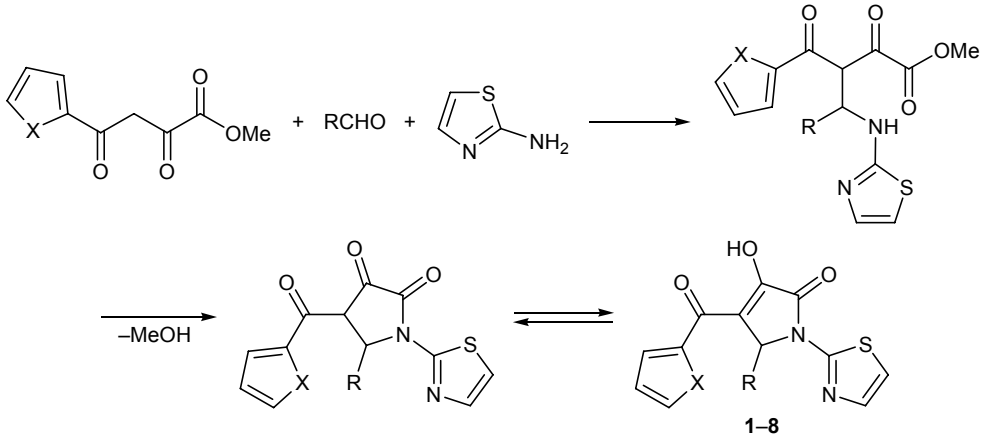
DOI: 10.1134/S1070428015010194

In continuation of our studies in the field of synthesis and chemical behavior of 1,4,5-trisubstituted pyrrolidine-2,3-diones [1], we set ourselves the task of obtaining 3-hydroxy-2,5-dihydro-1*H*-pyrrol-2-ones containing a 1,3-thiazol-2-yl substituent on the nitrogen atom and a 2-thenoyl or 2-furoyl substituent on C^4. These compounds attracted interest from the viewpoint of their subsequent transformation into fused heterocyclic systems via reactions with hydrazine, phenylhydrazine, and hydroxylamine.

By three-component condensation [2–4] of equimolar amounts of methyl 4-(furan-2-yl)- and 4-(thiophen-2-yl)-2,4-dioxobutanoates with aromatic aldehydes and 1,3-thiazol-2-amine on heating for a short time in acetic acid we synthesized 5-aryl-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)pyrrolidine-2,3-diones **1**–**4** and 4-(furan-2-ylcarbonyl)-1-(1,3-thiazol-2-yl)pyrrolidine-2,3-diones **5**–**8**, respectively (Scheme 1). Compounds **1**–**8** are light yellow to yellow–brown high-melting crystalline substances which are insoluble in water and soluble dioxane and glacial acetic acid, as well as in ethanol on heating. High melting points of the isolated compounds may be related to their ability to form intermolecular hydrogen bonds in crystal to give dimers [5].

The IR spectra of **1**–**8** contained absorption bands in the regions 1680–1690 (C=O, lactam), 1590–1620 (C=O, ketone), and 3200–3240 cm^{-1} (3-OH). Com-

Scheme 1.

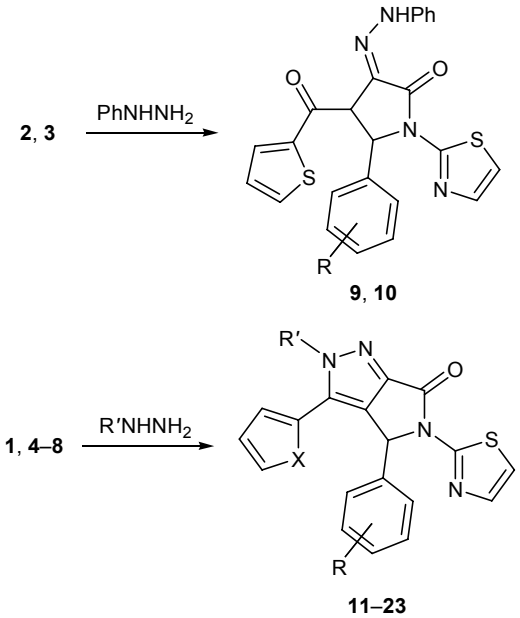


1–**4**, X = S; **5**–**8**, X = O; **1**, **5**, R = Ph; **2**, **6**, R = 2-ClC_6H_4; **3**, **7**, 4-(*i*-Pr)C_6H_4; **4**, **8**, R = 3-HOC_6H_4.

pounds **1**–**8** showed in the ^{1}H NMR spectra (DMSO-d_6) signals from protons in the benzene rings (δ 6.79–7.56 ppm), doublets from protons in the thiazole ring (δ 7.44–8.51 ppm), signals from protons in the furan (thiophene) ring, and a singlet from the 5-H proton at δ 6.02–6.40 ppm. No signal from the enolic hydroxy proton was observed, presumably due to its strong broadening as a result of exchange processes, which is typical of structurally related compounds [5]. The mass spectra of **1**–**8** displayed the molecular and fragment ion peaks which were consistent with the assumed structure, in particular *m*/*z* 111 $[C_4H_3SCO]^+$ and 127 $[C_4NSNHCO]^+$ for **1**–**4** and *m*/*z* 95 $[C_4H_3OCO]^+$ and 127 $[C_4NSNHCO]^+$ for **5**–**8**. All compounds **1**–**8** showed a positive test (cherry color) for enolic hydroxy group on treatment with an alcoholic solution of iron(III) chloride. Thus, compounds **1**–**8** exist mainly as 5-aryl-4-(hetaren-2-ylcarbonyl)-3-hydroxy-1-(1,3-thiazol-2-yl)-2,5-dihydro-1*H*-pyrrol-2-one tautomers.

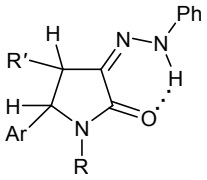
We previously found that 4-aroyl-, 4-acetyl-, and 4-hetaroyl-3-hydroxy-2,5-dihydro-1*H*-pyrrol-2-ones having various substituents on the nitrogen atom (alkyl, hetaryl, or amino acid residue or hydrogen atom) react with hydrazine hydrate and arylhydrazines to produce 3,4,5-trisubstituted pyrrolo[3,4-*c*]pyrazol-6-ones [1, 6].

Scheme 2.



11–**14**, **18**, **19**, X = S; **15**–**17**, **20**–**23**, X = O; **11**, **18**, **20**, R = H; **9**, **12**, **15**, **21**, R = 2-Cl; **14**, **17**, **19**, **23**, R = 3-HO; **10**, **13**, **16**, **22,** R = 4-*i*-Pr; **11**–**17**, R′ = H; **18**–**23**, R′ = Ph.

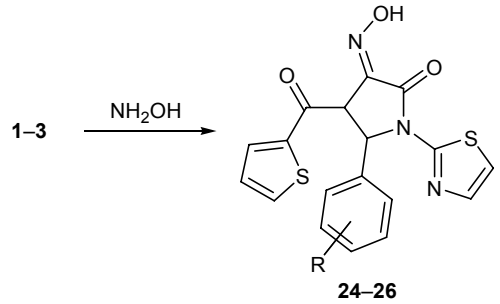
The reactions of **2** and **3** with phenylhydrazine gave the corresponding 3-hydrazones **9** and **10**, whereas pyrrolo[3,4-*c*]pyrazole derivatives **11**–**23** were obtained by reactions of **1** and **4**–**8** with hydrazine hydrate and phenylhydrazine on heating in glacial acetic acid (Scheme 2). Compounds **9** and **10** are yellow crystalline substances soluble in DMF, DMSO, glacial acetic acid, dioxane, and alcohols and insoluble in water. The IR spectra of **9** and **10** contained absorption bands due to stretching vibrations of the lactam (1670–1710 cm^{-1}) and ketone carbonyl groups (1590–1650 cm^{-1}) and NH group (3240–3260 cm^{-1}). In the ^{1}H NMR spectra of these compounds we observed signals from the NH proton (δ 11.82–11.84 ppm) and two CH protons (δ 4.70–4.80 and 6.07–6.37 ppm), which indicated their hydrazone structure. This structure is likely to be stabilized by intramolecular hydrogen bond.



Compounds **11**–**23** were isolated as light orange to light brown crystalline substances soluble in DMF, DMSO, glacial acetic acid, and dioxane, poorly soluble in other organic solvents, and insoluble in water. They displayed in the IR spectra absorption bands belonging to stretching vibrations of the lactam carbonyl (1700–1710 cm^{-1}) and NH groups (3260–3280 cm^{-1}). Signals due to aromatic protons, including doublets from protons in the thiazole ring (δ 7.68–8.17 ppm) and a singlet from the 4-H proton (δ 6.47–6.94 ppm) were observed in the ^{1}H NMR spectra of **11**–**23**. Compounds **11**–**17** characteristically showed in the ^{1}H NMR spectra a signal at δ 14.34–14.43 ppm (N^2H).

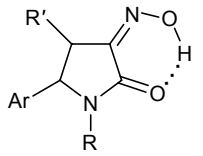
Treatment of compounds **1**–**3** with hydroxylamine led to the formation of the corresponding oximes **24**–**26** (Scheme 3) which were isolated as colorless or light yellow crystalline substances soluble in DMF, DMSO, glacial acetic acid, dioxane, and ethanol, as well as in propan-2-ol on heating, and insoluble in water. Absorption bands typical of lactam carbonyl (1700–1710 cm^{-1}), ketone carbonyl (1610–1660 cm^{-1}), and OH group (3260–3280 cm^{-1}) were present in the IR spectra of **24**–**26**. In the ^{1}H NMR spectra of **24**–**26**, aromatic protons resonated in the region δ 6.79–7.54 ppm, signals from protons in the thiazole ring appeared as doublets at δ 7.68–8.17 ppm, and the OH proton gave a singlet at δ 8.73–8.85 ppm; also, two

Scheme 3.



24, R = H; **25**, R = 2-Cl; **26**, R = 4-*i*-Pr.

symmetrical doublets belonging to 4-H and 5-H were observed at δ 4.86–5.09 and 6.14–6.54 ppm with a coupling constant *J* of 10 Hz. These findings indicated predominantly oxime structure of **24**–**26**, which is likely to be stabilized by intramolecular hydrogen bond.



EXPERIMENTAL

The IR spectra were recorded on a Specord M-80 spectrometer from samples dispersed in mineral oil. The ^{1}H NMR spectra were measured on a Bruker DRX 500 instrument at 500.13 MHz from solutions in DMSO-d_6 using tetramethylsilane as internal reference. The mass spectra (electron impact, 70 eV) were obtained on a Finnigan MAT INCOS-50 mass spectrometer. The elemental compositions were determined on a Perkin Elmer 2400 analyzer.

3-Hydroxy-5-phenyl-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)-2,5-dihydro-1*H*-pyrrol-2-one (1). A mixture of 1.06 g (5 mmol) of methyl 2,4-dioxo-4-(thiophen-2-yl)butanoate, 0.74 g (0.91 mL, 5.5 mmol) of benzaldehyde, and 0.5 g (5 mmol) of 1,3-thiazol-2-amine in 10 mL of glacial acetic acid was heated for 5–10 min under reflux. The mixture was cooled, and the precipitate was filtered off. Yield 1.10 g (60%), light yellow crystals, mp 218–220°C (from glacial AcOH). IR spectrum, ν, cm^{-1}: 3240 (OH), 1690 (C^2=O), 1620 (4-C=O). ^{1}H NMR spectrum, δ, ppm: 6.12 s (1H, 5-H), 7.10–7.30 m (8H, H$_{arom}$), 7.87 d and 7.96 d (1H each, 4′-H, 5′-H, *J* = 4.8 Hz). Found, %: C 59.01; H 3.14; N 7.51; S 17.32. $C_{18}H_{12}N_2O_3S_2$. Calculated, %: C 58.68; H 3.28; N 7.60; S 17.41.

Compounds **2**–**8** were synthesized in a similar way.

5-(2-Chlorophenyl)-3-hydroxy-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)-2,5-dihydro-1*H*-pyrrol-2-one (2). Yield 1.17 g (58%), yellow crystals, mp 228–230°C (from glacial AcOH). IR spectrum, ν, cm^{-1}: 3200 (OH), 1680 (C^2=O), 1590 (4-C=O). ^{1}H NMR spectrum, δ, ppm: 6.30 s (1H, 5-H), 6.60–7.40 m (7H, H$_{arom}$), 7.98 d and 8.10 d (1H each, 4′-H, 5′-H, *J* = 4.85 Hz). Found, %: C 53.56; H 2.97; N 7.15; S 15.74. $C_{18}H_{11}ClN_2O_3S_2$. Calculated, %: C 53.66; H 2.75; N 6.95; S 15.92.

3-Hydroxy-5-(4-isopropylphenyl)-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)-2,5-dihydro-1*H*-pyrrol-2-one (3). Yield 1.17 g (57%), light yellow crystals, mp 236–238°C (from glacial AcOH). IR spectrum, ν, cm^{-1}: 3220 (OH), 1690 (C^2=O), 1620 (4-C=O). ^{1}H NMR spectrum, δ, ppm: 1.09–1.11 d [6H, CH(C**H**$_3$)$_2$], 2.74–2.80 m [1H, C**H**(CH$_3$)$_2$], 6.15 s (1H, 5-H), 7.10–7.44 m (7H, H$_{arom}$), 7.98 d and 8.09 d (1H each, 4′-H, 5′-H, *J* = 4.85 Hz), 11.40–13.00 s (1H, OH). Found, %: C 61.92; H 4.67; N 6.31; S 15.74. $C_{21}H_{18}N_2O_3S_2$. Calculated, %: C 61.44; H 4.42; N 6.82; S 15.62.

3-Hydroxy-5-(3-hydroxyphenyl)-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)-2,5-dihydro-1*H*-pyrrol-2-one (4). Yield 0.92 g (48%), light brown crystals, mp 220–222°C (from glacial AcOH). ^{1}H NMR spectrum, δ, ppm: 6.12 s (1H, 5-H), 6.54–7.44 m (7H, H$_{arom}$), 7.99 d and 8.02 d (1H each, 4′-H, 5′-H, *J* = 4.85 Hz), 9.30 s (1H, OH), 11.60–12.90 s (1H, OH). Found, %: C 55.77; H 3.57; N 7.11; S 16.93. $C_{18}H_{12}N_2O_4S_2$. Calculated, %: C 56.24; H 3.15; N 7.29; S 16.68.

4-(Furan-2-ylcarbonyl)-3-hydroxy-5-phenyl-1-(1,3-thiazol-2-yl)-2,5-dihydro-1*H*-pyrrol-2-one (5). Yield 0.99 g (56%), brown crystals, mp 223–225°C (from glacial AcOH). ^{1}H NMR spectrum, δ, ppm: 6.15 s (1H, 5-H), 6.60–7.35 m (8H, H$_{arom}$), 7.50 d and 7.90 d (1H each, 4′-H, 5′-H, *J* = 2.56 Hz). Found, %: C 61.74; H 3.63; N 7.31; S 9.51. $C_{18}H_{12}N_2O_4S$. Calculated, %: C 61.36; H 3.43; N 7.95; S 9.10.

5-(2-Chlorophenyl)-4-(furan-2-ylcarbonyl)-3-hydroxy-1-(1,3-thiazol-2-yl)-2,5-dihydro-1*H*-pyrrol-2-one (6). Yield 1.20 g (62%), light brown crystals, mp 223–225°C (from glacial AcOH). ^{1}H NMR spectrum, δ, ppm: 6.32 s (1H, 5-H), 6.62–7.39 m (7H, H$_{arom}$), 7.63 d and 7.98 d (1H each, 4′-H, 5′-H, *J* = 2.56 Hz), 11.80–12.20 s (1H, OH). Found, %: C 56.17; H 2.70; N 7.10; S 7.98. $C_{18}H_{11}ClN_2O_4S$. Calculated, %: C 55.89; H 2.87; N 7.24; S 8.29.

4-(Furan-2-ylcarbonyl)-3-hydroxy-5-(4-isopropylphenyl)-1-(1,3-thiazol-2-yl)-2,5-dihydro-1*H*-pyrrol-2-one (7). Yield 1.09 g (55%), brown crystals, mp 226–228°C (from glacial AcOH). ^{1}H NMR spectrum, δ, ppm: 1.09–1.11 d [6H, CH(C**H**$_3$)$_2$], 2.74–2.80 m [1H, C**H**(CH$_3$)$_2$], 6.20 s (1H, 5-H), 6.71–7.45 m (7H, H$_{arom}$), 7.61 d and 7.99 d (1H each, 4′-H, 5′-H, *J* = 2.56 Hz), 11.40–12.90 s (1H, OH). Found, %: C 64.34; H 4.73; N 6.79; S 8.31. $C_{21}H_{18}N_2O_4S$. Calculated, %: C 63.95; H 4.60; N 7.10; S 8.13.

4-(Furan-2-ylcarbonyl)-3-hydroxy-5-(3-hydroxyphenyl)-1-(1,3-thiazol-2-yl)-2,5-dihydro-1*H*-pyrrol-2-one (8). Yield 0.62 g (34%), brown crystals, mp 224–226°C (from glacial AcOH). ^{1}H NMR spectrum, δ, ppm: 6.15 s (1H, 5-H), 6.54–7.44 m (7H, H$_{arom}$), 7.54 d and 8.00 d (1H each, 4′-H, 5′-H, *J* = 2.56 Hz), 9.34 s (1H, OH), 11.50–12.70 s (1H, OH). Found, %: C 58.27; H 3.49; N 7.31; S 8.92. $C_{18}H_{12}N_2O_5S$. Calculated, %: C 58.69; H 3.28; N 7.60; S 8.70.

5-(2-Chlorophenyl)-3-(2-phenylhydrazinylidene)-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)-pyrrolidin-2-one (9). A mixture of 1.21 g (3 mmol) of compound **2** and 0.5 mL (5 mmol) of phenylhydrazine in 10 mL of glacial acetic acid was heated for 3 h under reflux. The mixture was cooled, and the precipitate was filtered off. Yield 0.69 g (47%), light yellow crystals, mp 201–203°C (from glacial AcOH). IR spectrum, ν, cm^{-1}: 3240 (NH), 1670 (C^2=O), 1590 (4-C=O). ^{1}H NMR spectrum, δ, ppm: 4.80 d (1H, 4-H, *J* = 5.02 Hz), 6.37 d (1H, 5-H, *J* = 5.02 Hz), 6.85–8.24 m (14H, H$_{arom}$), 11.82 s (1H, NH). Found, %: C 58.27; H 3.65; N 11.58; S 13.49. $C_{24}H_{17}ClN_4O_2S_2$. Calculated, %: C 58.47; H 3.48; N 11.36; S 13.01.

5-(4-Isopropylphenyl)-3-(2-phenylhydrazinylidene)-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)-pyrrolidin-2-one (10) was synthesized in a similar way from compound **3**. Yield 0.71 g (47%), yellow–orange crystals, mp 206–208°C (from glacial AcOH). IR spectrum, ν, cm^{-1}: 1650 (4-C=O), 1710 (C^2=O), 3260 (NH). ^{1}H NMR spectrum, δ, ppm: 1.14–1.21 d [6H, CH(C**H**$_3$)$_2$], 2.76–2.83 m [1H, C**H**(CH$_3$)$_2$], 4.70 d (1H, 4-H, *J* = 5.02 Hz), 6.07 d (1H, 5-H, *J* = 5.02 Hz), 6.85–8.13 m (14H, H$_{arom}$), 11.84 s (1H, NH). Found, %: C 64.37; H 4.52; N 11.58; S 13.25. $C_{27}H_{24}N_4O_2S_2$. Calculated, %: C 64.78; H 4.83; N 11.19; S 12.81.

4-Phenyl-5-(1,3-thiazol-2-yl)-3-(thiophen-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (11). A mixture of 1.1 g (3 mmol) of compound **1** and 0.2 mL (4.1 mmol) of hydrazine hydrate in 10 mL of glacial acetic acid was heated for 2 h under reflux. The mixture was cooled and the precipitate was filtered off. Yield 0.88 g (75%), light yellow crystals, mp >280°C (from glacial AcOH). IR spectrum, ν, cm^{-1}: 3200 (NH), 1690 (C=O). ^{1}H NMR spectrum, δ, ppm: 6.62 s (1H, 5-H), 6.97–7.59 m (10H, H$_{arom}$), 14.37 s (1H, NH). Found, %: C 58.96; H 3.44; N 15.73; S 17.25. $C_{18}H_{12}N_4OS_2$. Calculated, %: C 59.32; H 3.32; N 15.37; S 17.60.

Compounds **12**–**17** were synthesized in a similar way.

4-(2-Chlorophenyl)-5-(1,3-thiazol-2-yl)-3-(thiophen-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (12). Yield 0.92 g (73%), light orange crystals, mp >280°C (from glacial AcOH). IR spectrum, ν, cm^{-1}: 3240 (NH), 1720 (C=O). ^{1}H NMR spectrum, δ, ppm: 6.94 s (1H, 5-H), 6.94–7.62 m (9H, H$_{arom}$), 14.40 s (1H, NH). Found, %: C 54.63; H 3.01; N 14.58; S 16.59. $C_{18}H_{11}ClN_4OS_2$. Calculated, %: C 54.20; H 2.78; N 14.05; S 16.08.

4-(4-Isopropylphenyl)-5-(1,3-thiazol-2-yl)-3-(thiophen-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (13). Yield 0.85 g (70%), yellow–orange crystals, mp >280°C (from glacial AcOH). IR spectrum, ν, cm^{-1}: 1650 (C=O), 3150 (NH). ^{1}H NMR spectrum, δ, ppm: 1.11–1.13 d [6H, CH(C**H**$_3$)$_2$], 2.78–2.84 m [1H, C**H**(CH$_3$)$_2$], 6.59 s (1H, 5-H), 6.59–7.61 m (9H, H$_{arom}$), 14.36 s (1H, NH). Found, %: C 61.73; H 4.61; N 13.49; S 16.02. $C_{21}H_{18}N_4OS_2$. Calculated, %: C 62.05; H 4.46; N 13.78; S 15.77.

4-(3-Hydroxyphenyl)-5-(1,3-thiazol-2-yl)-3-(thiophen-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (14). Yield 0.75 g (61%), light orange crystals, mp >280°C (from glacial AcOH). ^{1}H NMR spectrum, δ, ppm: 6.53 s (1H, 5-H), 6.53–7.63 m (9H, H$_{arom}$), 9.35 s (1H, OH), 14.35 s (1H, NH). Found, %: C 56.33; H 3.41; N 14.50; S 17.05. $C_{18}H_{12}N_4O_2S_2$. Calculated, %: C 56.83; H 3.18; N 14.73; S 16.86.

4-(2-Chlorophenyl)-3-(furan-2-yl)-5-(1,3-thiazol-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (15). Yield 0.69 g (57%), light brown crystals, mp 259–261°C (from glacial AcOH). ^{1}H NMR spectrum, δ, ppm: 6.57 s (1H, 5-H), 6.57–7.72 m (9H, H$_{arom}$), 14.43 s (1H, NH). Found, %: C 56.30; H 3.12; N 14.38; S 8.51. $C_{18}H_{11}ClN_4O_2S$. Calculated, %: C 56.47; H 2.90; N 14.63; S 8.38.

3-(Furan-2-yl)-4-(4-isopropylphenyl)-5-(1,3-thiazol-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (16). Yield 0.41 g (35%), light gray crystals, mp 241–243°C (from glacial AcOH). IR spectrum, ν,

cm^{-1}: 3150 (NH), 1650 (C=O). ^1H NMR spectrum, δ, ppm: 1.11–1.13 d [6H, $CH(CH_3)_2$], 2.77–2.83 m [1H, $CH(CH_3)_2$], 6.54 s (1H, 5-H), 6.54–7.77 m (9H, H_{arom}), 14.39 s (1H, NH). Found, %: C 64.82; H 4.75; N 14.13; S 7.99. $C_{21}H_{18}N_4O_2S$. Calculated, %: C 64.60; H 4.65; N 14.35; S 8.21.

3-(Furan-2-yl)-4-(3-hydroxyphenyl)-5-(1,3-thiazol-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (17). Yield 0.52 g (45%), light orange crystals, mp 273–275°C (from glacial AcOH). ^1H NMR spectrum, δ, ppm: 6.55 s (1H, 5-H), 6.55–7.78 m (9H, H_{arom}), 9.35 s (1H, OH), 14.40 s (1H, NH). Found, %: C 59.51; H 3.48; N 15.11; S 8.60. $C_{18}H_{12}N_4O_3S$. Calculated, %: C 59.33; H 3.32; N 15.38; S 8.80.

2,4-Diphenyl-5-(1,3-thiazol-2-yl)-3-(thiophen-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (18). A mixture of 1.1 g (3 mmol) of compound **1** and 0.5 mL (5 mmol) of phenylhydrazine in 10 mL of glacial acetic acid was heated for 3 h under reflux. The mixture was cooled, and the precipitate was filtered off. Yield 0.40 g (30%), light yellow crystals, mp 277–279°C (from glacial AcOH). IR spectrum: ν 1720 cm^{-1} (C=O). ^1H NMR spectrum, δ, ppm: 6.75 s (1H, 5-H), 7.01–8.24 m (15H, H_{arom}). Found, %: C 65.75; H 3.91; N 12.33; S 14.12. $C_{24}H_{16}N_4OS_2$. Calculated, %: C 65.43; H 3.66; N 12.72; S 14.56.

Compounds **19**–**23** were synthesized in a similar way.

4-(3-Hydroxyphenyl)-2-phenyl-5-(1,3-thiazol-2-yl)-3-(thiophen-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (19). Yield 0.51 g (37%), light yellow crystals, mp 257–259°C (from glacial AcOH). ^1H NMR spectrum, δ, ppm: 6.47 s (1H, 5-H), 6.58–8.16 m (14H, H_{arom}), 9.36 s (1H, OH). Found, %: C 63.51; H 3.86; N 12.01; S 13.82. $C_{24}H_{16}N_4O_2S_2$. Calculated, %: C 63.14; H 3.53; N 12.27; S 14.05.

3-(Furan-2-yl)-2,4-diphenyl-5-(1,3-thiazol-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (20). Yield 0.45 g (35%), light yellow crystals, mp 245–247°C (from glacial AcOH). ^1H NMR spectrum, δ, ppm: 6.69 s (1H, 5-H), 6.53–8.26 m (15H, H_{arom}). Found, %: C 67.49; H 3.57; N 13.39; S 7.91. $C_{24}H_{16}N_4O_2S$. Calculated, %: C 67.91; H 3.80; N 13.20; S 7.55.

4-(2-Chlorophenyl)-3-(furan-2-yl)-2-phenyl-5-(1,3-thiazol-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (21). Yield 0.26 g (18.8%), light yellow crystals, mp 252–254°C (from glacial AcOH). ^1H NMR spectrum, δ, ppm: 6.55 s (1H, 5-H), 6.61–8.25 m (14H, H_{arom}). Found, %: C 63.13; H 3.49; N 12.01; S 6.62. $C_{24}H_{15}ClN_4O_2S$. Calculated, %: C 62.81; H 3.29; N 12.21; S 6.99.

3-(Furan-2-yl)-4-(4-isopropylphenyl)-2-phenyl-5-(1,3-thiazol-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (22). Yield 0.37 g (26%), light yellow crystals, mp 237–239°C (from glacial AcOH). ^1H NMR spectrum, δ, ppm: 1.12–1.14 d [6H, $CH(CH_3)_2$], 2.76–2.83 m [1H, $CH(CH_3)_2$], 6.66 s (1H, 5-H), 6.54–8.25 m (14H, H_{arom}). Found, %: C 69.85; H 4.60; N 12.34; S 7.01. $C_{27}H_{22}N_4O_2S$. Calculated, %: C 69.51; H 4.75; N 12.01; S 6.87.

3-(Furan-2-yl)-4-(3-hydroxyphenyl)-2-phenyl-5-(1,3-thiazol-2-yl)-4,5-dihydropyrrolo[3,4-*c*]pyrazol-6(2*H*)-one (23). Yield 0.33 g (25%), light yellow crystals, mp 266–268°C (from glacial AcOH). ^1H NMR spectrum, δ, ppm: 6.56 s (1H, 5-H), 6.56–8.25 m (14H, H_{arom}), 9.38 s (1H, OH). Found, %: C 65.67; H 3.81; N 12.39; S 6.97. $C_{24}H_{16}N_4O_3S$. Calculated, %: C 65.44; H 3.66; N 12.72; S 7.28.

3-Hydroxyimino-5-phenyl-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)pyrrolidine-2-one (24). A mixture of 1.1 g (3 mmol) of compound **1** and 0.12 g (3.6 mmol) of hydroxylamine in 10 mL of ethanol–glacial acetic acid (1:1) was heated for 3 h under reflux and was then left to stand for 24 h at room temperature. The resinous material was ground with ethanol, and the precipitate was filtered off. Yield 0.24 g (21%), light yellow crystals, mp 217–219°C (from EtOH). IR spectrum, ν, cm^{-1}: 3260 (OH), 1700 (C^2=O), 1660 (4-C=O). ^1H NMR spectrum, δ, ppm: 4.86–4.89 d (1H, 4-H, J = 10 Hz), 6.20–6.23 d (1H, 5-H, J = 10 Hz), 6.92–8.17 m (10H, H_{arom}), 8.76 s (1H, OH). Found, %: C 56.65; H 3.53; N 10.57; S 16.61. $C_{18}H_{13}N_3O_3S_2$. Calculated, %: C 56.38; H 3.42; N 10.96; S 16.72.

Compounds **25** and **26** were synthesized in a similar way.

5-(2-Chlorophenyl)-3-hydroxyimino-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)pyrrolidin-2-one (25). Yield 0.25 g (20%), white crystals, mp 194–196°C (from EtOH). IR spectrum, ν, cm^{-1}: 3280 (OH), 1710 (C^2=O), 1610 (4-C=O). ^1H NMR spectrum, δ, ppm: 5.07–5.09 d (1H, 4-H, J = 10 Hz), 6.51–6.54 d (1H, 5-H, J = 10 Hz), 6.81–7.92 m (9H, H_{arom}), 8.85 s (1H, OH). Found, %: C 52.01; H 3.12; N 9.85; S 15.10. $C_{18}H_{12}ClN_3O_3S_2$. Calculated, %: C 51.74; H 2.89; N 10.06; S 15.35.

3-Hydroxyimino-5-(4-isopropylphenyl)-1-(1,3-thiazol-2-yl)-4-(thiophen-2-ylcarbonyl)pyrrolidin-2-one (26). Yield 0.45 g (35%), light yellow

crystals, mp 195–197°C (from EtOH). ^{1}H NMR spectrum, δ, ppm: 1.10–1.12 d [6H, CH(C**H**$_3$)$_2$], 2.64–2.80 m [1H, C**H**(CH$_3$)$_2$], 4.86–4.88 d (1H, 4-H, J = 10 Hz), 6.14–6.16 d (1H, 5-H, J = 10 Hz), 6.79–8.17 m (9H, H$_{arom}$), 8.73 s (1H, OH). Found, %: C 59.51; H 4.68; N 9.69; S 14.85. $C_{21}H_{19}N_3O_3S_2$. Calculated, %: C 59.28; H 4.50; N 9.87; S 15.07.

REFERENCES

1. Mar'yasov, M.A. and Gein, V.L., *Tetragidropirrol-2,3-diony* (Tetrahydropyrrole-2,3-diones): Perm: Perm. Gos. Farm. Akad., 2013, p. 155.
2. Gein, V.L., Gein, L.F., Porseva, N.Yu., Voronina, E.V., Vakhrin, M.I., Potemkin, K.D., Kolla, V.E., Drovosekova, L.P., Milyutin, A.V., Shchuklina, N.S., and Veikhman, G.A., *Pharm. Chem. J.*, 1998, vol. 32, no. 9, p. 477.
3. Silina, T.A., Pulina, N.A., Gein, L.F., and Gein, V.L., *Chem. Heterocycl. Compd*., 1998, vol. 34, no. 6, p. 739.
4. Gein, V.L., Yushkov, V.V., Silina, T.A., Gein, L.F., Yatsenko, K.V., and Shevtsova, V.G., *Pharm. Chem. J*., 2008, vol. 42, no. 5, p. 255.
5. Andreichikov, Yu.S., Gein, V.L., and Anikina, I.N., *Zh. Org. Khim*., 1986, vol. 22, p. 1749.
6. Southwick, P.I., Previc, E.P., Casanova, L., and Carlson, E.H., *J. Org. Chem*., 1956, vol. 21, p. 1087.