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Reactions of substituted furo[3,2-*b*]pyrrole-5-carboxhydrazides and their biological activity

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Abstract: The reactions of substituted furo[3,2-*b*]pyrrole-5-carboxhydrazides **1** with 5-arylfuran-2-carboxaldehydes **2,** 4,5-disubstituted furan-2-carboxaldehydes **3** and thiophene-2-carboxaldehyde **4** has been studied. The advantage of microwave irradiation on some of these reactions was reflected in the reduced reaction time and increased yields. Reactions of **1** with 4-substituted 1,3-oxazol-5(4*H*)-ones **11** led to diacylhydrazines **13** or to imidazole derivatives **14** depending on the temperature. 1,2,4-Triazole-3-thione **17** was synthesized by two-step reaction of **1** with phenylisothiocyanate and subsequent base-catalyzed cyclization of thiosemicarbazide **16**. The effects of hydrazones **5-10** on inhibition of photosynthetic electron transport in spinach chloroplasts and chlorophyll content in the antialgal suspensions of *Chlorella vulgaris* were investigated.

Keywords: furo[3,2-b]pyrrole-5-carboxhydrazide, furan-2-carboxaldehyde, thiophene-2-carboxaldehyde, antialgal activity, microwave irradiation

1 Introduction

Carboxhydrazides and their derivatives have been described as useful building blocks for various heterocyclic rings [1-4]. A large number of carboxhydrazides exhibit wide variety of biological activities, e.g. antimicrobial [5,6], antifungal [7], antimycobacterial [8], analgesic and anti-inflammatory [9]. The synthesis and the study of physical and chemical properties of heterocyclic compounds containing a furan ring fused with different heterocyclic systems, including furo[3,2-*b*]pyrrole derivatives, has been well documented over the last few decades. Substituted furans are structural units in natural products and pharmaceuticals [10] and have been widely used as synthetic intermediates [11,12]. 5-Substituted furan-2-carboxaldehydes and some of their derivatives show antibacterial [13] or antiviral [14] activities**.** All these facts encouraged us to synthesize new furo[3,2-*b*]pyrrole-derived carboxhydrazides **5-10** and investigate some reactions of furo[3,2-*b*]pyrrole-5-carboxhydrazides **1** as a convenient way to the new heterocycles **13, 14** and **17**.

This paper presents the continuation of our previous work, dealing with the research on the synthetic feasibility of furo[3,2-*b*]pyrrole system [15-18] and the study of the effect of microwave irradiation on their reactions with heterocyclic aldehydes [19-21]. The use of microwave technology in organic synthesis has had a remarkable influence on rate enhancement of a wide variety of reactions as well as in increasing the purity and yields of products. The aim of this study was to synthesize some new hydrazones **5-10** derived from furo[3,2-*b*]pyrrole-5-carboxhydrazides **1** by their reactions with substituted furan-2-carboxaldehydes **2, 3** or thiophene-2-carboxaldehyde (**4**). Microwave irradiation was shown [22] to have a beneficial effect and shortened reaction time with increased reaction yields.

2 Experimental

Elemental analyses, ^{1}H NMR spectra and IR spectra were used to characterize all products. Melting points of products were determined on a Kofler hot plate apparatus and are uncorrected. All solvents were pre-distilled and dried appropriately prior to use. Elemental analyses were determined using a Carlo Erba CHNS-OEA 1108-Elemental analyzer. ^{1}H NMR spectra were obtained on a 300 MHz spectrometer VARIAN GEMINI 200 in DMSO-d_6 with tetramethylsilane as an internal standard. IR spectra were measured on a NICOLET NEXUS 470 spectrometer in KBr. The course of reactions was monitored by TLC chromatography in ethyl acetate – $n-$hexane. All microwave experiments were performed in Whirpool M401 type microwave oven. The apparatus was adapted for laboratory applications – *n*-hexane was used as coolant for the condenser. The protocols in [17] and [23] were followed for the synthesis of furo[3,2-*b*]pyrrole-5-carboxhydrazides and 5-arylfuran-2-carboxaldehydes, respectively.

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2.1 N'-{[5-(4-Nitrophenyl)furan-2-yl]methylene}-4H-furo[3,2-b]pyrrole-5-carboxhydrazide (5a)

The mixture of furo[3,2-*b*]pyrrole-5-carboxhydrazide (**1a**) (0.2 g, 1.21 mmol), 5-(4-nitrophenyl)-furan-2-carboxaldehyde (**2**) (0.26 g, 1.21 mmol) and catalytic amount of p-toluenesulfonic acid in ethanol (5 ml) was heated at 60 °C for 10 min. After cooling, the solid product was filtered off, dried and crystallized (ethanol). Yield 0.21 g (48 %); m.p. 279-282 °C. Anal. Calcd. for $C_{18}H_{12}N_4O_5$ (364.3) C, 59.34; H, 3.32; N, 15.38. Found: C, 59.48; H, 3.26; N, 15.53 %. IR: 3375 (ν /NH), 1650 (ν/C=O/), 1437 (ν /C-N/), 1352 (ν /NO_2), 1070 (ν /C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.59 (s, 2H, NH); 8.31 (s, 1H, CH); 7.76-7.85 (m, 4H, H-2", H-3", H-5", H-6"); 7.58 (d, 1H, J(3',4') = 12, H-3'); 7.55 (d, 1H, J(4',3') = 12, H-4'); 7.21 (d, 1H, J(2,3) = 6, H-2); 7.11 (s, 1H, H-6); 6.59 (d, 1H, J(3,2) = 6, H-3).

The compounds **5-10** were prepared similarly.

2.2 *N'*-{[5-(3-Nitrophenyl)furan-2-yl]methylene}-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (5b)

Yield 75 %; React. time: 15 min; m.p. 261-264 °C (ethanol). Anal. Calcd. for $C_{18}H_{12}N_4O_5$ (364.3) C, 59.34; H, 3.32; N, 15.38. Found: C, 59.51; H, 3.28; N, 15.06 %. IR: 3379 (ν/NH), 1650 (ν/C=O/), 1435 (ν/C-N/), 1352 (ν/NO_2), 1072 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.63 (s, 2H, NH); 8.34 (s, 1H (CH); 7.77-7.91 (m, 4H, H-2", H-4", H-5", H-6"); 7.57 (d, 1H, J(3',4') = 11.8, H-3'); 7.55 (d, 1H, J(4',3') = 11.8, H-4'); 7.27 (d, 1H, J(2,3) = 6.1, H-2); 7.09 (s, 1H, H-6); 6.69 (d, 1H, J(3,2) = 6, H-3).

2.3 *N'*-{[5-(4-Chlorophenyl)furan-2-yl]methylene}-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (5c)

Yield 72 %; React. time: 15 min; m.p. 246-248 °C (ethanol). Anal. Calcd. for $C_{18}H_{12}ClN_3O_3$(353.8) C, 61.11; H, 3.42; N, 11.88. Found: C, 61.32; H, 3.29; N, 11.66 %. IR: 3357 (ν /NH), 1633 (ν/C=O/), 1431 (ν/C-N/), 1071 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.61 (s, 2H, NH); 8.27 (s, 1H, CH); 7.75-7.84 (m, 4H, H-2", H-3", H-5", H-6"); 7.56 (d, 1H, J(3',4') = 12, H-3'); 7.52 (d, 1H, J(4',3') = 12, H-4'); 7.21 (d, 1H, J(2,3) = 6, H-2); 7.05 (s, 1H, H-6); 6.60 (d, 1H, J(3,2) = 6, H-3).

2.4 *N'*-{[5-(4-Bromophenyl)furan-2-yl]methylene}-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (5d)

Yield 71 %; React. time: 15 min; m.p. 258-261 °C (ethanol). Anal. Calcd. for $C_{18}H_{12}BrN_3O_3$ (398.2) C, 54.29; H, 3.04; N, 10.55. Found: C, 54.01; H, 2.97; N, 10.43 %. IR: 3353 (ν/NH), 1646 (ν/C=O/), 1438 (ν/C-N/), 1072 (ν/C-H/). ^{1}H NMR δ_H DMSO-

d_6: 11.58 (s, 2H, NH); 8.23 (s, 1H, CH); 7.81-7.73 (m, 4H, H-2", H-3", H-5", H-6"); 7.54 (d, 1H, J(3',4') = 11.5, H-3'); 7.50 (d, 1H, J(4',3') = 12, H-4'); 7.20 (d, 1H, J(2,3) = 5.8, H-2); 7.08 (s, 1H, H-6); 6.62 (d, 1H, J(3,2) = 5.8, H-3).

2.5 N'-({5-[3-(Trifluoromethyl)phenyl]furan-2-yl}methylene)-4H-furo [3,2-b]pyrrole-5-carboxhydrazide (5e)

Yield 32 %; React. time: 15 min; m.p. 188-191 °C (ethanol). Anal. Calcd. for $C_{19}H_{12}F_3N_3O_3$ (387.3) C, 58.92; H, 3.12; N, 10.85. Found: C, 58.68; H, 3.16; N, 10.61 %. IR: 3390 (ν/NH), 1630 (ν/C=O/), 1430 (ν/C-N/), 1070 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.60 (s, 2H, NH); 8.37 (s, 1H, CH); 7.95-7.78 (m, 4H, H-2", H-4", H-5", H-6"); 7.63 (d, 1H, J(3',4') = 12, H-3'); 7.59 (d, 1H, J(4',3') = 12, H-4'); 7.28 (d, 1H, J(2,3) = 6, H-2); 7.11 (s, 1H, H-6); 6.71 (d, 1H,J(3,2) = 6, H-3).

2.6 N'-[(5-Phenylfuran-2-yl)methylene]-4H-furo[3,2-b]pyrrole-5-carboxhydrazide (5f)

Yield 25 %; React. time: 30 min; m.p. 198-200 °C (ethanol). Anal. Calcd. for $C_{18}H_{13}N_3O_3$ (319.3) C, 67.71; H, 4.10; N, 13.16. Found: C, 67.56; H, 4.14; N, 12.91 %. IR: 3410 (ν/NH), 1650 (ν/C=O/), 1429 (ν/C-N/), 1071 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.60 (s, 2H, NH); 8.29 (s, 1H, CH); 7.85-7.75 (m, 3H, H-2", H-4", H-6"); 7.51-7.34 (m, 3H, H-2, H-3", H-5"); 7.16 (d, 1H, J(4',3') = 3.6, H-4'); 7.05 (d, 1H, J(3',4') = 3.6, H-3'); 6.99 (s, 1H, H-6); 6.61 (d, 1H, J(3,2) = 5.8, H-3).

2.7 N'-{[5-(4-Methylphenyl)furan-2-yl]methylene}-4H-furo[3,2-b]pyrrole-5-carboxhydrazide (5g)

Yield 53 %; React. time: 30 min; m.p. 207-210 °C (ethanol). Anal. Calcd. for $C_{19}H_{15}N_3O_3$ (333.3) C, 68.46; H, 4.54; N, 12.61. Found: C, 68.21; H, 4.51; N, 12.44 %. IR: 3350 (ν/NH), 2917 (ν/CH_3), 1634 (ν/C=O/), 1431 (ν/C-N/), 1072 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.49 (s, 2H, NH); 8.28 (s, 1H, CH); 7.77 (d, 1H, J(2,3) = 3.9, H-2); 7.71 (d, 1H, J(2",6") = 8.4, H-2"); 7.69 (d, 1H, J(6",2") = 8.4, H-6"); 7.30 (d, 1H, J(3",5") = 8.4, H-3"); 7.27 (d, 1H, J(5",3") = 8.4, H-5"); 7.08 (d, 1H, J(4',3') = 3.6, H-4'); 7.02 (d, 1H, J(3',4') = 3.6, H-3'); 6.99 (s, 1H, H-6); 6.61 (d, 1H, J(3,2) = 3.9, H-3); 2.36 (s, 3H, CH_3).

2.8 *N′*-{[5-(4-Nitrophenyl)furan-2-yl]methylene}-2-methyl-4*H*-furo [3,2-*b*]pyrrole-5-carboxhydrazide (6a)

Yield 66 %; React. time: 30 min; m.p. 292-295 °C (ethanol). Anal. Calcd. for $C_{19}H_{14}N_4O_5$ (378.3) C, 60.32; H, 3.73; N, 14.81. Found: C, 60.42; H, 3.80; N, 15.09 %. IR: 3445 (ν/NH), 2891 (ν/CH_3), 1640 (ν/C=O/), 1440 (ν/C-N/), 1350 (ν/NO_2), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.54 (s, 1H, NH); 11.39 (s, 1H, NH); 8.34 (d, 1H, J(3",5") = 9, H-3"); 8.31 (d, 1H, J(5",3") = 9, H-5"); 8.28 (s, 1H, CH); 8.05 (d, 1H, J(2",6") = 9, H-2"); 8.02 (d, 1H, J(6",2") = 9, H-6"); 7.49 (d, 1H, J(4',3') = 6, H-4'); 7.12 (d, 1H, J(3',4') = 6, H-3'); 6.98 (s, 1H, H-6); 6.24 (s, 1H, H-3); 2.39 (s, 3H, CH_3).

2.9 *N′*-{[5-(3-Nitrophenyl)furan-2-yl]methylene}-2-methyl-4*H*-furo[3,2-*b*] pyrrole-5-carboxhydrazide (6b)

Yield 66 %; React. time: 30 min; m.p. 250-255 °C (ethanol). Anal. Calcd. for $C_{19}H_{14}N_4O_5$ (378.3) C, 60.32; H, 3.73; N, 14.81. Found: C, 60.51; H, 3.77; N, 14.49 %. IR: 3442 (ν/NH), 2924 (ν/CH_3), 1643 (ν/C=O/), 1437 (ν C-N/), 1352 (ν/NO_2), 1080 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.56 (s, 1H, NH); 11.39 (s, 1H, NH); 8.59 (s, 1H, CH); 8.29-8.16 (m, 3H, H-2", H-4", H-5"); 7.81-7.79 (m, 1H, H-6"); 7.45 (d, 1H, J(4',3') = 6, H-4'); 7.10 (d, 1H, J(3',4') = 6, H-3'); 6.98 (s, 1H, H-6); 6.28 (s, 1H, H-3); 2.38 (s, 3H, CH_3).

2.10 *N′*-{[5-(4-Chlorophenyl)furan-2-yl]methylene}-2-methyl-4*H*-furo [3,2-*b*]pyrrole-5-carboxhydrazide (6c)

Yield 65 %; React. time: 50 min; m.p. 249-251 °C (ethanol). Anal. Calcd. for $C_{19}H_{14}ClN_3O_3$ (367.8) C, 62.05; H, 3.84; N, 11.43. Found: C, 61.81; H, 3.80; N, 11.26 %. IR: 3442 (ν/NH), 2916 (ν/CH_3), 1638 (ν/C=O/), 1440 (ν/C-N/), 1076 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 10.55 (s, 2H, NH); 8.21 (s, 1H, CH); 7.82 (d, 1H, J(3",5") = 6, H-3"); 7.80 (d, 1H, J(5",3") = 6, H-5"); 7.51 (d, 1H, J(2",6") = 6, H-2"); 7.49 (d, 1H, J(6",2") = 6, H-6"); 7.10-6.99 (m, 2H, H-3', H-4'); 6.91 (s, 1H, H-6); 6.26 (s, 1H, H-3); 2.40 (s, 3H, CH_3).

2.11 *N′*-{[5-(4-Bromophenyl)furan-2-yl]methylene}-2-methyl-4*H*-furo [3,2-*b*]pyrrole-5-carboxhydrazide (6d)

Yield 65 %; React. time: 1 h; m.p. 255-257 °C (ethanol). Anal. Calcd. for $C_{19}H_{14}BrN_3O_3$ (412.2) C, 55.36; H, 3.42; N, 10.19. Found: C, 55.59; H, 3.45; N, 9.91 %. IR: 3440 (ν/NH), 2921 (ν/CH_3), 1640 (ν/C=O/), 1440 (ν/C-N/), 1073 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.45 (s, 1H, NH); 11.38 (s, 1H, NH); 8.22 (s, 1H, CH); 7.76-7.66 (m, 4H, H-2", H-3", H-5", H-6"); 7.21 (d, 1H, J(4',3') = 3.3, H-4'); 7.03 (d, 1H, J(3',4') = 3.6, H-3'); 6.88 (s,

1H, H-6); 6.25 (s, 1H, H-3); 2.39 (s, 3H, CH_3).

2.12 *N′*-({5-[3-(Trifluoromethyl)phenyl]furan-2-yl}methylene)-2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (6e)

Yield 26 %; React. time: 20 min; m.p. 207-210 °C (ethanol). Anal. Calcd. for $C_{20}H_{14}F_3N_3O_3$ (401.3) C, 59.85; H, 3.52; N, 10.47. Found: C, 59.67; H, 3.57; N, 10.63 %. IR: 3394 (ν/NH), 2913 (ν/CH_3), 1638 (ν/C=O/), 1452 (ν/C-N/), 1076 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.51 (s, 1H, NH); 11.39 (s, 1H, NH); 8.27 (s, 1H, CH); 8.09-7.71 (m, 4H, H-2", H-4", H-5", H-6"); 7.39 (d, 1H, J(4',3') = 3.6, H-4'); 7.08 (d, 1H, J(3',4') = 3.6, H-3'); 6.99 (s, 1H, H-6); 6.26 (s, 1H, H-3); 2.39 (s, 3H, CH_3).

2.13 *N′*-[(5-Phenylfuran-2-yl)methylene]-2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (6f)

Yield 21 %; React. time: 30 min; m.p. 231-233 °C (ethanol). Anal. Calcd. for $C_{19}H_{15}N_3O_3$ (333.3) C, 68.46; H, 4.54; N, 12.61. Found: C, 68.22; H, 4.51; N, 12.39 %. IR: 3441 (ν/NH), 2890 (ν/CH_3), 1631 (ν/C=O/), 1441 (ν/C-N/), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.45 (s, 1H, NH); 11.38 (s, 1H, NH); 8.25 (s, 1H, CH); 7.82 (d, 1H, J(2",6") = 7.1, H-2"); 7.79 (d, 1H, J(6",2") = 7.1, H-6"); 7.51-7.34 (m, 3H, H-3", H-4", H-5"); 7.15 (d, 1H, J(4',3') = 3.3, H-4'); 7.03 (d, 1H, J(3',4') = 3.6, H-3'); 6.97 (s, 1H, H-6); 6.26 (s, 1H, H-3); 2.39 (s, 3H, CH_3).

2.14 *N′*-{[5-(4-Methylphenyl)furan-2-yl]methylene}-2-methyl-4*H*-furo [3,2-*b*]pyrrole-5-carboxhydrazide (6g)

Yield 64 %; React. time: 30 min; m.p. 244-246 °C (ethanol). Anal. Calcd. for $C_{20}H_{17}N_3O_3$ (347.4) C, 69.15; H, 4.93; N, 12.10. Found: C, 69.37; H, 5.01; N, 12.33 %. IR: 3441 (ν NH), 2914 (ν/CH_3), 1635 (ν/C=O/), 1441 (ν/C-N/), 1076 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.44 (s, 1H, NH); 11.38 (s, 1H, NH); 8.24 (s, 1H, CH); 7.71 (d, 1H, J(2",6") = 7.9, H-2"); 7.68 (d, 1H, J(6",2") = 7.9, H-6"); 7.30 (d, 1H, J(3",5") = 7.9, H-3"); 7.28 (d, 1H, J(5",3") = 7.9, H-5"); 7.07 (d, 1H, J(4',3') = 3.6, H-4'); 7.00 (d, 1H, J(3',4') = 3.6, H-3'); 6.98 (s, 1H, H-6); 6.26 (s, 1H, H-3); 2.39 (s, 3H, CH_3); 2.35 (s, 3H, CH_3).

2.15 *N′*-{[5-(4-Nitrophenyl)furan-2-yl]methylene}-2,3-dimethyl-4*H*-furo [3,2-*b*]pyrrole-5-carboxhydrazide (7a)

Yield 46 %; React. time: 15 min; m.p. 300-303 °C (ethanol). Anal. Calcd. for $C_{20}H_{16}N_4O_5$ (392.4) C, 61.22; H, 4.11; N, 14.28. Found: C, 61.49; H, 4.09; N, 14.45 %. IR: 3375 (ν/NH), 2920 (ν/CH_3), 1640 (ν/C=O/), 1441 (ν/C-N/), 1330 (ν/NO_2),

1074 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.65 (s, 1H, NH); 11.44 (s, 1H, NH); 8.23 (s, 1H, CH); 8.07-8.03 (m, 2H, H-3", H-5"); 7.80-7.74 (m, 2H, H-2", H-6"); 7.04(d, 1H, J(4',3') = 3.5, H-4'); 7.37(d, 1H, J (3',4') = 3.5, H-3'); 6.89 (s, 1H, H-6); 2.11 (s, 3H, CH_3); 2.05 (s, 3H, CH_3).

2.16 N'-{[5-(3-Nitrophenyl)furan-2-yl]methylene}-2,3-dimethyl-4H-furo [3,2-b]pyrrole-5-carboxhydrazide (7b)

Yield 76 %; React. time: 1 h; m.p. 272-275 °C (ethanol). Anal. Calcd. for $C_{20}H_{16}N_4O_5$ (392.4) C, 61.22; H, 4.11; N, 14.28. Found: C, 60.98; H, 4.16; N, 14.43 %. IR: 3383 (ν/NH), 2924 (ν/CH_3), 1630 (ν/C=O/), 1438 (ν/C-N/), 1335 (ν/NO_2), 1073 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.49 (s, 2H, NH); 8.53 (s, 1H, CH); 8.28-8.16 (m, 3H, H-2", H-4", H-5"); 7.79-7.74 (m, 1H, H-6"); 7.45 (d, 1H, J(4',3') = 3.9, H-4'); 7.09 (d, 1H, J(3',4') = 3.9, H-3'); 6.93 (s, 1H, H-6); 2.31 (s, 3H, CH_3); 2.07 (s, 3H, CH_3).

2.17 N'-{[5-(4-Chlorophenyl)furan-2-yl]methylene}-2,3-dimethyl-4H-furo [3,2-b]pyrrole-5-carboxhydrazide (7c)

Yield 73 %; React. time: 50 min; m.p. 288-290 °C (ethanol). Anal. Calcd. for $C_{20}H_{16}ClN_3O_3$ (381.8) C, 62.91; H, 4.22; N, 11.01. Found: C, 63.19; H, 4.27; N, 10.89 %. IR: 3373 (ν/NH), 2875 (ν/CH_3), 1626 (ν/C=O/), 1445 (ν/C-N/), 1076 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.45 (s, 2H, NH); 8.27 (s, 1H, CH); 8.10-8.07 (m, 2H, H-3", H-5"); 7.72-7.70 (m, 2H, H-2", H-6"); 7.37 (d, 1H, J(4',3') = 3.6, H-4'); 7.06 (d, 1H, J(3',4') = 3.6, H-3'); 6.96 (s, 1H, H-6); 2.05 (s, 6H, 2 CH_3).

2.18 N'-{[5-(4-Bromophenyl)furan-2-yl]methylene}-2,3-dimethyl-4H-furo [3,2-b]pyrrole-5-carboxhydrazide (7d)

Yield 63 %; React. time: 1 h; m.p. 288-291 °C (ethanol). Anal. Calcd. for $C_{20}H_{16}BrN_3O_3$ (426.3) C, 56.35; H, 3.78; N, 9.86. Found: C, 56.61; H, 3.76; N, 10.03 %. IR: 3370 (ν/NH), 2910 (ν/CH_3), 1630 (ν/C=O/), 1442 (ν/C-N/), 1074 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.48 (s, 1H, NH); 11.45 (s, 1H, NH); 8.23 (s, 1H, CH); 7.77-7.74 (m, 2H, H-2", H-6"); 7.68-7.65 (m, 2H, H-3", H-5"); 7.21 (d, 1H, J(4',3') = 3.9, H-4'); 7.03 (d, 1H, J(3',4') = 3.9, H-3'); 6.91 (s, 1H, H-6); 2.31 (s, 3H, CH_3); 2.07 (s, 3H, CH_3).

2.19 N'-({5-[3-(Trifluoromethyl)phenyl]furan-2-yl}methylene)-2,3-dimethyl-4H-furo[3,2-b]pyrrole-5-carboxhydrazide (7e)

Yield 46 %; React. time: 15 min; m.p. 235-238 °C (ethanol). Anal. Calcd. for $C_{21}H_{16}F_3N_3O_3$ (415.4) C, 60.72; H, 3.88; N, 10.12. Found: C, 60.91; H, 3.85; N, 10.31 %. IR: 3372 (ν/NH), 2915 (ν/CH_3), 1635 (ν/C=O/), 1446 (ν/C-N/), 1075 (ν/C-H/). ^{1}H

NMR δ_H DMSO-d_6: 11.46 (s, 2H, NH); 8.26 (s, 1H, CH); 8.12-8.09 (m, 2H, H-2", H-4"); 7.73-7.71 (m, 2H, H-5", H-6"); 7.39 (d, 1H, J(4',3') = 3.6, H-4'); 7.07 (d, 1H, J(3',4') = 3.6, H-3'); 6.94 (s, 1H, H-6); 2.09 (s, 6H, CH_3).

2.20 N'-[(5-Phenylfuran-2-yl)methylene]-2,3-dimethyl-4H-furo[3,2-b]pyrrole-5-carboxhydrazide (7f)

Yield 33 %; React. time: 30 min; m.p. 260-263 °C (ethanol). Anal. Calcd. for $C_{20}H_{17}N_3O_3$ (347.4) C, 69.15; H, 4.93; N, 12.10. Found: C, 68.88; H, 4.99; N, 12.36 %. IR: 3420 (ν/NH), 2920 (ν/CH_3), 1650 (ν/C=O/), 1446 (ν/C-N/), 1077 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.48 (s, 1H, NH); 11.43 (s, 1H, NH); 8.24 (s, 1H, CH); 7.82 (d, 1H, J(2",6") = 8.7, H-2"); 7.79 (d, 1H, J(6",2") = 8.7, H-6"); 7.51-7.34 (m, 3H, H-3", H-4", H-5"); 7.15 (d, 1H, J(4',3') = 3.6, H-4'); 7.03 (d, 1H, J(3',4') = 3.6, H-3'); 6.92 (s, 1H, H-6); 2.31 (s, 3H, CH_3); 2.07 (s, 3H, CH_3).

2.21 N'-{[5-(4-Methylphenyl)furan-2-yl]methylene}-2,3-dimethyl-4H-furo[3,2-b]pyrrole-5-carboxhydrazide (7g)

Yield 73 %; React. time: 30 min; m.p. 285-289 °C (ethanol). Anal. Calcd. for $C_{21}H_{19}N_3O_3$ (361.4) C, 69.79; H, 5.30; N, 11.63. Found: C, 69.52; H, 5.26; N, 11.37 %. IR: 3390 (ν/NH), 2910 (ν/CH_3), 1645 (ν/C=O/), 1446 (ν/C-N/), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.47 (s, 1H, NH); 11.40 (s, 1H, NH); 8.22 (s, 1H, CH); 7.71 (d, 1H, J(2",6") = 7.9, H-2"); 7.68 (d, 1H, J(6",2") = 7.9, H-6"); 7.30 (d, 1H, J(3",5") = 7.8, H-3"); 7.28 (d, 1H, J(5",3") = 7.8, H-5"); 7.07 (d, 1H, J(4',3') = 3.6, H-4'); 6.99 (d, 1H, J(3',4') = 3.6, H-3'); 6.92 (s, 1H, H-6); 2.35 (s, 3H, CH_3); 2.31 (s, 3H, CH_3); 2.07 (s, 3H, CH_3).

2.22 N'-{[5-(4-Nitrophenyl)furan-2-yl]methylene}-2-phenyl-4H-furo[3,2-b]pyrrole-5-carboxhydrazide (8a)

Yield 85 %; React. time: 10 min; m.p. 314-316 °C (ethanol). Anal. Calcd. for $C_{24}H_{16}N_4O_5$(440.4) C, 65.45; H, 3.66; N, 12.72. Found: C, 65.24; H, 3.61; N, 12.98 %. IR: 3425 (ν/NH), 1630 (ν/C=O/), 1440 (ν/C-N/), 1330 (ν/NO_2), 1074 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.66 (s, 1H, NH); 11.57 (s, 1H, NH); 8.29 (s, 1H, CH); 7.88-7.79 (m, 4H, H-2", H-3", H-5", H-6"); 7.56-7.28 (m, 6H, H-4', H-7", H-8", H-9", H-10", H-11"); 7.22-7.18 (m, 2H, H-6, H-3'); 7.06 (s, 1H, H-3).

2.23 *N′*-{[5-(3-Nitrophenyl)furan-2-yl]methylene}-2-phenyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (8b)

Yield 97 %; React. time: 20 min; m.p. 282-285 °C (ethanol). Anal. Calcd. for $C_{24}H_{16}N_4O_5$ (440.4) C, 65.45; H, 3.66; N, 12.72. Found: C, 65.67; H, 3.64; N, 12.49 %. IR: 3422 (ν/NH), 1640 (ν/C=O/), 1440 (ν/C-N/), 1340 (ν/NO_2), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.71 (s, 1H, NH); 11.64 (s, 1H, NH); 8.56 (s, 1H, CH); 8.27 – 8.19 (m, 4H, H-2", H-4", H-5", H-6"); 7.85 –7.76 (m, 3H, H-7", H-9", H-11"); 7.47–7.42 (m, 3H, H-4', H-8", H-10"); 7.33 (d, 1H, J(3',4') = 5.8, H-3'); 7.16 (s, 1H, H-6); 7.13 (d, 1H, J(3,6) = 3.6, H-3).

2.24 *N′*-{[5-(4-Chlorophenyl)furan-2-yl]methylene}-2-phenyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (8c)

Yield 84 %; React. time: 50 min; m.p. 278-281 °C (ethanol). Anal. Calcd. for $C_{24}H_{16}ClN_3O_3$ (429.9) C, 67.06; H, 3.75; N, 9.78. Found: C, 67.29; H, 3.72; N, 9.99 %. IR: 3350 (ν/NH), 1640 (ν/C=O/), 1440 (ν/C-N/), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.69 (s, 1H, NH); 11.56 (s, 1H, NH); 8.29 (s, 1H, CH); 7.87-7.82 (m, 4H, H-2", H-3", H-5", H-6"); 7.30.55 (m, 6H, H-4', H-7", H-8", H-9", H-10", H-11"); 7.24-7.17 (m, 2H, H-6, H-3'); 7.04 (d, 1H, J(3,6) = 3.3, H-3).

2.25 *N′*-{[5-(4-Bromophenyl)furan-2-yl]methylene}-2-phenyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (8d)

Yield 82 %; React. time: 1 h; m.p. 294-296 °C (ethanol). Anal. Calcd. for $C_{24}H_{16}BrN_3O_3$ (474.3) C, 60.77; H, 3.40; N, 8.86. Found: C, 60.55; H, 3.46; N, 8.62 %. IR: 3350 (ν/NH), 1640 (ν/C=O/), 1441 (ν/C-N/), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.61 (s, 1H, NH); 11.49 (s, 1H, NH); 8.18 (s, 1H, CH); 7.87-7.76 (m, 4H, H-2", H-3", H-5", H-6"); 7.59-7.31 (m, 6H, H-4', H-7", H-8", H-9", H-10", H-11"); 7.21-7.19 (m, 2H, H-6, H-3'); 7.02 (s, 1H, H-3).

2.26 *N′*-({5-[3-(Trifluoromethyl)phenyl]furan-2-yl}methylene)-2-phenyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (8e)

Yield 34 %; React. time: 10 min; m.p. 236-240 °C (ethanol). Anal. Calcd. for $C_{25}H_{16}F_3N_3O_3$ (463.4) C, 64.80; H, 3.48; N, 9.07. Found: C, 64.63; H, 3.52; N, 8.90 %. IR: 3420 (ν/NH), 1630 (ν/C=O/), 1440 (ν/C-N/), 1073 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.69 (s, 1H, NH); 11.62 (s, 1H, NH); 8.12 (s, 1H, CH); 7.84–7.72 (m, 5H, H-4', H-2", H-4", H-5", H-6"); 7.47-7.28 (m, 6H, H-3', H-7", H-8", H-9", H-10", H-11"); 7.16 (s, 1H, H-6); 7.11 (d, 1H, J(3,6) = 3.6, H-3).

2.27 *N′*-[(5-Phenylfuran-2-yl)methylene]-2-phenyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (8f)

Yield 55 %; React. time: 30 min; m.p. 224-227 °C (ethanol). Anal. Calcd. for $C_{24}H_{17}N_3O_3$ (395.4) C, 72.90; H, 4.33; N, 10.63. Found: C, 72.69; H, 4.32; N, 10.41 %. IR: 3375 (ν/NH), 1638 (ν/C=O/), 1442 (ν/C-N/), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.68 (s, 1H, NH); 11.56 (s, 1H, NH); 8.30 (s, 1H, CH); 7.86-7.80 (m, 5H, H-2", H-3", H-4", H-5", H-6"); 7.52-7.28 (m, 6H, H-4', H-7", H-8", H-9", H-10", H-11"); 7.17-7.15 (m, 2H, H-6, H-3'); 7.06 (d, 1H, J(3,6) = 3.6, H-3).

2.28 *N′*-{[5-(4-Methylphenyl)furan-2-yl]methylene}-2-phenyl-4*H*-furo [3,2-*b*]pyrrole-5-carboxhydrazide (8g)

Yield 65 %; React. time: 30 min; m.p. 290-292 °C (ethanol). Anal. Calcd. for $C_{25}H_{19}N_3O_3$ (409.4) C, 73.34; H, 4.68; N, 10.26. Found: C, 73.09; H, 4.62; N, 10.51 %. IR: 3400 (ν/NH), 1640 (ν/C=O/), 1442 (ν/C-N/), 1074 (/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.69 (s, 1H, NH); 11.55 (s, 1H, NH); 8.29 (s, 1H, CH); 7.84 (d, 1H,J(2",6") = 8.1, H-2"); 7.81 (d, 1H,J(6",2") = 8.1, H-6"); 7.73 (d, 1H, J(3",5") = 8.1, H-3"); 7.69 (d, 1H, J(5",3") = 8.1, H-5"); 7.47-7.29 (m, 6H, H-4', H-7", H-8", H-9", H-10", H-11"); 7.16 (s, 1H, H-6); 7.08 (d, 1H, J(3',4') = 3.3, H-3'); 7.04 (s, 1H, H-3); 2.35 (s, 3H, CH_3).

2.29 *N′*-[(Furan-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (9a)

Yield 74 %; React. time: 1h; m.p. 251-255 °C (ethanol). Anal. Calcd. for $C_{12}H_9N_3O_3$ (243.2) C, 59.26; H, 3.73; N, 17.28. Found: C 59.47; H, 3.75; N, 17.49 %. IR: 3370 (ν/NH), 1645 (ν/C=O/), 1438 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.62 (s, 1H, NH), 11.53 (s, 1H, NH); 8.14 (s, 1H, CH); 7.68 (d, 1H, J(5',4') = 3.3, H-5'); 7.38 (d, 1H, J(2,3) = 3.5, H-2); 7.31 (d,d, 1H, J(4',3') = 5.8, J(4',5') = 5.8, H-4'); 7.15-7.12 (m, 2H, H-6, H-3'); 6.41 (d, 1H, J(3,2) = 3.5, H-3).

2.30 *N′*-[(Furan-2-yl)methylene]-2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (9b)

Yield 56 %; React. time: 1 h; m.p. 236-239 °C (ethanol). Anal. Calcd. for $C_{13}H_{11}N_3O_3$ (257.2) C, 60.70; H, 4.31; N, 16.33. Found: C 60.94; H, 4.35; N, 16.57 %. IR: 3395 (ν/NH), 2905 (ν/CH_3), 1635 (ν/C=O/), 1440 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.37 (s, 2H, NH); 8.09 (s, 1H, CH); 7.85 (d, 1H, J(5',4') = 3, H-5'); 6.87 (s, 1H, H-6); 6.85 (d, 1H, J (3',4') = 3, H-3'); 6.64 (d,d, 1H, J(4',5') = 5.1, J(4',3') = 5.1, H-4'); 6.24 (s, 1H, H-3); 2.37 (s, 3H, CH_3).

2.31 *N′*-[(Furan-2-yl)methylene]-2,3-dimethyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (9c)

Yield 55 %; React. time: 30 min; m.p. 223-225 °C (ethanol). Anal. Calcd. for $C_{14}H_{13}N_3O_3$ (271.3) C, 61.99; H, 4.83; N, 15.49. Found: C, 62.22; H, 4.89; N, 15.64 %. IR: 3420 (ν/NH), 2910 (ν/CH_3), 1630 (ν/C=O/), 1442 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.47 (s, H, NH); 11.36 (s, 1H, NH); 8.18 (s, 1H, CH); 7.84 (d, 1H, J(5',4') = 3, H-5'); 6.89 (d, 1H,J(3',4') = 3 Hz, H-3'); 6.66 (s, 1H, H-6); 6.64 (d,d, 1H, J(4', 3') = 5.2, J(4',5') = 5.2, H-4'); 2.29 (s, 3H, CH_3); 2.05 (s, 3H, CH_3).

2.32 *N′*-[(Furan-2-yl)methylene]-2-phenyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (9d)

Yield 75 %; React. time: 1 h; m.p. 267-269 °C (ethanol). Anal. Calcd. for$C_{18}H_{13}N_3O_3$ (319.3) C, 67.71; H, 4.10; N, 15.03. Found: C, 67.87; H, 4.14; N, 14.89 %. IR: 3358 (ν/NH), 1635 (ν/C=O/), 1442 (ν/C-N/), 1071 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.65 (s, 1H, NH); 11.48 (s, 1H, NH); 8.62 (s, 1H, CH); 7.84 (d, 1H, J(7",11") = 6, H-7"); 7.82 (d, 1H, J(11",7") = 6, H-11"); 7.70 (s, 1H, H-2'); 7.45-7.2 (m, 4H, H-4', H-8", H-9", H-10"); 7.16-7.14 (m, 2H, H-6, H-3'); 7.04 (s, 1H, H-3).

2.33 *N′*-[(4,5-Dimethylfuran-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (9e)

Yield 42 %; React. time: 30 min; m.p. 216-218 °C (ethanol). Anal. Calcd. for$C_{14}H_{13}N_3O_3$ (271.3) C, 61.99; H, 4.83; N, 15.49. Found: C, 61.75; H, 4.87; N, 15.31 %. IR: 3436 (ν/NH), 2923 (ν/CH_3), 1628 (ν /C=O/), 1433 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.55 (s, 1H, NH); 11.37 (s, 1H, NH); 8.10 (s, 1H, CH); 7.75 (d, 1H, J(2,3) = 2, H-2); 6.97 (s, 1H, H-3'); 6.69 (s, 1H, H-6); 6.60 (d, 1H, J(3,2) = 2, H-3); 2.27 (s, 3H, CH_3); 1.95 (s, 3H, CH_3).

2.34 *N′*-[(4,5-Dimethylfuran-2-yl)methylene]-2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (9f)

Yield 45 %; React. time: 1 h; m.p. 249-251 °C (ethanol). Anal. Calcd. for$C_{15}H_{15}N_3O_3$ (285.3) C, 63.15; H, 5.30; N, 14.73. Found: C, 63.37; H, 5.35; N, 14.57 %. IR: 3446 (ν/NH), 2916 (ν/CH_3), 1624 (ν/C=O/), 1429 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.43 (s, 1H, NH); 11.24 (s, 1H, NH); 8.07 (s, 1H, CH); 6.86 (s, 1H, H-3'); 6.68 (s, 1H, H-6); 6.25 (s, 1H, H-3); 2.25 (s, 3H, CH_3); 2.23 (s, 3H, CH_3); 1.92 (s, 3H, CH_3).

2.35 *N*′-[(4,5-Dimethylfuran-2-yl)methylene]-2,3-dimethyl-4*H*-furo[3,2-*b*] pyrrole-5-carboxhydrazide (9g)

Yield 56 %; React. time: 1 h; m.p. 235-237 °C (ethanol). Anal. Calcd. for $C_{16}H_{17}N_3O_3$ (299.3) C, 64.20; H, 5.72; N, 14.04. Found: C, 64.37; H, 5.67; N, 14.31 %. IR: 3440 (ν/NH), 2921 (ν/CH_3), 1630 (ν/C=O/), 1425 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.41 (s, 1H, NH); 11.28 (s, 1H, NH); 8.03 (s, 1H, CH); 6.82 (s, 1H, H-3'); 6.65 (s, 1H, H-6); 2.16 (s, 3H, CH_3); 2.15 (s, 3H, CH_3); 2.05 (s, 3H, CH_3); 1.99 (s, 3H, CH_3).

2.36 *N*′-[(4,5-Dimethylfuran-2-yl)methylene]-2-phenyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (9h)

Yield 78 %; React. time: 1 h; m.p. 288-290 °C (ethanol). Anal. Calcd. for $C_{20}H_{17}N_3O_3$ (347.4) C, 69.15; H, 4.93; N, 12.10. Found: C, 69.38; H, 4.89; N, 12.33 %. IR: 3395 (ν/NH), 2922 (ν/CH_3), 1645 (ν/C=O/), 1425 (ν/C-N/), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.47 (s, 1H, NH); 11.26 (s, 1H, NH); 8.02 (s, 1H, CH); 7.69–7.57 (m, 5H, H-7", H-8", H-9", H-10", H-11"); 6.86 (s, 1H, H-3'); 6.67 (s, 1H, H-6); 6.27 (s, 1H, H-3); 2.26 (s, 3H, CH_3); 1.99 (s, 3H, CH_3).

2.37 *N*′-[(Thiophen-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (10a)

Yield 65 %; React. time: 20 min; m.p. 235-238 °C (ethanol). Anal. Calcd. for $C_{12}H_9N_3O_2S$ (259.3) C, 55.59; H, 3.50; N, 16.21. Found: C, 55.84; H, 3.54; N, 16.45 %. IR: 3370 (ν/NH), 1640 (ν/C=O/), 1430 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.49 (s, 1H, NH); 11.54 (s, 1H, NH); 7.77 (d, 1H, J(2,3) = 2.4, H-2); 7.67 (d, 1H, J(5',4') = 5.4, H-5'); 7.46 (d, 1H, J(3',4') = 3.6, H-3'); 7.16 (d,d, 1H, J(4',3') = 3.6 Hz, J(4',5') = 3.6 Hz, H-4'); 7.01 (s, 1H, H-6); 6.61 (d, 1H,J(3,2) = 2.1, H-3).

2.38 *N*′-[(Thiophen-2-yl)methylene]-2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (10b)

Yield 59 %; React. time: 30 min; m.p. 244-247 °C (ethanol). Anal. Calcd. for $C_{13}H_{11}N_3O_2S$ (273.3) C, 57.13; H, 4.06; N, 15.37. Found: C, 57.28; H, 4.07; N, 15.13 %. IR: 3375 (ν/NH), 2910 (ν/CH_3), 1635 (ν/C=O/), 1420 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.39 (s, 1H, NH); 11.33 (s, 1H, NH); 8.52 (s, 1H, CH); 7.65 (d, 1H, J(5',4') = 5.1, H-5'); 7.43 (d, 1H, J(3',4') = 4.5, H-3'); 7.15 (d,d, 1H, J(4',3') = 3.6, J (4',5') = 3.6, H-4'); 6.94 (s, 1H, H-6); 6.25 (s, 1H, H-3); 2.38 (s, 3H, CH_3).

2.39 *N*′-[(Thiophen-2-yl)methylene]-2,3-dimethyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (10c)

Yield 66 %; React. time: 30 min; m.p. 260-263 °C (ethanol). Anal. Calcd. for $C_{14}H_{13}N_3O_2S$ (287.3) C, 58.52; H, 4.56; N, 14.62. Found: C, 58.34; H, 4.61; N, 14.83 %. IR: 3416 (ν/NH), 2915 (ν/CH_3), 1635 (ν/C=O/), 1426 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.45 (s, 1H, NH); 11.38 (s, 1H, NH); 8.50 (s, 1H, CH); 7.65 (d, 1H, J(5',4') = 5.7, H-5'); 7.43 (d, 1H, J(3',4') = 3.6, H-3'); 7.15 (d,d, 1H,J(4', 3') = 3.5, J(4',5') = 3.5, H-4'); 6.91 (s, 1H, H-6); 2.29 (s, 3H, CH_3); 2.06 (s, 3H, CH_3).

2.40 *N*′-[(Thiophen-2-yl)methylene]-2-phenyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (10d)

Yield 66 %; React. time: 30 min; m.p. 294-296 °C (ethanol). Anal. Calcd. for $C_{18}H_{13}N_3O_2S$ (335.4) C, 64.46; H, 3.91; N, 12.53. Found: C, 64.29; H, 3.89; N, 12.35 %. IR: 3418 (ν/NH), 1624 (ν/C=O/), 1446 (ν/C-N/), 1075 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.64 (s, 1H, NH); 11.51 (s, 1H, NH); 8.60 (s, 1H, CH); 7.84 (d, 1H, J(7",11") = 8.7, H-7"); 7.81 (d, 1H, J(11",7") = 8.7, H-11"); 7.68 (d, 1H, J(5',4') = 5.4, H-5'); 7.46-7.41 (m, 3H, H-8", H-9", H-10"); 7.33 (d,d, 1H, J(4', 3') = 3.8, J(4', 5') = 3.8, H-4'); 7.17–7.14 (m, 2H, H-3', H-6); 7.04 (s, 1H, H-3).

2.41 *N*-{4-[(Furan-2-yl)methylene]-5-oxo-2-phenyl-4,5-dihydro-1*H*-imidazol-1-yl}-2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxamide (13a)

The mixture of 2-phenyl-4-[(furan-2-yl)methylene]-1,3-oxazol-5(4*H*)-one (**11a**) (0.24 g, 1.4 mmol), 2-metyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (**1b**) (0.27 g, 1.5 mmol) and catalytic amount of freshly fused potassium acetate in conc. acetic acid (10 ml) was heated at 120 °C for 2 h. After cooling the solid product was filtered off and crystallized (ethanol). Yield 0.13 g (24 %); m.p. 290-292 °C. Anal. Calcd. for $C_{22}H_{16}N_4O_4$ (400.4) C, 65.99; H, 4.03; N, 13.99. Found: C, 66.23; H, 4.08; N, 13.75 %. IR: 3446 (ν/NH), 2923 (ν/CH_3), 1714 (ν/C=O/), 1635 (ν/C=O/), 1445 (ν/C-N/), 1082 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.41 (s, 1H, NH); 11.11 (s, 1H, NH); 8.07 (m, 3H, H-5', H-2", H-6"); 7.62 (d, 1H, J(3',4') = 3.3 Hz, H-3'); 7.59-7.51 (m, 3H, H-3", H-4", H-5"); 7.16 (s, 1H, CH); 6.95 (s, 1H, H-6); 6.84 (d,d, 1H, J(4',3') = 6, J(4',5') = 6, H-4'); 6.25 (s, 1H, H-3); 2.48 (s, 3H, CH_3).

Starting from **12,** compound **13b** was prepared in an analogous fashion.

2.42 *N*-{4-[(Thiophen-2-yl)methylene]-5-oxo-2-phenyl-4,5-dihydro-1*H*-imidazol-1-yl}-2,3-dimethyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxamide (13b)

Yield 71 %; React. time: 2h; m.p. 325-328 °C (ethanol). Anal. Calcd. for $C_{23}H_{18}N_4O_3S$ (430.5) C, 64.17; H, 4.21; N, 13.01. Found: C, 64.39; H, 4.27; N, 13.26 %. IR: 3442 (ν/NH), 2920 (ν/CH_3), 1689 (ν/C=O/), 1632 (ν/C=O/), 1446 (ν/C-N/), 1076 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.50 (s, 1H, NH); 11.10 (s, 1H, NH); 8.08 - 8.02 (m, 3H, H-5', H-2", H-6"); 7.85 (d, 1H, J(3',4') = 4.5, H-3'); 7.72 (s, 1H, CH); 7.52-7.60 (m, 3H, H-3", H-4", H-5"); 7.27 (d,d, 1H, J(4',3') = 5.1, J(4',5') = 5.1, H-4'); 6.92 (s, 1H, H-6); 2.30 (s, 3H, CH_3); 2.03 (s, 3H, CH_3).

2.43 2-Benzoylamino-3-[5-(4-chlorophenyl)furan-2-yl]propenic acid 2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (14a)

The mixture of 2-phenyl-4-[5-(4-chlorophenyl)furan-2-yl)methylene]-1,3-oxazol-5(4*H*)-one (**11b**) (0.49 g, 1.4 mmol), 2-methylfuro[3,2-*b*]pyrrole-5-carboxhydrazide (**1b**) (0.27 g, 1.5 mmol) and freshly fused potassium acetate (0.4 g) in 10 ml conc. acetic acid was heated at 80 °C for 1h. After cooling the solid product was filtered off and crystallized. Yield 0.49 g (67 %); m.p. 300-303 °C (ethanol). Anal. Calcd. for $C_{28}H_{21}ClN_4O_5$ (528.9) C, 63.58; H, 4.00; N, 10.59. Found: C, 63.74; H, 4.04; N, 11.83 %. IR: 3455 (ν/NH), 2895 (ν/CH_3), 1677 (ν/C=O/), 1659 (ν/C=O/), 1634 (ν/C=O/), 1431 (ν/C-N/), 1083 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.19 (s, 1H, NH); 10.16 (s, 1H, NH); 10.03 (s, 1H, NH); 9.95 (s, 1H, NH); 8.17 (d, 1H, J(2",6") = 7.2 , H-2"); 8.14 (d, 1H, J(6",2") = 7.2, H-6"); 7.70-7.57 (m, 3H, H-3", H-4", H-5"); 7.44 (d, 1H, J(7',9') = 9, H-7'); 7.41 (d, 1H, J(9',7') = 9, H-9'); 7.30 (s, 1H, CH); 7.19 (d, 1H, J(6',10') = 9, H-6'); 7.17 (d, 1H, J (10',6') = 9, H-10'); 7.14 (d, 1H, J(4',3') = 3, H-4'); 6.96 (d, 1H, J(3',4') = 3, H-3'); 6.90 (s, 1H, H-6); 6.22 (s, 1H, H-3); 2.36 (s, 3H, CH_3).

Compounds **14b** and **14c** were prepared in analogous fashion.

2.44 2-Benzoylamino-3-[5-(2-bromophenyl)furan-2-yl]propenic acid 4*H*-benzo[4,5]furo[3,2-*b*]pyrrole-5-carboxhydrazide (14b)

Yield 81 %; React. time: 5 h; m.p. 251-253 °C (ethanol). Anal. Calcd. for$C_{31}H_{21}BrN_4O_5$ (608.1) C, 61.10; H, 3.47; N, 9.19. Found: C, 61.34; H, 3.50; N, 9.43 %. IR: 3447 (ν/NH), 1683 (ν/C=O/), 1661 (ν/C=O/), 1631 (ν/C=O/), 1426 (ν/C-N/), 1074 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 12.01 (s, 1H, NH); 10.28 (s, 1H, NH); 10.26 s, 1H (NH); 10.08 s, 1H (NH); 8.15 (d, 1H, J(2",6") = 7.5, H-2"); 8.12 (d, 1H, J(6",2") = 7.5, H-6"); 7.76-7.48 (m, 7H, H-7'–H-10', H-3", H-4", H-5"); 7.33 (s, 1H, CH); 7.30-7.27 (m, 4H, benzo[4,5]); 7.17 (d,d, 1H, J(4',3') = 6, J(4',5') = 6 , H-4'); 7.11 (s, 1H, H-6); 7.02 (d, 1H,J(3',4') = 3.6, H-3').

2.45 2-Benzoylamino-3-(thiophen-2-yl)propenic acid 2,3-dimethyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (14c)

Yield 69 %; React. time: 5 h; m.p. 193-196 °C (ethanol). Anal. Calcd. for $C_{23}H_{20}N_4O_4S$ (448.5) C, 61.59; H, 4.49; N, 12.49. Found: C, 61.81; H, 4.46; N, 12.72 %. IR: 3441 (/NH), 2916 (ν/CH_3), 1670 (ν/C=O/), 1661 (ν/C=O/), 1637 (ν/C=O/), 1445 (ν/C-N/). ^{1}H NMR δ_H DMSO-d_6: 11.28 (s, 1H, NH); 10.08 (s, 1H, NH); 9.89 (s, 2H, NH); 8.12 (d, 1H, J(2",6") = 8.25, H-2"); 8.09 (d, 1H, J (6",2") = 8.25, H-6"); 7.82 (s, 1H, CH); 7.68 (d, 1H, H-5'); 7.60-7.49 (m, 4H, H-3', H-3", H-4", H-5"); 7.14 (d,d, 1H, J(4',3') = 5.1 J(4',5') = 5.1, H-4'); 6.85 (s, 1H, H-6); 2.28 (s, 3H, CH_3); 2.04 (s, 3H, CH_3).

2.46 4-Phenyl-1-(2-methylfuro[3,2-*b*]pyrrole-5-formyl)thiosemicarbazide (16)

The mixture of 2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (**1b**) (0.2 g, 1.12 mmol) and phenylisothiocyanate (**15**) (0.15 g, 1.12 mmol) in ethanol (6 ml) was stirred at room temperature for 20 h and then refluxed for 5 h. The white solid product was filtered off and crystallized. Yield 0.35 g (94 %); m.p. 225-228 °C (ethanol). Anal. Calcd. for $C_{15}H_{14}N_4O_2S$ (314.4) C, 57.31; H, 4.49; N, 17.82. Found: C, 57.55; H, 4.46; N, 17.67 %. IR: 3329 (ν/NH), 2914 (ν/CH_3), 1640 (ν/C=O/), 1422 (ν/C-N/), 1074 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.29 (s, 1H, NH); 10.00 (s, 1H, NH); 9.79s (s, 1H, NH); 9.62 (s, 1H, NH); 7.48-7.11 (m, 5H, H-2', H-3', H-4', H-5', H-6'); 6.85 (s, 1H, H-6); 6.24 (s, 1H, H-3); 2.37 (s, 3H, CH_3).

2.47 4-Phenyl-5-(2-methyl-4*H*-furo[3,2-*b*]pyrrol-5-yl)-1,2,4-triazole-3-thione (17)

Thiosemicarbazide **16** (0.22 g, 0.7 mmol) was refluxed in aqueous sodium hydroxide solution (8 %, 10 ml) for 6 h. The solid product was cooled, filtered and crystallized. Yield 0.05 g (25 %); m.p. 195-198 °C (ethanol). Anal. Calcd. for $C_{15}H_{12}N_4OS$ (296.4) C, 60.79; H, 4.08; N, 18.91. Found: C, 60.62; H, 4.12; N, 18.75 %. IR: 3403 (ν/NH), 2918 (ν/CH_3), 1584 (ν/C=S/), 1447 (ν/C-N/), 1048 (ν/C-H/). ^{1}H NMR δ_H DMSO-d_6: 11.68 (s, 1H, NH); 10.52 (s, 1H, NH); 7.63-7.33 (m, 5H, H-2', H-3', H-4', H-5', H-6'); 6.55 (s, 1H, H-6); 6.29 (s, 1H, H-3); 2.38 (s, 3H, CH_3).

2.48 Microwave Synthesis

- A mixture of furo[3,2-*b*]pyrrole-5-carboxhydrazides **1a** or **1b** (1.21 mmol), 5-R-phenyl-furan-2-carboxaldehydes 2 (R = 4-NO_2, 3-CF_3, 4-Cl, 4-CH_3) (1.21 mmol) and catalytic amount of p-toluenesulfonic acid in ethanol (5 ml) was irradiated in microwave oven at 90 W over a time period as stated in Table 1. The products were isolated and purified in the manner identical to the classical method.

- A mixture of 2,3-dimethylfuro[3,2-*b*]pyrrole-5-carboxhydrazide (**1d**) (1.4 mmol), 2-phenyl-4-[(thiophen-2-yl)methylene]-1,3-oxazol-5(4*H*)-one (**12**) (1.5 mmol) and catalytic amount of p-toluenesulfonic acid in ethanol (5 ml) was irradiated in microwave oven for 11 min (see Table 1). The product was isolated and purified in the same manner as the classical method.

Compound	Classical conditions		MWO reaction	
	Reaction time (min)	Yield (%)	Reaction time (min)	Yield (%)
5a	10	48	3	73
5e	15	32	5	55
5g	30	53	4.5	65
6a	30	66	3	85
6c	50	65	2	90
6e	20	26	5	55
13b	300	69	11	78

Table 1 Comparisons between "classical" and microwave reaction.

2.49 Study of Inhibition of Photosynthetic Electron Transport in Spinach Chloroplasts

Spinach chloroplasts were prepared according to Walker [24]. The effect of the compounds on the inhibition of photosynthetic electron transport (PET) in spinach chloroplasts was investigated spectrophotometrically in the presence of electron acceptor 2,6-dichlorophenol indophenol (DCPIP) (30 μmol.l^{-1}). Before measurements, the chloroplasts were resuspended in phosphate buffer (20 mmol.l^{-1}; pH = 7.2) containing 5 mmol l^{-1} $MgCl_2$ and 15.mmol l^{-1} NaCl. The chlorophyll content in the suspension was adjusted to 30 mg.l^{-1}. Samples were irradiated at 25 ^{o}C with a halogen lamp (250 W) at a distance of 1 dm. A 4 cm water filter was used to prevent overheating of the samples. The PET-inhibitory activity of the compounds studied was expressed in term of IC_{50} values as their negative logarithms thus, corresponding to molar concentrations of inhibitors causing a 50% decrease of oxygen evolution rate (OER) with respect to the untreated control sample. Due to lower aqueous solubility of the compounds studied, these were dissolved in dimethyl sulfoxide. The effect of DMSO on OER in the suspensions of spinach chloroplasts was in the range of experimental error and could be neglected.

2.50 Study of Chlorophyll Content in *Chlorella vulgaris*

The algae *Chlorella vulgaris* were statically cultivated (photoperiod: 16h light / 8h dark; illumination: 5 000 lx; temperature: 23 ± 1 ^{o}C) in liquid cultivation medium (pH = 7.2) [25]. The effect of the compounds applied at seven stepwise increasing concentrations

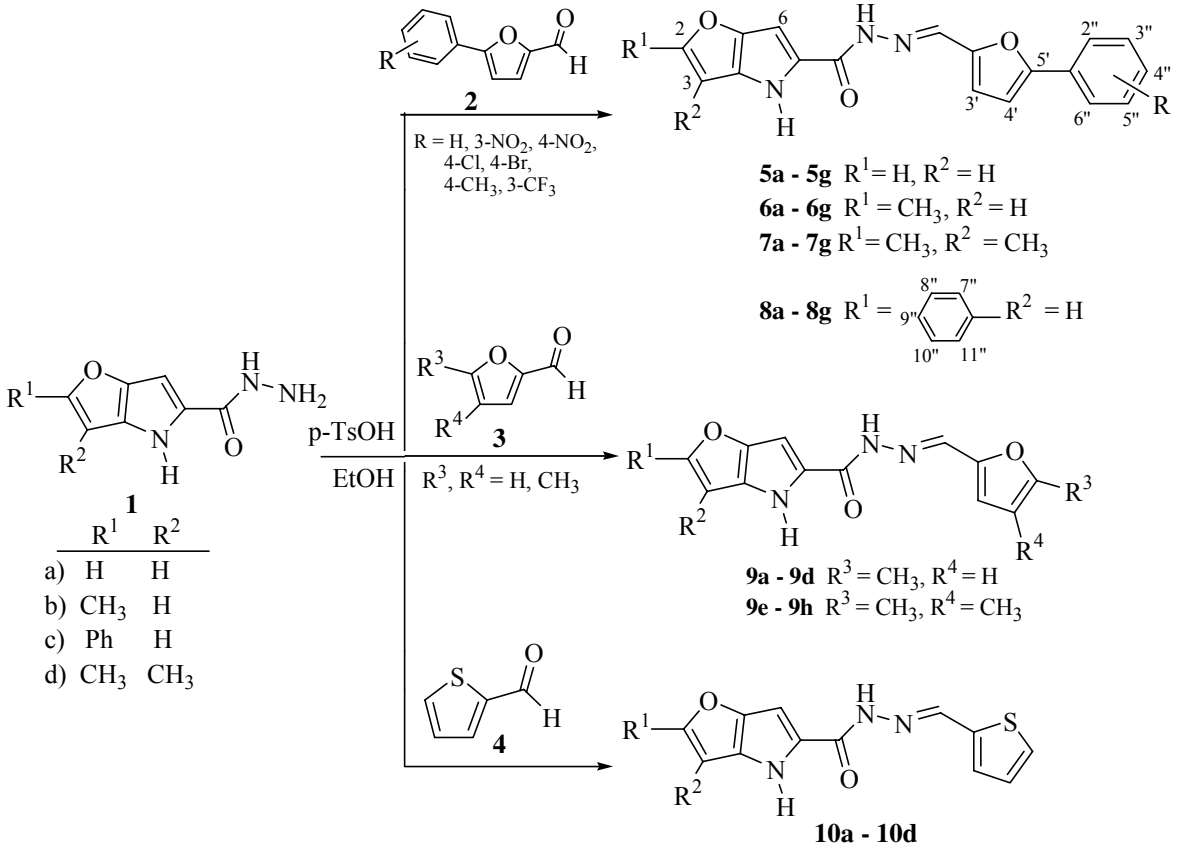
(1, 4.2, 10, 25, 50, 75 a 100 μmol.l^{-1}) on the content of chlorophyll *a*, chlorophyll *b* as well as total chlorophyll content of algal suspension was determined after 7 days of cultivation spectrophotometrically (Kontron Uvikon 800) and after extraction into methanol according to Wellburn [26]. The chlorophyll content in the suspensions at the beginning of cultivation was 0.1 mg.l^{-1}. The effect of the compounds studied and applied in the concentration range 1–100 μmol.l^{-1} on the content of chlorophyll in the suspensions was expressed as the percentage from the corresponding value obtained for the control.

3 Results and discussion

N′-[(6-R^3-Furan-2-yl)methylene]-2-R^1-3-R^2-4-R-furo[3,2-*b*]pyrrole-5-carboxhydrazides **5a** – **9h** and *N*′-[(thiophen-2-yl)methylene]-2-R^1-3-R^2-4-R-furo[3,2-*b*]pyrrole-5-carboxhydrazides **10a** – **10d** were synthesized in 21 – 97 % yields by reaction of **1** with **2** - **4** in ethanol in the presence of p-toluenesulfonic acid by heating at 60°C for 10 min – 1h (Scheme 1). Microwave-assisted reactions of **5a**, **5e**, **5g**, **6a**, **6c** and **6e** were performed using a power output of 90 W. Reaction times were only 2 – 5 min while the yields were comparable or higher (55 -90 %) than those (32 –66 %) achieved in the "classical" synthesis. The ^{1}H NMR spectra of compounds (**5a** – **10d**) displayed signals of H-6 pyrrole protons in the 6.65 – 7.17 ppm range and signals due to CH=N bonded protons in 8.03 – 8.62 ppm range. The chemical shifts and the multiplicity confirmed the proposed structures. The characteristic bands found in IR spectra at 1624 –1650 cm^{-1} corresponding to the C=O group were also observed.

It is known that the reactions of aldehydes with hippuric acid lead to 1,3-oxazol-5(4*H*)-one derivatives [27,28], which serve as the precursors of amino acids [29] or as convenient reagents for synthesis of new heterocycles [30]. Nálepa and co-workers [31] described synthesis of 1-arylamino-substituted imidazol-5(4*H*)-ones by treatment of substituted 4-aryliden-2-phenyl-1,3-oxazol-5(4*H*)-ones with substituted phenylhydrazines. This reaction is a convenient route to new heterocycles, bearing 1,3-imidazole moiety. Therefore, we investigated the reaction of 5-substituted furan or thiophene derived 1,3-oxazol-5(4*H*)-ones, **11a-11c** and **12,** with substituted furo[3,2-*b*]pyrrole-5-carboxhydrazides **1b**, **1d** and **1e**. When 2-phenyl-4-[(5-R-furan-2-yl)methylene]-1,3-oxazol-5(4*H*)-ones **11b**, **11c** or 2-phenyl-4-[(thiophen-2-yl)methylene]-1,3-oxazol-5(4*H*)-one (**12**) were treated with furo[3,2-*b*]pyrrole-5-carboxhydrazides **1b**, **1d** or **1e** in acetic acid in the presence of a catalytic amount of fused potassium acetate at 80 °C for 1-5 h, diacylhydrazines **14a-14c** were obtained in moderate yields (67-81 %) (Scheme 2). On the other hand when the reaction mixture was heated at a higher temperature of 120°C for 2 h, imidazoles **13a** or **13b** were obtained in 24 and 71 % yields, respectively. Microwave-assisted reaction of 2,3-dimethylfuro[3,2-*b*]pyrrole-5-carboxhydrazide **1d** with oxazolone **12**, in the same reaction medium as the "classical" one, gave 78 % of **13b** after 11 min of irradiation.

N′-{4-[(Thiophen-2-yl)methylene]-5-oxo-2-phenyl-4,5-dihydro-1*H*-imidazol-1-yl}-2,3-dimethyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxamide (**13b**) was also prepared in 89 % yield by cyclization of **14c** in acetic acid under reflux for 2 hr in presence of potassium acetate



Scheme 1 The reactions of furo[3,2-*b*]pyrrole-5-carboxhydrazides **1a-1d** with substituted furan-2-carbox- aldehydes **2**, **3** and thiophen-2-carboxaldehyde (**4**).

(Scheme 2). ^{1}H NMR spectra of compounds **13a**, **13b** displayed the signals of H-6 pyrrole protons at 6.92 and 6.95 ppm while the signal of CH=C bonded protons at 7.08 and 7.72 ppm, respectively. The presence of two signals of NH protons in 11.10 - 11.50 ppm range gives evidence of the 1,3-imidazole ring formation. On the other hand, ^{1}H NMR spectra of **14a** − **14c** display four signals corresponding to *N*-bonded protons in 9.89 – 12.01 ppm range which show presence of diacylhydrazine as well as benzoylamino moieties in **14** and thus confirm the proposed structures. Two characteristic bands of C=O groups were found in IR spectra of **13a**, **13b** at 1632 – 1635 cm^{-1} and 1689-1714 cm^{-1} and three bands of C=O for each **14a** – **14c** at 1615 - 1634 cm^{-1}, 1631 – 1659 cm^{-1}and 1661 - 1677cm^{-1}.

1,2,4-Triazole derivatives have been reported to show antifungal, antiparasitic, herbicidal, anti-inflammatory or insecticidal activities [32,33]. This fact led us to synthesize new furo[3,2-*b*]pyrrole-derived 1,2,4-triazole-3-thione **17** (Scheme 2). In the first step, 2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (**1b**) was condensed with phenylisothiocyanate (**15**) in ethanol to give the appropriate thiosemicarbazide **16** in 94 % yield, which was subsequently cyclized to 4-phenyl-5-(2-methyl-4*H*-furo[3,2-*b*]pyrrol-5-yl)-1,2,4-triazole-3-thione (**17**) by refluxing in 8 % aqueous sodium hydroxide solution. ^{1}H NMR

spectrum of **16** displays the signal of H-6 pyrrole proton at 6.85 ppm and four NH protons in the 9.60 – 11.25 ppm range, while only two signals of *N*-bonded protons at 10.52 and 11.68 ppm are observed in ^{1}H NMR spectrum of **17**. The characteristic band of C=O group of **16** was found at 1640 cm^{-1}, while IR spectrum of compound **17** displays band of C=S group at 1574 cm^{-1}.

3.1 Study of inhibition of photosynthetic electron transport in spinach chloroplasts:

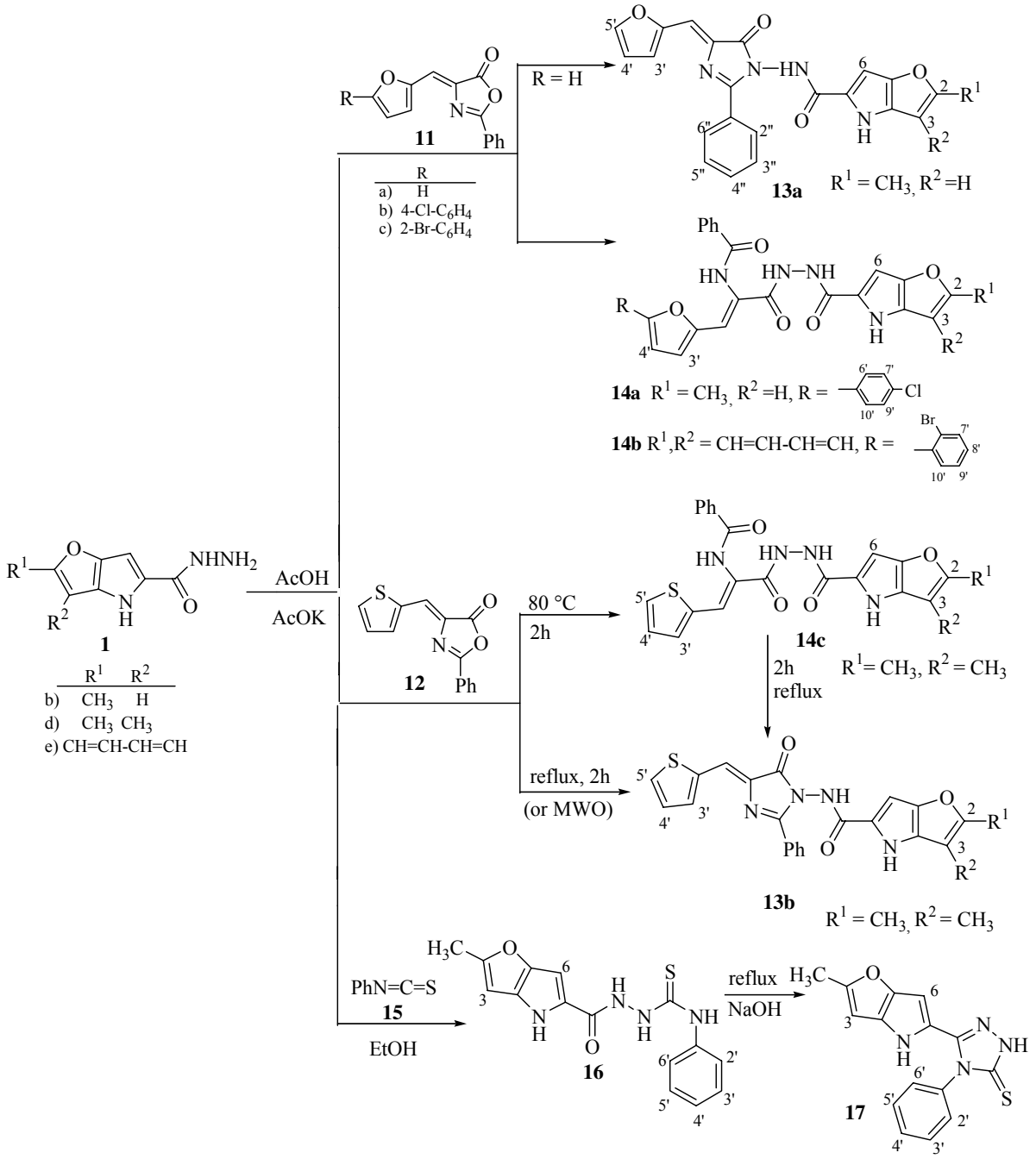
N′-[(5-R-furan-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazides showed relatively low inhibitory effect on photosynthetic electron transport (PET) in spinach chloroplasts (Table 2). The most effective inhibitors were compounds **5c** (R^1= R^2= H, R = 4-Cl), **6c** (R^1= CH_3, R^2= H, R = 4-Cl) and **5d** (R^1= R^2= H, R = 4-Br), indicating that the halogen substituent at position 4 on the benzene ring contributed to the enhanced inhibition of PET by the compounds. As is shown in Figure 1, the inhibitory activity of the compounds with halogen substituent in position 4 on the benzene ring on the sum of π parameters of R^1, R^2 and R substituents decreased with increasing lipophilicity of the compound. The values of π parameters characterizing hydrophobicity of the substituents were taken from Norrington [34].

At comparable lipophilicity the compounds with a halogen substituent at position 4 on the benzene ring showed significantly higher inhibitory activity than the compounds containing 3-NO_2 substituent (Figure 1) thus, demonstrating the importance of the electron acceptor properties of R substituent on PET-inhibitory activity. PET-inhibitory activity is exhibited by many compounds possessing X = C-NH group with an sp^2 hybridized carbon atom (i.e. ureas, triazines, anilides [35,36], etc). Due to formation of hydrogen bonds between this group and the target proteins in photosynthetic centers of thylakoid membranes, changes in protein conformation may occur resulting in inhibition of photosynthetic electron transport [37].

Among the standards, used for testing of herbicidal as well as antialgal activity [39, 40] are 2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine (atrazine), 2-chloro-4,6-bis(ethylamino)-1,3,5-triazine (simazine) or 1-(3,4-dichlorophenyl)-3,3-dimethylurea (diurone). IC_{50}values related to inhibition of photosynthetic electron transport in plant chloroplasts determined for these herbicides that act in the photosystem 2, varied in the range 0.25 – 0.79 μmol.l^{-1}for atrazine, 0.40 – 3.98 μmol.l^{-1} for simazine and 0.032-0.200μ mol.l^{-1} for diurone [38] (see Table 2).

3.2 Study of chlorophyll content in *Chlorella vulgaris*:

In the concentration range (1 – 100 μmol.l^{-1}) the majority of *N*′-[(5-R-furan-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazides only slightly reduced chlorophyll content in statically cultivated algal suspensions of *Chlorella vulgaris* (see Table 3). The most effective inhibitors were compounds **8a** [R^1= Ph, R^2= H, R = 4-NO_2] and **5e** [R^1= H,



Scheme 2 Reactions of furo[3,2-*b*]pyrrole-5-carboxhydrazides **1b**, **1d** or **1e** with oxazolones **11**, **12** leading to carbox- amides **13b** or propenic acid carbohydrazides **14**. Reaction of 2-methyl-4H-furo[3,2-b]pyrrole-5-carboxhydrazide (**1b**) with phenylisothiocyanate (**15**) gave thiosemicarbazide **16**, which was subsequently cyclised to 1,2,4-triazole-3-thione **17**.

R^2= H, R = 3-CF_3]. On the other hand, in the presence of compound **8d** [R^1= Ph, R^2= H, R = 4-Br] statistically significant stimulation of chlorophyll production was observed.

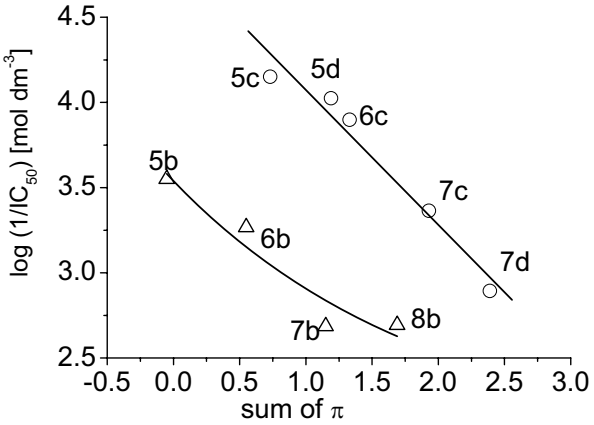


Fig. 1 Dependence of PET-inhibitory activity of the compounds on the sum of π parameters of R^1, R^2 and R substituents for spinach chloroplasts.

Compound	IC_{50} [mmol.l^{-1}]	Compound	IC_{50} [mmol.l^{-1}]	Compound	IC_{50} [mmol.l^{-1}]
5b	0.282	**7b**	2.060	**9d**	0.314
5c	0.071	**7c**	0.432	**9e**	0.518
5d	0.095	**7d**	1.278	**9f**	0.604
5e	0.507	**7f**	0.201	**9g**	0.601
5f	0.201	**8b**	2.028	**9h**	0.173
5g	0.270	**8f**	0.220	**10a**	0.764
6b	0.540	**8g**	0.410	**10b**	0.850
6c	0.127	**9c**	0.883	**10c**	0.531
atrazine	0.00025	**simazine**	0.0004	**diurone**	0.000032

Table 2 Comparison of inhibitory effect of compounds **5-10** and three commonly used standards on photosynthetic electron transport in spinach chloroplasts.

4 Conclusions

(A) Title *N*′-[(5-R-furan-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazides and *N*′-[(thiophen-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazides were synthesized by reaction of appropriate furo[3,2-*b*]pyrrole-5-carboxhydrazides with substituted furan-2-carboxaldehydes or thiophene-2-carboxaldehyde in ethanol in the presence of p-toluenesulfonic acid.

(B) The reaction of 5-substituted furan-2-yl or thiophen-2-yl derived 1,3-oxazol-5(4*H*)-ones **11a** and **12** with substituted furo[3,2-*b*]pyrrole-5-carboxhydrazides **1b, 1d** in acetic acid in the presence of a catalytic amount of fused potassium acetate at 120°C led to imidazoles **13a** or **13b**.

(C) The reaction of 5-substituted furan-2-yl or thiophen-2-yl derived 1,3-oxazol-5(4*H*)-ones **11b, 11c** and **12** with substituted furo[3,2-*b*]pyrrole-5-carboxhydrazides **1b**, **1d** and **1e** in acetic acid in the presence of a catalytic amount of fused potassium acetate at 80 °C gave diacylhydrazines **14a-14c**.

Compound	% control ± S.E. **Chlorophyll *a***	**Chlorophyll *b***	**Chlorophyll *a* + Chlorophyll *b***
5a	87.5 ± 1.6***	87.9 ± 3.3***	87.7 ± 1.5***
5b	93.0 ± 2.6^{ns}	96.0 ± 2.6^{ns}	94.3 ± 2.6^{ns}
5c	88.2 ± 2.2*	91.2 ± .1.7**	89.5 ± 2.0**
5d	92.1 ± 6.5^{ns}	97.2 ± 5.9^{ns}	94.0 ± 6.3^{ns}
5e	83.4 ± 2.2***	89.5 ± 2.0**	85.8 ± 2.0***
6a	85.6 ± 4.5*	87.4 ± 3.8**	86.3 ± 4.2*
6b	95.0 ± 3.9^{ns}	94.7 ± 2.9^{ns}	94.9 ± 3.5^{ns}
6c	97.3 ± 2.9^{ns}	95.2 ± 2.3^{ns}	96.4 ± 2.6^{ns}
6d	102.5 ± 4.0^{ns}	102.0 ± 4.1^{ns}	102.3 ± 4.0^{ns}
6e	101.4 ± 5.3^{ns}	98.2 ±3.7^{ns}	100.1 ± 4.6^{ns}
7a	87.1 ± 4.8*	88.7 ± 4.2*	87.8 ± 4.5*
7b	97.2 ± 2.5^{ns}	97.7 ± 2.1^{ns}	97.4 ± 2.3^{ns}
7c	91.2 ± 3.4^{ns}	91.2 ± 2.6*	91.2 ± 3.0^{ns}
7d	98.4 ± 4.9^{ns}	99.4 ± 4.0^{ns}	98.8 ± 4.5^{ns}
7e	98.6 ± 2.8^{ns}	97.5 ± 2.0^{ns}	98.2 ± 2.4^{ns}
8a	79.9 ± 5.6**	81.6 ± 5.0**	80.5 ± 5.3**
8b	108.0 ± 2.8*	104.3 ± 2.3^{ns}	106.5 ± 2.5*
8c	92.4 ± 2.2^{ns}	93.2 ± 1.8*	92.7 ± 2.0^{ns}
8d	118.2 ± 3.0***	114.9 ± 3.8**	117.1 ± 3.2***
8e	98.8 ± 3.8^{ns}	95.7 ± 3.8^{ns}	97.6 ± 3.8^{ns}
control	100 ± 3.5	100 ± 1.8	100 ± 2.8

Table 3 The effect of compounds **5 - 8** on chlorophyll content in algal suspensions of *Chlorella vulgaris*. S. E. =standard error; * significant difference at P = 0.05; ** significant difference at P = 0.01; *** significant difference at P = 0.001; ns = non significant.

(D) New furo[3,2-*b*]pyrrole-derived 1,2,4-triazole-3-thione **17** was obtained by two-step reaction. In the first step, 2-methyl-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazide (**1b**) was added to phenylisothiocyanate **15** in ethanol to give appropriate thiosemicarbazide **16**, which was subsequently cyclized to 4-phenyl-5-(2-methyl-4*H*-furo[3,2-*b*]pyrrol-5-yl)-1,2,4-triazole-3-thione (**17**) by refluxing in 8 % sodium hydroxide aqueous solution.

(E) The results of microwave irradiation on reactions when compared with the "classical" conditions, showed that microwave irradiation shortens the reaction time while affording comparable or higher yields.

(F) *N*′-[(5-R-furan-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazides showed relatively low inhibitory effect on the photosynthetic electron transport of spinach chloroplasts. The most effective inhibitors were compounds **5c** (R^1= R^2= H, R = 4-Cl), **6c** (R^1= CH_3, R^2= H, R = 4-Cl) and **5d** (R^1= R^2= H, R = 4-Br), indicating that halogen substituent at position 4 of the benzene ring contributed to the

enhanced inhibitory effect.

(G) *N′*-[(5-R-furan-2-yl)methylene]-4*H*-furo[3,2-*b*]pyrrole-5-carboxhydrazides only slightly reduced chlorophyll content in statically cultivated algal suspensions of *Chlorella vulgaris*. The most effective inhibitors were compounds **8a** [R^1= Ph, R^2= H, R = 4-NO_2] and **5e** [R^1= H, R^2= H, R = 3-CF_3]. On the other hand, in the presence of compound **8d** [R^1= Ph, R^2= H, R = 4-Br] statistically significant stimulation of chlorophyll production was observed.

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