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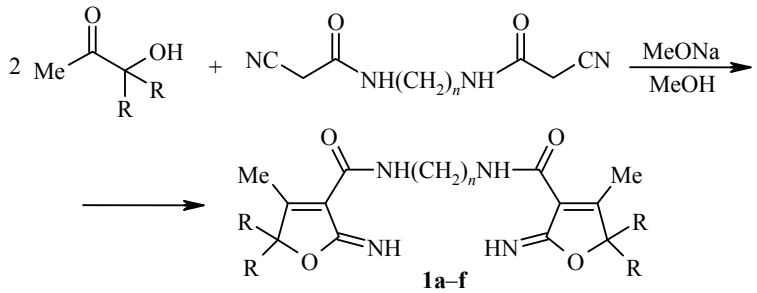
SYNTHESIS AND CHEMICAL TRANSFORMATIONS OF BIS-2-IMINO-2,5-DIHYDROFURANS

The new *N*,*N*'-(alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides) have been synthesized by the condensation of tertiary α-hydroxyketones with *N*,*N*'-(alkanediyl)bis-(2-cyanoacetamides). The obtained products were transformed to corresponding bisiminium chlorides, 2-oxo-, 2-dicyanomethylene and 2-*N*-methylimino derivatives.

Keywords: *N*,*N*'-(alkanediyl)bis(2-cyanoacetamides), *N*,*N*'-(alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides), sodium methoxide, tertiary α-hydroxyketones, condensation.

2-Oxo-2,5-dihydrofuran subunit has been found both in several bioactive natural, synthetic products [1–11] and in a number of drugs with diverse biological activities, such as antifungal, antibacterial, and anti-inflammatory [1, 2, 12–14]. Moreover, 2-oxo-2,5-dihydrofuran derivatives have variety applications in organic synthesis [15–17]. One of the most convenient and common methods of synthesis of functionalized 2-oxo-2,5-dihydrofurans is the condensation of tertiary α-hydroxyketones with compounds containing active methylene group (dimethyl malonate, ethyl cyanoacetate, ethyl acetoacetate) under basic conditions [2, 3, 18]. The condensation of tertiary α-hydroxyketones with other methylene active compounds such as *N*-(alkyl)-2-cyanoacetamides has produced functionalized *N*-(alkyl)-2-imino-2,5-dihydrofuran-3-carboxamides. The hydrolysis of these 2-imino-2,5-dihydrofurans afforded the corresponding 2-oxo-2,5-dihydrofurans [19–23].

With the purpose of synthesis of new derivatives of 2,5-dihydrofurans and to find biologically active compounds among the synthesized structures, we prepared *N*,*N*'-(alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides). For these investigations we used a method involving the condensation of tertiary α-hydroxyketones with *N*-(alkyl)-2-cyanoacetamides [19]. As the result, *N*,*N*'-(alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides) **1a**–**f** were obtained with good yields (Table 1). Cyclization between the hydroxyl group of tertiary α-hydroxyketone and the cyano group of *N*,*N*'-(alkanediyl)bis(2-cyanoacetamides) followed by a Knoevenagel reaction led to final products **1a**–**f**. The ease of ring formation was due to the presence of a *gem*-dialkyl moiety producing a Thorpe–Ingold conformational effect [24–26]. The suggested mechanism is described in literature [19].



1a–**f**

a–**c** R = Me, **d**–**f** R+R = $(CH_2)_5$; **a**, **d** *n* = 2; **b**, **e** *n* = 4; **c**, **f** *n* = 6

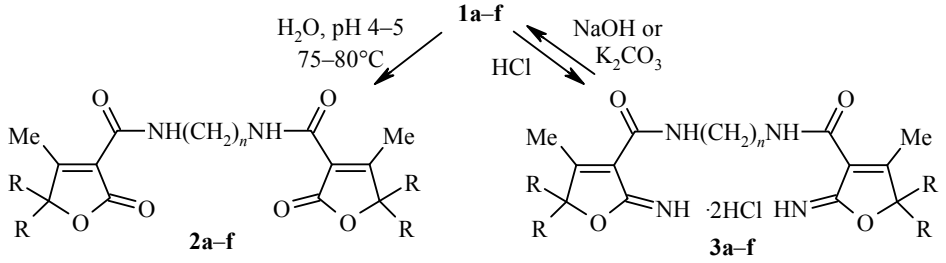
Table 1

The physicochemical characteristics of compounds 1–5 a–f

Compound	Empirical formula	Found, % / Calculated, %				Mp, °C	Yield, %
		C	H	N	Cl		
1a	$C_{18}H_{26}N_4O_4$	59.69 / 59.65	7.28 / 7.23	15.44 / 15.46		190–191	98
1b	$C_{20}H_{30}N_4O_4$	61.54 / 61.52	7.77 / 7.74	14.34 / 14.35		175–177	98
1c	$C_{22}H_{34}N_4O_4$	63.14 / 63.13	8.24 / 8.19	13.41 / 13.39		89–90	98
1d	$C_{24}H_{34}N_4O_4$	65.24 / 65.14	7.78 / 7.74	12.71 / 12.66		230–232	88
1e	$C_{26}H_{38}N_4O_4$	66.30 / 66.44	8.14 / 8.19	11.91 / 11.95		182–183	94
1f	$C_{28}H_{42}N_4O_4$	67.54 / 67.44	8.58 / 8.49	11.31 / 11.24		151–152	92
2a	$C_{18}H_{24}N_2O_6$	59.39 / 59.33	6.71 / 6.64	7.72 / 7.69		220–222	83
2b	$C_{20}H_{28}N_2O_6$	61.24 / 61.21	7.17 / 7.19	7.18 / 7.14		141–142	89
2c	$C_{22}H_{32}N_2O_6$	62.87 / 62.84	7.71 / 7.67	6.67 / 6.66		130–131	89
2d	$C_{24}H_{32}N_2O_6$	64.87 / 64.85	7.28 / 7.26	6.35 / 6.30		253–255	90
2e	$C_{26}H_{36}N_2O_6$	66.17 / 66.08	7.74 / 7.68	5.96 / 5.93		143–145	85
2f	$C_{28}H_{40}N_2O_6$	67.24 / 67.18	8.11 / 8.05	5.67 / 5.60		142–143	85
3a	$C_{18}H_{28}Cl_2N_4O_4$	49.69 / 49.66	6.49 / 6.48	12.94 / 12.87	16.34 / 16.29	207–212	97
3b	$C_{20}H_{32}Cl_2N_4O_4$	51.89 / 51.84	6.99 / 6.96	12.14 / 12.09	15.33 / 15.30	197–203	98
3c	$C_{22}H_{36}Cl_2N_4O_4$	53.84 / 53.77	7.44 / 7.38	11.45 / 11.40	14.52 / 14.43	240–245	98
3d	$C_{24}H_{36}Cl_2N_4O_4$	55.94 / 55.92	7.28 / 7.04	10.91 / 10.87	13.82 / 13.76	220–225	97
3e	$C_{26}H_{40}Cl_2N_4O_4$	57.46 / 57.45	7.44 / 7.42	10.33 / 10.31	13.06 / 13.05	209–213	97
3f	$C_{28}H_{44}Cl_2N_4O_4$	58.86 / 58.84	7.74 / 7.76	9.83 / 9.80	12.41 / 12.41	224–226	97
4a	$C_{24}H_{24}N_6O_4$	62.64 / 62.60	5.28 / 5.25	18.24 / 18.25		196–197	97
4b	$C_{26}H_{28}N_6O_4$	63.94 / 63.92	5.80 / 5.78	17.24 / 17.20		305–307	98
4c	$C_{28}H_{32}N_6O_4$	65.14 / 65.10	6.27 / 6.24	16.29 / 16.27		129–131	94
4d	$C_{30}H_{32}N_6O_4$	66.64 / 66.65	5.97 / 5.97	15.59 / 15.55		158–160	93
4e	$C_{32}H_{36}N_6O_4$	67.62 / 67.59	6.37 / 6.38	14.79 / 14.78		208–210	94
4f	$C_{34}H_{40}N_6O_4$	68.45 / 68.43	6.78 / 6.76	14.09 / 14.08		193–195	94
5a	$C_{20}H_{30}N_4O_4$	61.54 / 61.52	7.78 / 7.74	14.34 / 14.35		93–95	95
5b	$C_{22}H_{34}N_4O_4$	63.14 / 63.13	8.18 / 8.19	13.41 / 13.39		136–137	91
5c	$C_{24}H_{38}N_4O_4$	64.54 / 64.55	8.59 / 8.58	12.56 / 12.55		144–145	91
5d	$C_{26}H_{38}N_4O_4$	66.37 / 66.36	8.16 / 8.14	11.94 / 11.91		182–183	92
5e	$C_{28}H_{42}N_4O_4$	67.45 / 67.44	8.50 / 8.49	11.25 / 11.24		107–109	96
5f	$C_{30}H_{46}N_4O_4$	68.44 / 68.41	8.81 / 8.80	10.65 / 10.64		127–129	95

The structures of synthesized carboxamides **1a**–**f** were determined by spectral data and chemical transformations. The IR, ^{1}H and ^{13}C NMR spectroscopic data are in agreement with the proposed structures. The IR spectra showed bands of C=N and =N–H as well C=C and C=O groups. The ^{1}H NMR spectra exhibited singlet identified as C=NH proton (Table 2). The chemical shifts values in ^{13}C NMR spectra confirmed the formation of *N*,*N*'-(alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides).

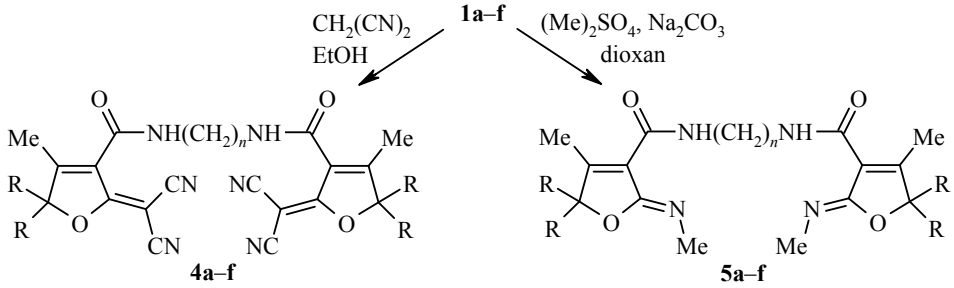
The readily treatment of products **1a**–**f** by aqueous hydrochloric acid led to the hydrolysis of the imino groups affording the corresponding 2-oxocarboxamides **2a**–**f**. The C=N absorptions of the imino group observed in the IR spectra are at lower wave numbers than C=O absorptions of the lactone (Table 2).



2, **3** **a**–**c** R = Me, **d**–**f** R+R = $(CH_2)_5$; **a**, **d** *n* = 2; **b**, **e** *n* = 4; **c**, **f** *n* = 6

N,*N*'-(Alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides) **1a**–**f** readily formed bisiminium salts **3a**–**f** upon passing gaseous hydrogen chloride through benzene solution of compounds **1a**–**f**. Bisiminium salts **3a**–**f** are water-soluble compounds that can be readily titrated by alkali solution (0.1N NaOH) and are easily transformed to the initial 2-iminocarboxamides **1a**–**f** upon treatment with potassium carbonate.

The condensation of compounds **1a**–**f** with malononitrile in ethanol afforded the bis[2-(dicyanomethylene)-2,5-dihydrofurans] **4a**–**f** while treatment by dimethyl sulfate in the presence of sodium carbonate in dioxane led to the methylation of the imino group affording corresponding bis(*N*-methyl)-2,5-dihydrofurans **5a**–**f**.



4, **5** **a**–**c** R = Me, **d**–**f** R+R = $(CH_2)_5$; **a**, **d** *n* = 2; **b**, **e** *n* = 4; **c**, **f** *n* = 6

The obtained compounds **1**–**5** **a**–**f** were tested for antibacterial activity. As shown by preliminary investigations conducted at the Chemotherapy Laboratory, A. L. Mndzhoyan Institute of Fine Organic Chemistry, National Academy of Sciences of the Republic of Armenia, these compounds have moderately well defined antibacterial activity *in vitro*, making it expedient to conduct further investigations in this field.

Table 2

Spectral characteristics of the obtained compounds

Compound	IR spectrum,* ν, cm^{-1}	^1H NMR spectrum, δ, ppm (*J*, Hz)	^{13}C NMR spectrum, δ, ppm
1	2	3	4
1a	3300 (NH), 3140 (NH), 1645 (C=N)	1.49 (12H, s, $4CH_3$); 2.42 (6H, s, $2CH_3C$=C); 3.42–3.48 (4H, m, $2CH_2$); 7.23 (2H, s, 2C=NH); 8.20 (2H, t, *J* = 5.5, 2NH)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 41.6 ($2CH_2$); 87.28 (2C-5); 118.9 (2C-3); 162.3 (2C-4); 166.3 (2C=NH); 170.8 (2C=O)
1b	3300 (NH), 3140 (NH), 1640 (C=N)	1.49 (12H, s, $4CH_3$); 1.59–1.64 (4H, m, $CH_2C\underline{H_2}C\underline{H_2}CH_2$); 2.43 (6H, s, $2CH_3C$=C); 3.28–3.34 (4H, m, $2NHC\underline{H_2}$), 7.24 (2H, s, 2C=NH); 8.08 (2H, t, *J* = 5.9, $2N\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 40.1 ($2CH_2$); 41.7 ($2CH_2$); 87.3 (2C-5); 118.9 (2C-3); 162.3 (2C-4); 166.3 (2C=NH); 170.9 (2C=O)
1c	3300 (NH), 3145 (NH), 1640 (C=N)	1.49 (12H, s, $4CH_3$); 1.61–1.72 (8H, m, $CH_2(C\underline{H_2})_4CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.24–3.28 (4H, m, $2NHC\underline{H_2}$); 7.24 (2H, s, 2C=NH); 8.06 (2H, t, *J* = 6.5, $2N\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 40.1 ($4CH_2$); 41.7 ($2CH_2$); 87.7 (2C-5); 118.9 (2C-3), 162.3 (2C-4); 166.3 (2C=NH); 170.9 (2C=O)
1d	3280 (NH), 3145 (NH), 1650 (C=N)	1.29–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.84 (8H, m, $2C_5H_{10}$); 2.42 (6H, s, $2CH_3C$=C); 3.42–3.46 (4H, m, $2NHC\underline{H_2}$); 7.23 (2H, s, 2C=NH); 8.20 (2H, t, *J* = 5.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 41.6 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 162.4 (2C-4); 166.4 (2C=NH); 170.9 (2C=O)
1e	3300 (NH), 3150 (NH), 1645 (C=N)	1.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.63–1.86 (12H, m, $2C_5H_{10}$, $CH_2C\underline{H_2}C\underline{H_2}CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.42–3.46 (4H, m, $2NHC\underline{H_2}$); 7.23 (2H, s, 2C=NH); 8.20 (2H, t, *J* = 5.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 40.1 ($2CH_2$); 41.6 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 162.4 (2C-4); 166.4 (2C=NH); 170.9 (2C=O)
1f	3300 (NH), 3145 (NH), 1650 (C=N)	1.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.89 (16H, m, $2C_5H_{10}$, $CH_2(C\underline{H_2})_4CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.24–3.28 (4H, m, $2NHC\underline{H_2}$); 7.24 (2H, s, 2C=NH); 8.06 (2H, t, *J* = 6.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 40.1 ($4CH_2$); 41.7 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 162.4 (2C-4); 166.4 (2C=NH); 170.9 (2C=O)
2a	3280 (NH), 1760 (C=O lactone)	1.49 (12H, s, $4CH_3$); 2.42 (6H, s, $2CH_3C$=C); 3.44–3.48 (4H, m, $2CH_2$); 8.22 (2H, t, *J* = 5.5, $2N\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 41.6 ($2CH_2$); 87.3 (2C-5); 118.9 (2C-3); 161.3 (2C-4); 170.9 (2C=O); 176.7 (2C(2)=O)
2b	3280 (NH), 1755 (C=O lactone)	1.49 (12H, s, $4CH_3$); 1.60–1.64 (4H, m, $CH_2C\underline{H_2}C\underline{H_2}CH_2$); 2.45 (6H, s, $2CH_3C$=C); 3.30–3.34 (4H, m, $2NHC\underline{H_2}$); 8.10 (2H, t, *J* = 5.9, $2N\underline{H}CH_2$)	11.7 ($2CH_3$); 24.12 ($4CH_3$); 40.1 ($2CH_2$); 41.66 ($2CH_2$); 87.3 (2C-5); 118.9 (2C-3); 161.3 (2C-4); 170.9 (2C=O); 176.7 (2C(2)=O)
2c	3280 (NH), 1755 (C=O lactone)	1.49 (12H, s, $4CH_3$); 1.61–1.72 (8H, m, $CH_2(C\underline{H_2})_4CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.24–3.28 (4H, m, $2NHC\underline{H_2}$); 7.24 (2H, s, 2C=NH); 8.06 (2H, t, *J* = 6.5, $2NHCH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 40.1 ($4CH_2$); 41.7 ($2CH_2$); 87.3 (2C-5); 118.9 (2C-3); 161.3 (2C-4); 170.9 (2C=O); 176.7 (2C(2)=O)

End of Table 2

1	2	3	4
2d	3280 (NH), 1750 (C=O lactone)	1.29–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.84 (8H, m, $2C_5H_{10}$); 2.44 (6H, s, $2CH_3C$=C); 3.43–3.47 (4H, m, 2NHC$\underline{H}_2$); 8.22 (2H, t, J = 5.5, 2N$\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 41.6 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 161.3 (2C-4); 170.9 (2C=O); 176.7 (2C(2)=O)
2e	3280 (NH), 1760 (C=O lactone)	1.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.63–1.86 (12H, m, $2C_5H_{10}$, $CH_2C\underline{H}_2C\underline{H}_2CH_2$); 2.44 (6H, s, $2CH_3C$=C); 3.42–3.46 (4H, m, 2NHC$\underline{H}_2$); 8.24 (2H, t, J = 5.5, 2N$\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 40.1 ($2CH_2$); 41.6 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 161.3 (2C-4); 170.9 (2C=O); 176.7 (2C(2)=O)
2f	3280 (NH), 1755 (C=O lactone)	1.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.89 (16H, m, $2C_5H_{10}$, $CH_2(C\underline{H}_2)_4CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.22–3.27 (4H, m, 2NHC$\underline{H}_2$); 8.08 (2H, t, J = 6.5, 2N$\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 40.1 ($4CH_2$); 41.7 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 161.4 (2C-4); 170.9 (2C=O); 176.77 (2C(2)=O)
3a		1.49 (12H, s, $4CH_3$); 2.42 (6H, s, $2CH_3C$=C); 3.42–3.47 (4H, m, $2CH_2$); 8.20 (2H, t, J = 5.5, 2N$\underline{H}CH_2$); 10.44 (4H, br. s, 2NH·HCl)	
3b		1.49 (12H, s, $4CH_3$); 1.60–1.64 (4H, m, $CH_2C\underline{H}_2C\underline{H}_2CH_2$); 2.43 (6H, s, $2CH_3C$=C); 3.30–3.34 (4H, m, 2NHC$\underline{H}_2$); 8.08 (2H, t, J = 5.9, 2N$\underline{H}CH_2$); 10.40 (4H, br. s, 2NH·HCl)	
3c		1.49 (12H, s, $4CH_3$); 1.61–1.72 (8H, m, $CH_2(C\underline{H}_2)_4CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.24–3.27 (4H, m, 2NHC$\underline{H}_2$); 8.06 (2H, t, J = 6.5, 2N$\underline{H}CH_2$); 10.38 (4H, br. s, 2NH·HCl)	
3d		11.29–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.84 (8H, m, $2C_5H_{10}$); 2.42 (6H, s, $2CH_3C$=C); 3.42–3.46 (4H, m, 2NHC$\underline{H}_2$); 8.20 (2H, t, J = 5.5, 2N$\underline{H}CH_2$); 10.40 (4H, br. s, 2NH·HCl)	
3e		1.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.63–1.86 (12H, m, $2C_5H_{10}$, $CH_2C\underline{H}_2C\underline{H}_2CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.42–3.47 (4H, m, 2NHC$\underline{H}_2$); 8.21 (2H, t, J = 5.5, 2N$\underline{H}CH_2$); 10.42 (4H, br. s, 2NH·HCl)	
3f		11.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.89 (16H, m, $2C_5H_{10}$, $CH_2(C\underline{H}_2)_4CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.24–3.27 (4H, m, 2NHC$\underline{H}_2$); 8.26 (2H, t, J = 6.5, 2N$\underline{H}CH_2$); 10.44 (4H, br. s, 2NH·HCl)	
4a		1.49 (12H, s, $4CH_3$); 2.42 (6H, s, $2CH_3C$=C); 3.43–3.48 (4H, m, $2CH_2$); 8.20 (2H, t, J = 5.5, 2N$\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 41.6 ($2CH_2$); 46.0 (2$\underline{C}$=C(2)); 87.3 (2C-5); 115.1 (4CN); 118.9 (2C-3); 162.3 (2C-4); 166.2 (2C-2); 170.9 (2C=O)
4b		1.49 (12H, s, $4CH_3$); 1.60–1.64 (4H, m, $CH_2C\underline{H}_2C\underline{H}_2CH_2$); 2.45 (6H, s, $2CH_3C$=C); 3.30–3.34 (4H, m, 2NHC$\underline{H}_2$); 8.18 (2H, t, J = 5.9, 2N$\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 40.1 ($2CH_2$); 41.7 ($2CH_2$); 46.0 (2$\underline{C}$=C(2)); 87.3 (2C-5); 115.1 (4CN); 118.9 (2C-3); 162.3 (2C-4); 166.3 (2C-2); 170.9 (2C=O)

4c		1.49 (12H, s, $4CH_3$); 1.61–1.72 (8H, m, $CH_2(C\underline{H}_2)_4CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.26 (4H, m, $2NHC\underline{H}_2$); 8.16 (2H, t, *J* = 6.5, $2N\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 40.1 ($4CH_2$); 41.7 ($2CH_2$); 46.0 (2<u>C</u>=C(2)); 87.3 (2C-5); 115.1 (4CN); 118.9 (2C-3); 162.3 (2C-4); 166.3 (2C-2); 170.9 (2C=O)
4d		1.29–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.84 (8H, m, $2C_5H_{10}$); 2.42 (6H, s, $2CH_3C$=C); 3.42–3.47 (4H, m, $2NHC\underline{H}_2$); 8.22 (2H, t, *J* = 5.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 41.6 ($2CH_2$); 46.0 (2<u>C</u>=C(2)); 88.7 (2C-5); 115.1 (4CN); 119.1 (2C-3); 162.4 (2C-4); 166.4 (2C-2); 170.9 (2C=O)
4e		1.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.63–1.86 (12H, m, $2C_5H_{10}$, $CH_2C\underline{H}_2C\underline{H}_2CH_2$); 2.42 (6H, s, $2CH_3C$=C); 3.42–3.47 (4H, m, $2NHC\underline{H}_2$); 8.22 (2H, t, *J* = 5.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 40.1 ($2CH_2$); 41.6 ($2CH_2$); 46.0 (2<u>C</u>=C(2)), 88.7 (2C-5); 115.1 (4CN); 119.1 (2C-3); 162.4 (2C-4); 166.4 (2C-2); 170.9 (2C=O)
4f		1.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.89 (16H, m, $2C_5H_{10}$, $CH_2(C\underline{H}_2)_4CH_2$); 2.40 (6H, s, $2CH_3C$=C); 3.22–3.26 (4H, m, $2NHC\underline{H}_2$); 8.16 (2H, t, *J* = 6.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 40.1 ($4CH_2$); 41.7 ($2CH_2$); 46.0 (2<u>C</u>=C(2)); 88.7 (2C-5); 115.2 (4CN); 119.1 (2C-3); 162.4 (2C-4); 166.4 (2C-2); 170.9 (2C=O)
5a		1.49 (12H, s, $4CH_3$); 2.42 (6H, s, $2CH_3C$=C); 2.98 (6H, s, $2C=NCH_3$); 3.42–3.47 (4H, m, $2CH_2$); 8.20 (2H, t, *J* = 5.5, $2N\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 35.1 ($2NCH_3$); 41.6 ($2CH_2$); 87.3 (2C-5); 118.9 (2C-3); 162.3 (2C-4); 166.3 (2C-2); 170.9 (2C=O)
5b		1.49 (12H, s, $4CH_3$), 1.59–1.64 (4H, m, $CH_2C\underline{H}_2C\underline{H}_2CH_2$); 2.44 (6H, s, $2CH_3C$=C); 2.96 (6H, s, $2C=NCH_3$); 3.30–3.35 (4H, m, $2NHC\underline{H}_2$); 8.12 (2H, t, *J* = 5.9, $2N\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 35.3 ($2NCH_3$); 40.1 ($2CH_2$); 41.7 ($2CH_2$); 87.3 (2C-5); 118.9 (2C-3); 162.3 (2C-4); 166.3 (2C-2); 170.9 (2C=O)
5c		1.49 (12H, s, $4CH_3$); 1.61–1.72 (8H, m, $CH_2(C\underline{H}_2)_4CH_2$); 2.42 (6H, s, $2CH_3C$=C); 2.94 (6H, s, $2C=NCH_3$); 3.24–3.28 (4H, m, $2NHC\underline{H}_2$); 8.16 (2H, t, *J* = 6.5, $2N\underline{H}CH_2$)	11.7 ($2CH_3$); 24.2 ($4CH_3$); 35.2 ($2NCH_3$); 40.1 ($4CH_2$); 41.7 ($2CH_2$); 87.3 (2C-5); 118.9 (2C-3); 162.3 (2C-4); 166.3 (2C-2); 170.8 (2C=O)
5d		1.29–1.33 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.84 (8H, m, $2C_5H_{10}$); 2.42 (6H, s, $2CH_3C$=C); 2.98 (6H, s, $2C=NCH_3$); 3.42–3.47 (4H, m, $2NHC\underline{H}_2$); 8.20 (2H, t, *J* = 5.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 35.2 ($2NCH_3$); 41.6 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 162.4 (2C-4); 166.4 (2C-2); 170.9 (2C=O)
5e		11.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.63–1.86 (12H, m, $2C_5H_{10}$, $CH_2C\underline{H}_2C\underline{H}_2CH_2$); 2.42 (6H, s, $2CH_3C$=C); 2.96 (6H, s, $2C=NCH_3$); 3.42–3.47 (4H, m, $2NHC\underline{H}_2$); 8.18 (2H, t, *J* = 5.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 35.3 ($2NCH_3$); 40.1 ($2CH_2$); 41.6 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 162.43 (2C-4); 166.42 (2C-2); 170.9 (2C=O)
5f		1.25–1.32 (4H, m), 1.50–1.54 (8H, m) and 1.62–1.89 (16H, m, $2C_5H_{10}$, $CH_2(C\underline{H}_2)_4CH_2$); 2.44 (6H, s, $2CH_3C$=C); 2.96 (6H, s, $2C=NCH_3$); 3.26 (4H, m, $2NHC\underline{H}_2$); 8.16 (2H, t, *J* = 6.5, $2N\underline{H}CH_2$)	12.1 ($2CH_3$); 21.2 (4C, β-CH_2); 23.9 (2C, γ-CH_2); 32.4 (4C, α-CH_2); 35.3 ($2NCH_3$); 40.1 ($4CH_2$); 41.7 ($2CH_2$); 88.7 (2C-5); 119.1 (2C-3); 162.43 (2C-4); 166.42 (2C-2); 170.9 (2C=O)

* For compounds **1**, **2 a**–**f**: 1680 (C=O amide), 1620 (C=C).

We have reported here the synthesis of new *N*,*N*'-(alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides) *via* a simple and convenient method by condensation of tertiary α-hydroxyketones with corresponding *N*,*N*'-(alkanediyl)bis-(2-cyanoacetamides) under mild basic conditions. The obtained products were transformed to the respective bisiminium chlorides, 2-oxo-, 2-dicyanomethylene and 2-*N*-methylimino derivatives. Their chemical transformations confirmed that the obtained compounds are iminodihydrofurans and not pyrrolidones [27], which are isomeric to them.

EXPERIMENTAL

IR spectra were recorded on a Specord 75 IR spectrometer. ^{1}H and ^{13}C NMR spectra were recorded on a Varian Mercury-300 VX spectrometer (300 and 75 MHz respectively) in DMSO-d_6–CCl_4, 1:3, using TMS as an internal standard. Elemental analyses (C, H, N) were performed using a Heraeus CHN-O-Rapid analyzer. Melting points were measured with an Electrothermal 9100 apparatus. The purity of synthesized compounds are controlled by TLC (Silufol UV-254, eluent acetone–benzene, 1:2, developed by iodine vapor).

The syntheses of starting tertiary α-hydroxyketones (3-hydroxy-3-methylbutan-2-one, 1-(1-hydroxycyclohexyl)ethanone) were conducted according to known procedures [28]. *N*,*N*'-(ethane(butane, hexane)-1,2(1,4, 1,6)-diyl)bis(2-cyanoacetamides) were prepared by the reaction of ethyl cyanoacetate with diamines [27].

***N*,*N*'-(Alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides) 1a–f**. To a solution of MeONa (0.02 g, 1 mmol) in abs. MeOH (20 ml), a suitable tertiary α-hydroxyketone (10 mmol), and then *N*,*N*'-(alkanediyl)bis-(2-cyanoacetamide) (5 mmol) are added. Te mixture is stirred at room temperature during 10–12 h. The solvent is removed under reduced pressure, and the residue is dissolved in water. The solid precipitate obtained is filtered, washed with water, recrystallized from EtOH.

***N*,*N*'-(Alkanediyl)bis(2-oxo-2,5-dihydrofuran-3-carboxamides) 2a–f**. A solution of compound **1a–f** (3 mmol) in EtOH (3 ml) is added to diluted HCl (pH 4–5, 8 ml). The mixture is heated up to 75–80°C during 3 h, cooled, extracted with Et_2O (3 × 10 ml). The combined organic layers are dried over $MgSO_4$, filtered, and concentrated in vacuum. The obtained solid is recrystallized from petroleum ether.

***N*,*N*'-(Alkanediyl)bis(2-imino-2,5-dihydrofuran-3-carboxamides) dihydrochlorides 3a–f**. A stream of dry gaseous HCl is passed through a solution of compound **1a–f** (1 mmol) in benzene (5 ml) for 15 min. A resulting precipitate is filtered off, washed with Et_2O and dried.

***N*,*N*'-(Alkanediyl)bis[2-(dicyanomethylene)-4,5,5-trimethyl-2,5-dihydrofuran-3-carboxamides] 4a–f**. A mixture of compound **1a–f** (5 mmol) and malononitrile (0.66 g, 10 mmol) in abs. EtOH (10 ml) is stirred at room temperature until ammonia no longer evolves. Evaporation of the solvent gives a residue, which is treated with water. The precipitate is filtered off, washed with water, and recrystallized from hexane–acetone, 2:1.

***N*,*N*'-(Alkanediyl)bis[4,5,5-trimethyl-2-(methylimino)-2,5-dihydrofuran-3-carboxamides] 5a–f**. To a solution of compound **1a–f** (1 mmol) in 10 ml of dioxane, 10 ml of concentrated aqueous solution of Na_2CO_3, and then dimethyl sulfate (0.76 g, 6 mmol) are added. This reaction mixture is stirred at room temperature during 5 h, then 50 ml of H_2O is added, and the stirring is continued for 1 h. The organic layer is separated and unorganic layer is extracted with diethyl ether (3 × 10 ml). Combined organic layers are dried over $MgSO_4$, filtered and concentrated in vacuum. An obtained solid is recrystallized from hexane.

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