

Ureas and amides of the 5-(2-nitrophenyl)-2-furyl type

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A synthesis and an utilization of 3-[5-(2-nitrophenyl)-2-furyl]propenoyl azide and 5-(2-nitrophenyl)-2-furoyl azide is presented. The ureas and amides containing 5-(2-nitrophenyl)-2-furyl residue in their structure are described.

В работе описано получение и использование азидов 3-[5-(2-нитрофенил)-2-фурил]пропеновой и 5-(2-нитрофенил)-2-фуранкарбоновой кислоты. Также описаны мочевины и амиды, в структуре которых находится 5-(2-нитрофенил)-2-фурильный избыток.

There are wide possibilities of the utilization of the furan derivatives as biologically active compounds. Amides arising by the reactions of 2-furoyl chloride with amines show the fungicidal [1—4] and herbicidal [5, 6] properties. It is known that *N*-(2-furyl)-*N*-[(1'-methoxycarbonyl)-1-ethyl]-2,6-dimethylaniline represents a new class of the systemic fungicides [7, 8].

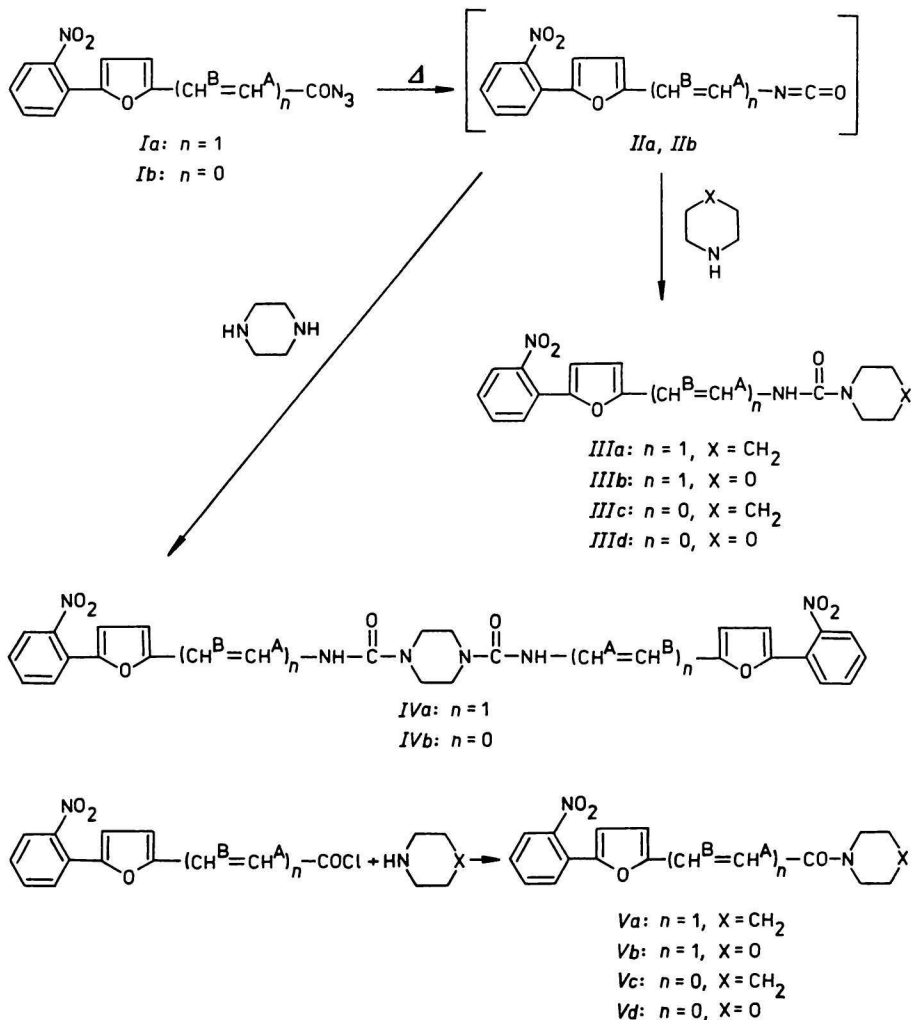
The synthesis of 3-[5-(2-nitrophenyl)-2-furyl]propenoyl azide (*Ia*) and its utilization in the preparation of furo[3,2-*c*] pyridine derivatives was described in [9].

In this paper, the synthesis of 5-(2-nitrophenyl)-2-furoyl azide (*Ib*) and the utilization of the compounds *Ia*, *Ib* in the synthesis of next derivatives is presented.

Azides *Ia* and *Ib* were obtained from the corresponding chlorides [10—12]. Isocyanates *IIa*, *IIb* originated from thermal decomposition of *Ia*, *Ib* (*via* Curtius rearrangement) were used without further isolation in addition reactions with the nitrogenic bases for the synthesis of corresponding ureas *IIIa—IIIc*, *IVa*, *IVb* (Scheme 1).

Starting from 3-[5-(2-nitrophenyl)-2-furyl]propenoyl and 5-(2-nitrophenyl)-2-furoyl chlorides [11, 12] corresponding amides *Va—Vd* were prepared.

The IR spectra of these compounds showed an absorption band at $\tilde{\nu} = 1607\text{—}1680\text{ cm}^{-1}$ ($\nu(\text{C}=\text{O})$). The wavenumbers of N—H bonds varied within $3210\text{—}3250\text{ cm}^{-1}$. The synthesized compounds exhibited $\nu_{\text{as}}(\text{NO}_2)$ and $\nu_{\text{s}}(\text{NO}_2)$ bands at $\tilde{\nu} = 1480\text{—}1550\text{ cm}^{-1}$ and $1340\text{—}1360\text{ cm}^{-1}$, respectively.



Scheme 1

Electronic spectra of the synthesized compounds displayed an intense band at $\lambda = 335\text{--}380$ nm and a weaker one at $\lambda = 215\text{--}240$ nm. The relatively high λ_{max} values are subject to the extension of the conjugated system.

Structure of the synthesized compounds was corroborated by ^1H NMR spectroscopy. Compounds *III*, *IV*, *Va*, *Vb* are *E* isomers, since the coupling constant between protons H^{A} and H^{B} $J_{\text{A,B}} = 15.7$ Hz. The spectra show broad proton signals of NH groups and methylene groups as well.

Experimental

The IR spectra of the synthesized compounds were measured on a Specord 71 IR (Zeiss, Jena) spectrophotometer using KBr technique (1 mg/100 mg KBr). The electronic spectra of methanolic (*Ib*, *Ila*, *Ilb*, *IIIa—IIIc*) or ethanolic (*IVa*, *IVb*, *Va—Vd*) solutions ($c = 5 \times 10^{-5}$ mol dm⁻³) were taken with a Specord UV VIS (Zeiss, Jena) apparatus in the range of $\lambda = 200\text{--}800$ nm at room temperature. The ¹H NMR spectra of the compounds in hexadeuterodimethyl sulfoxide were recorded with a Tesla BS 487 C instrument, hexamethyldisiloxane being the reference. The mass spectra were run with an MS 902 S (AEI Manchester) spectrometer at ionizing energy 70 eV, trap current 100 μ A and ion source temperature 115—215 °C depending on the volatility of the respective derivative.

5-(2-Nitrophenyl)-2-furoyl azide (Ib)

A solution of 5-(2-nitrophenyl)-2-furoyl chloride (2.52 g; 0.01 mol) in dioxan (10 cm³) was added to sodium azide (1.26 g; 0.02 mol) dissolved in water—dioxan (14 cm³, $\varphi_r = 1 : 1$) at 0 °C; the mixture was kept at 5 °C for 10 min, poured on crushed ice and the precipitate was filtered off. Yield = 2.33 g (90.3 %), m.p. = 79—81 °C (benzene). For C₁₁H₆N₄O₄ ($M_r = 258.2$) w_i (calc.): 51.21 % C, 2.34 % H, 21.70 % N; w_i (found): 51.04 % C, 2.25 % H, 21.80 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 2100 ($\nu(\text{N}_3)$), 1680 ($\nu(\text{C}=\text{O})$), 1505 ($\nu_{\text{as}}(\text{NO}_2)$), 1360 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2 \text{mol}^{-1}))$): 220 (3.18), 305 (3.28). ¹H NMR spectrum, δ/ppm : 7.65—7.99 (4H, m, H_{arom}), 7.49 (1H, d, H-3), 7.07 (1H, d, H-4), $J_{3,4} = 3.96$ Hz.

1-{2-[5-(2-Nitrophenyl)-2-furyl]vinyl}-3,3-pentamethyleneurea (IIIa)

3-[5-(2-Nitrophenyl)-2-furyl]propenoyl azide [9] (3 g; 0.0105 mol) was refluxed in benzene (200 cm³) for 4 h. To the reaction mixture piperidine (1.04 cm³; 0.0105 mol) was added dropwise and the reflux was kept for 2 h. After benzene had been removed, the residue was dissolved in diethyl ether. The ethereal solution was washed with diluted hydrochloric acid and water. The solvent was distilled off under reduced pressure and a solid residue was crystallized. Yield = 2.33 g (65 %), m.p. = 197—199 °C (ethanol). For C₁₈H₁₉N₃O₄ ($M_r = 341.4$) w_i (calc.): 63.33 % C, 5.61 % H, 12.31 % N; w_i (found): 63.21 % C, 5.49 % H, 12.47 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 3220 ($\nu(\text{NH})$), 1670 ($\nu(\text{C}=\text{O})$), 1520 ($\nu_{\text{as}}(\text{NO}_2)$), 1340 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2 \text{mol}^{-1}))$): 240 (3.20), 335 (3.31). ¹H NMR spectrum, δ/ppm : 9.25 (1H, s, NH), 7.31—7.80 (4H, m, H_{arom}), 7.22 (1H, d, H^A), 6.77 (1H, d, H-3), 6.11 (1H, d, H-4), 5.86 (1H, d, H^B), 3.32 (4H, m, N—CH₂), 1.46 (6H, m, H_{aliph}), $J_{3,4} = 3.45$ Hz, $J_{\text{A,B}} = 14.5$ Hz.

Morpholine with *Ia* gave analogously 1-{2-[5-(2-nitrophenyl)-2-furyl]vinyl}-3,3-(3-oxopentamethylene)urea (*IIIb*). Yield = 62 %, m.p. = 181—183 °C (ethanol). For

$C_{17}H_{17}N_3O_5$ ($M_r = 343.3$) w_i (calc.): 59.48 % C, 4.99 % H, 12.24 % N; w_i (found): 59.28 % C, 4.75 % H, 12.14 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 3250 ($\nu(\text{NH})$), 1680 ($\nu(\text{C}=\text{O})$), 1520 ($\nu_{\text{as}}(\text{NO}_2)$), 1350 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2 \text{mol}^{-1}))$): 240 (3.20), 335 (3.30). ^1H NMR spectrum, δ/ppm : 9.20 (1H, s, NH), 7.30—7.81 (4H, m, H_{arom}), 7.30 (1H, d, H^A), 6.83 (1H, d, H-3), 6.27 (1H, d, H-4), 5.97 (1H, d, H^B), 3.65 (4H, m, O—CH₂), 3.40 (4H, m, N—CH₂), $J_{3,4} = 3.50$ Hz, $J_{A,B} = 14.6$ Hz.

Analogously from *Ib* was prepared 1-[5-(2-nitrophenyl)-2-furyl]-3,3-pentamethyleneurea (*IIIc*). Yield = 64 %, m.p. = 130—132 °C (ethanol). For $C_{16}H_{17}N_3O_4$ ($M_r = 315.3$) w_i (calc.): 60.95 % C, 5.43 % H, 13.33 % N; w_i (found): 59.89 % C, 5.32 % H, 13.54 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 3200 ($\nu(\text{NH})$), 1605 ($\nu(\text{C}=\text{O})$), 1510 ($\nu_{\text{as}}(\text{NO}_2)$), 1345 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2 \text{mol}^{-1}))$): 218 (3.19), 308 (3.16). ^1H NMR spectrum, δ/ppm : 9.49 (1H, s, NH), 7.29—7.80 (4H, m, H_{arom}), 6.72 (1H, d, H-3), 6.25 (1H, d, H-4), 3.52 (4H, m, N—CH₂), 1.57 (6H, m, H_{aliph}), $J_{3,4} = 4.0$ Hz.

Morpholine with *Ib* gave 1-[5-(2-nitrophenyl)-2-furyl]-3,3-(3-oxopentamethylene)urea (*IIIId*). Yield = 62 %, m.p. = 208—210 °C (ethanol). For $C_{15}H_{15}N_3O_5$ ($M_r = 317.3$) w_i (calc.): 56.78 % C, 4.77 % H, 13.24 % N; w_i (found): 56.63 % C, 4.56 % H, 13.30 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 3220 ($\nu(\text{NH})$), 1655 ($\nu(\text{C}=\text{O})$), 1505 ($\nu_{\text{as}}(\text{NO}_2)$), 1340 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2 \text{mol}^{-1}))$): 225 (3.03), 274 (2.75). ^1H NMR spectrum, δ/ppm : 9.50 (1H, s, NH), 7.30—7.76 (4H, m, H_{arom}), 6.70 (1H, d, H-3), 6.09 (1H, d, H-4), 3.39 (4H, s, O—CH₂), 3.34 (4H, s, N—CH₂), $J_{3,4} = 3.5$ Hz. Mass spectrum, m/z ($I_r/\%$): 317 (4.8), 230 (32.3), 188 (48.4), 144 (29), 106 (58), 101 (24.2), 87 (64.5), 77 (32.3), 70 (100), 57 (90.3), 44 (24.2), 29 (71).

1,4-bis{2-[5-(2-Nitrophenyl)-2-furyl]vinylaminocarbonyl}piperazine (*IVa*)

3-[5-(2-Nitrophenyl)-2-furyl]propenoyl azide (3 g; 0.0105 mol) in benzene (200 cm³) was refluxed for 4 h. To the reaction mixture piperazine (0.45 g; 0.00528 mol) was added and the reflux was continued for 2 h. The separated solid was filtered off. Yield = 1.95 g (61.5 %), m.p. = 224—226 °C (acetone—methanol, $\varphi_r = 1:1$). For $C_{30}H_{26}N_6O_8$ ($M_r = 598.6$) w_i (calc.): 60.20 % C, 4.38 % H, 14.04 % N; w_i (found): 60.02 % C, 4.20 % H, 14.03 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 3210 ($\nu(\text{NH})$), 1650 ($\nu(\text{C}=\text{O})$), 1500 ($\nu_{\text{as}}(\text{NO}_2)$), 1360 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2 \text{mol}^{-1}))$): 240 (3.27), 335 (3.36). ^1H NMR spectrum, δ/ppm : 9.15 (2H, s, NH), 7.29—7.80 (8H, m, H_{arom}), 7.04 (2H, d, H^A), 6.17 (2H, d, H-3), 5.60 (2H, d, H-4), 5.29 (2H, d, H^B), 3.37 (8H, s, N—CH₂), $J_{3,4} = 3.50$ Hz, $J_{A,B} = 14.95$ Hz. Mass spectrum, m/z ($I_r/\%$): 342 (2.3), 299 (3.5), 256 (10.3), 184 (9.2), 126 (11.5), 96 (32), 85 (13.8), 77 (20.7), 69 (23.0), 57 (32.2), 43 (100), 28 (19.5).

Analogously from *Ib* was prepared 1,4-bis{2-[5-(2-nitrophenyl)-2-furyl]aminocarbonyl}piperazine (*IVb*). Yield = 70 %, m.p. = 219—221 °C (acetone—methanol, $\varphi_r =$

= 1 : 1). For $C_{26}H_{22}N_6O_8$ ($M_r = 546.5$) w_i (calc.): 57.14 % C, 4.06 % H, 15.38 % N; w_i (found): 56.98 % C, 3.94 % H, 15.50 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 3220 ($\nu(\text{NH})$), 1620 ($\nu(\text{C}=\text{O})$), 1480 ($\nu_{\text{as}}(\text{NO}_2)$), 1350 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2\text{mol}^{-1}))$): 225 (3.28), 310 (3.20). ^1H NMR spectrum, δ/ppm : 9.51 (2H, s, NH), 7.27—7.79 (8H, m, H_{arom}), 6.75 (2H, d, H-3), 6.15 (2H, d, H-4), 3.56 (8H, s, N— CH_2), $J_{3,4} = 3.51$ Hz. Mass spectrum, m/z ($I_r/\%$): 316 (4.2), 230 (41.7), 188 (75), 144 (37.5), 116 (62.5), 86 (37.5), 85 (33.3), 77 (33.3), 70 (100), 44 (58.3), 28 (18.8).

N,N-Pentamethylene-3-[5-(2-nitrophenyl)-2-furyl]propenamide (*Va*)

To a solution of 3-[5-(2-nitrophenyl)-2-furyl]propenoyl chloride (2.22 g; 0.008 mol) in benzene (100 cm^3) piperidine (0.07 g; 0.008 mol) was added under reflux. After 5 h benzene was distilled off, the residue was dissolved in diethyl ether. The ethereal solution was washed with diluted hydrochloric acid and water. The solvent was distilled off under reduced pressure and a solid residue was crystallized. Yield = 2.0 g (78 %), m.p. = 102—103 °C (ethanol). For $C_{18}H_{18}N_2O_4$ ($M_r = 326.4$) w_i (calc.): 66.24 % C, 5.56 % H, 8.58 % N; w_i (found): 65.97 % C, 5.34 % H, 9.02 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 1610 ($\nu(\text{C}=\text{O})$), 1510 ($\nu_{\text{as}}(\text{NO}_2)$), 1345 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2\text{mol}^{-1}))$): 237 (3.09), 335 (3.08). ^1H NMR spectrum, δ/ppm : 7.55—7.97 (4H, m, H_{arom}), 7.31 (1H, d, H^{B}), 7.04 (1H, d, H-3), 6.97 (1H, d, H-4), 6.91 (1H, d, H^{A}), 3.61 (4H, s, N— CH_2), 1.57 (6H, s, H_{aliph}), $J_{3,4} = 3.37$ Hz, $J_{\text{A,B}} = 15.50$ Hz. Mass spectrum, m/z ($I_r/\%$): 326 (36.2), 296 (19.1), 242 (21.3), 226 (12.8), 212 (17), 192 (100), 84 (80.9), 28 (49).

From 3-[5-(2-nitrophenyl)-2-furyl]propenoyl chloride and morpholine was prepared *N,N*-(3-oxopentamethylene)-3-[5-(2-nitrophenyl)-2-furyl]propenamide (*Vb*). Yield = 75 %, m.p. = 107—109 °C (ethanol). For $C_{17}H_{16}N_2O_5$ ($M_r = 328.3$) w_i (calc.): 62.20 % C, 4.91 % H, 8.53 % N; w_i (found): 61.98 % C, 4.79 % H, 8.81 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 1607 ($\nu(\text{C}=\text{O})$), 1520 ($\nu_{\text{as}}(\text{NO}_2)$), 1340 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2\text{mol}^{-1}))$): 237 (3.20), 335 (3.23). ^1H NMR spectrum, δ/ppm : 7.45—7.95 (4H, m, H_{arom}), 7.26 (1H, d, H^{B}), 6.92 (2H, s, H-3 and H-4), 6.79 (1H, d, H^{A}), 3.40 (4H, s, O— CH_2), 3.25 (4H, s, N— CH_2), $J_{\text{A,B}} = 15.0$ Hz.

Starting from the corresponding chloride *N,N*-pentamethylene-5-(2-nitrophenyl)-2-furancarboxamide was prepared as well (*Vc*). Yield = 75.6 %, m.p. = 101—103 °C (ethanol). For $C_{16}H_{16}N_2O_4$ ($M_r = 300.3$) w_i (calc.): 63.99 % C, 5.37 % H, 9.33 % N; w_i (found): 63.82 % C, 5.24 % H, 9.45 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 1610 ($\nu(\text{C}=\text{O})$), 1520 ($\nu_{\text{as}}(\text{NO}_2)$), 1340 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, λ_{\max}/nm ($\log(\epsilon/(\text{m}^2\text{mol}^{-1}))$): 215 (3.06), 285 (3.11). ^1H NMR spectrum, δ/ppm : 7.50—7.90 (4H, m, H_{arom}), 7.05 (1H, d, H-3), 6.99 (1H, d, H-4), 3.51 (4H, s, N— CH_2), 1.54 (6H, s, H_{aliph}), $J_{3,4} = 3.73$ Hz.

N,N-(3-Oxopentamethylene)-5-(2-nitrophenyl)-2-furancarboxamide (*Vd*) was prepared from the corresponding chloride and morpholine. Yield = 75 %, m.p. = 90—

92 °C (ethanol). For $C_{15}H_{14}N_2O_5$ ($M_r = 302.3$) w_i (calc.): 59.60 % C, 4.67 % H, 9.27 % N; w_i (found): 59.48 % C, 4.52 % H, 9.38 % N. IR spectrum, $\tilde{\nu}_{\max}/\text{cm}^{-1}$: 1620 ($\nu(\text{C}=\text{O})$), 1525 ($\nu_{\text{as}}(\text{NO}_2)$), 1350 ($\nu_{\text{s}}(\text{NO}_2)$). UV spectrum, $\lambda_{\text{max}}/\text{nm}$ ($\log(\epsilon/(\text{m}^2 \text{mol}^{-1}))$): 218 (3.13), 280 (3.15). ^1H NMR spectrum, δ/ppm : 7.55–7.86 (4H, m, H_{arom}), 7.14 (1H, d, H-3), 7.01 (1H, d, H-4), 3.62 (4H, s, O—CH₂), 3.50 (4H, s, N—CH₂), $J_{3,4} = 3.52$ Hz.

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