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Iminofurans Chemistry: IV.* Synthesis and Structure of 2-*N*-Aryl-Substituted Derivatives of 2-Amino-4-aryl-4-oxobut-2-enoic and 2-Amino-5,5-Dimethyl-4-oxohex-2-enoic Acids

N. M. Igidov[b], A. E. Rubtsov[a], A. V. Tyuneva[a], V. V. Zalesov[a], A. Yu. Borodin[b], and E. V. Bukanova[b]

[a]*Perm State University, Perm, 614990 Russia,*
e-mail: Aleksandr.Rubtsov@psu.ru
[b] *Perm State Pharmaceutical Academy, Perm, Russia*

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Abstract—Reactions of arylamines with 4-aryl-2-hydroxy-4-oxobut-2-enoic and 2-hydroxy-5,5-dimethyl-4-oxohex-2-enoic acids gave rise to 4-aryl-2-arylamino-4-oxobut-2-enoic and 2-aryl-amino-5,5-dimethyl-4-oxohex-2-enoic acids that existed in solutions as *Z*- and *E*-isomers or in a ring form as 3-arylamino-5-*tert*-butyl-5-hydroxyfuran-2(5H)-ones. The probable cyclization mechanism of these compounds into 5-R-3-arylimino-3*H*-furan-2-one derivatives was considered.

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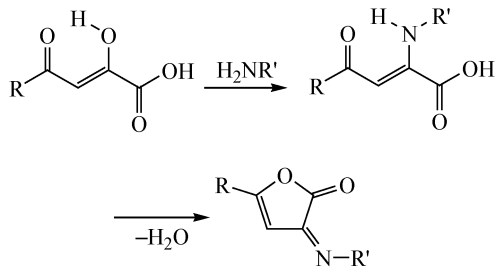
We showed formerly that N-substituted 2-amino-4-aryl-4-oxobut-2-enoic acids under the treatment with acetic anhydride underwent a cyclization into N-substituted 5-aryl-3-imino-3*H*-furan-2-ones [2]. The synthetic method proved to be fairly general, and using it we prepared a wide range of iminofuranones with various substituents both at the imine nitrogen and in the position *5* of the furan ring. However in some events we failed to isolate iminofurans either because the initial acids did not undergo cyclization under the reaction conditions or since the formed iminofuranones were very labile compounds.



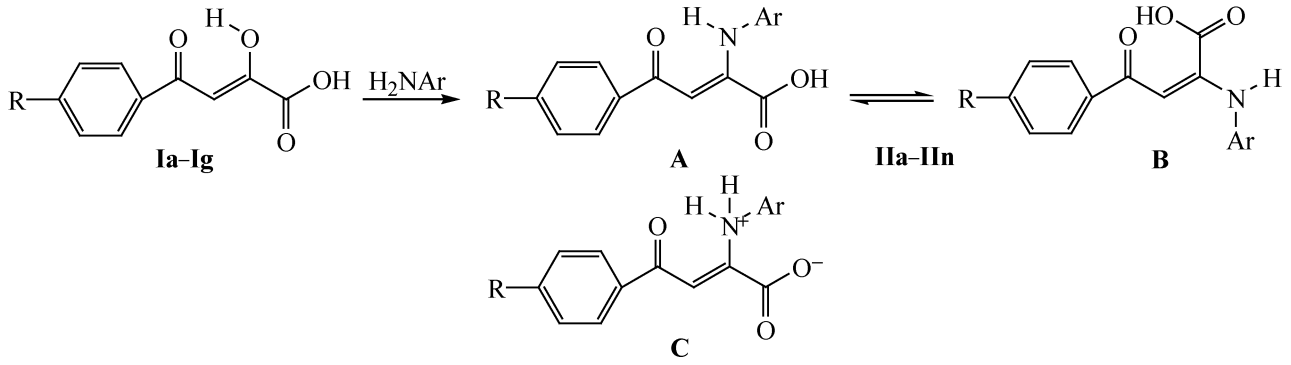
The investigation of the cyclization mechanism of acids **II** into iminofuranones requires not only elucidation of the factors governing this process but first of all the establishment of the fine structure of acids **II**. To this end we synthesized a series of previously unknown N-substituted 2-amino-4-aryl-4-oxobut-2-enoic acids **IIa–IIn** and N-substituted 2-amino-5,5-dimethyl-4-oxohex-2-enoic acids **IIIa–IIIk**. The choice of the amino compounds was not only based on the chemical targets but also on the possibility to obtain biologically active substances proceeding from 4-aryl-2-hydroxy-4-oxobut-2-enoic acids (aroylpyruvic acids) **Ia–Ig** [3–7] and 2-hydroxy-5,5-dimethyl-4-oxohex-2-enoic acid.

First from acids **Ia–Ig** and aromatic amines N-aryl derivatives of 2-amino-4-aryl-4-oxobut-2-enoic acids **IIa–IIn** were obtained in 63–91% yields. Compound **IIj** obtained in 44% yield was an exclusion (Scheme 1).

In the IR spectra of compounds **IIa–IIn** recorded from mulls in mineral oil a pronounced absorption band of NH group was observed in the region 3192–3256 cm^{-1} (compounds **IIa–IId, IIh–IIk, IIm, IIn**); in some compounds appeared a plateau in the region 3100–3150 cm^{-1} (compounds **IIf** and **III**)] or this band was totally absent (compounds **IIe** and **IIg**). The absorption band of the carboxy group of compounds **IIa, IIb, IIe**, **IIf, IIg** was present in the region 1700–1731 cm^{-1}, and the strong combined band of the stretching vibrations of the ester

* For communication III, see [1].

Scheme 1.



I, R = H (**a**), F (**b**), Br (**c**), Cl (**d**), Me (**e**), MeO (**f**), EtO (**g**); **II**, R = H, Ar = 2,4-$Me_2C_6H_3$ (**a**), 2,6-$Me_2C_6H_3$ (**b**), 2,4,6-$Me_3C_6H_2$ (**c**), 3-$CF_3C_6H_4$ (**d**), 2-Me-5-$NO_2C_6H_3$ (**e**), 4-$Et_2N(CH_2)_2OOCC_6H_4$ (**f**); R = Me, Ar = 2-Me-5-$NO_2C_6H_3$ (**g**); Ar = 4-$EtOOCC_6H_4$, R = H (h), F (**i**), Br (**j**), Cl (**k**), Me (**l**), MeO (**m**), EtO (**n**).

and the carboxy groups of compounds **IIf, IIh, IIj, IIk, IIm, IIn** was observed in the region 1711–1729 cm^{-1}. Compounds **IIi** and **III** formed an exclusion, since in their IR spectra individual bands were present corresponding to the stretching vibrations of the ester and the carboxy groups in the region 1709, 1707 and 1727, 1726 cm^{-1}. Besides in the IR spectra of compounds **IIc** and **IId** the absorption band of the carboxy group was absent but a shoulder was present in the region 1645 and 1661 cm^{-1} respectively, presumably because these compounds existed in the form **C**.

We studied the ^{1}H NMR spectra of compounds **IIa–IIn** and established that compounds **IId, IIe, IIj, III**, and **IIn** possessing electron-withdrawing substituents in the aromatic ring linked to the nitrogen atom existed in the DMSO-d_6 solution in one enamino-ketone form as *Z*-isomer (form **A**) as confirmed by the presence of one singlet from a vinyl proton at 6.53– 7.03 ppm and a proton signal from the NH group at 11.72–11.81 ppm. In contrast, as showed the ^{1}H NMR spectra, compounds **IIa–IIc** containing only electron-donor substituents at the aromatic ring existed in DMSO-d_6 in the form of two enamino-ketone isomers: **A** (*Z*-isomer) and **B** (*E*-isomer), the content of *Z*-isomer varying in the range 50–100%. The proton signal of the NH group of the *Z*-isomer of compounds **IIb** and **IIc** appeared at 11.54–11.98 ppm. We failed to find in the spectra the signal of the OH group proton apparently due to significant broadening.

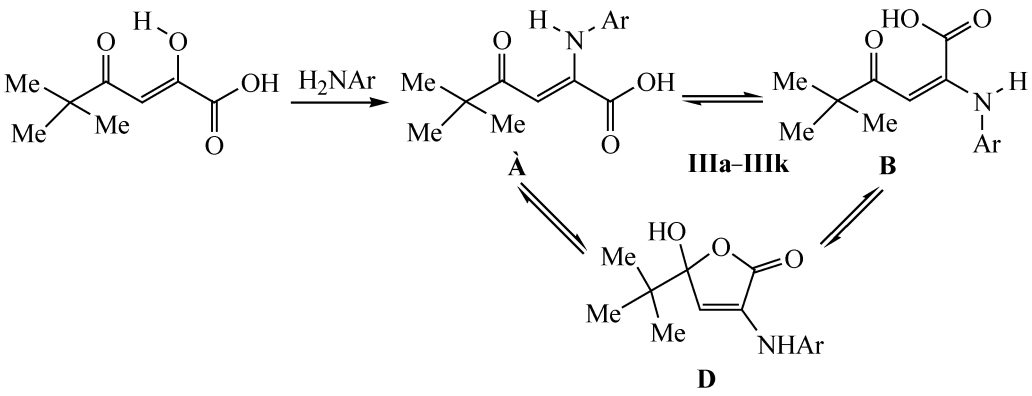
Further from the 2-hydroxy-5,5-dimethyl-4-oxohex-2-enoic acid and arylamines we obtained 2-arylamino-5,5-dimethyl-4-oxohex-2-enoic acids **IIIa–IIIk**.

In the IR spectra of compounds **IIIa–IIIk** recorded from mulls in mineral oil appeared one (compounds **IIIa–IIIe, IIIi**, in the region 3228–3256 cm^{-1}) or two (compounds **IIIf, IIIj**, in the region 3198–3375 cm^{-1}) absorption bands of the NH group. These bands are lacking in the spectra of compounds **IIIg, IIIh, IIIk**. The carboxy group absorption band of compounds **IIIc, IIIg–IIIi** is observed in the region 1670–1712 cm^{-1} (in the spectrum of compound **IIIk** a combined band is present in the region 1712 cm^{-1}). In the spectra of compounds **IIIa, IIIb, IIId–IIIf** the carboxy group gives rise to two absorption bands in the regions 1690–1748 and 1665–1680 cm^{-1}.

^{1}H NMR spectra of compounds **IIIa–IIIc, IIIe, IIIk** show that they exist in DMSO-d_6 in two enamino-ketone forms **A** (*Z*-isomer) and **B** (*E*-isomer), with the content of the *Z*-isomer 47–83%. *Z*-Isomer (form **A**) is characterized by the presence in the spectrum of vinyl proton signals at 5.66–6.52 ppm and of the NH group proton at 10.99–12.00 ppm. In the spectrum of *E*-isomer (form **B**) the signal of vinyl proton appeared at 4.88–5.41 ppm, and the signal of NH group proton at 9.65–9.67 ppm we succeeded to detect only in the spectra of compounds **IIIa–IIIc**. We failed to find in the spectra the signal of the OH group proton apparently due to significant broadening.

According to ^{1}H NMR spectra of compounds **IIId, IIIf–IIIh, IIIj** the fraction of the *Z*-isomer (form **A**) amounted to 22–82%. The signals of protons belonging to *E*-isomer are absent in the solution, but proton signals are observed corresponding to the 3-arylamino-5-*tert*-

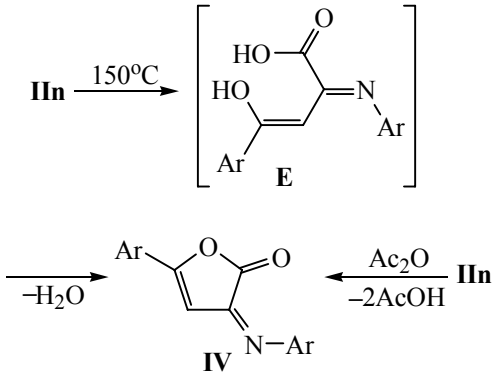
Scheme 2.



butyl-5-hydroxyfuran-2(5*H*)-ones (cyclic form **D**). Form **D** was characterized by the presence in the spectrum of a singlet from vinyl proton at 6.38–6.49 ppm and of a broadened proton signal from the alcoholic hydroxy group at 6.73–7.24 ppm. The signal of the NH group proton of compounds **IIIf, IIIj** appeared at 8.49, 8.68 ppm respectively, and of compounds **IIId**, **IIIg, IIIh**, in the region of aromatic protons. 5-*tert*-Butyl-5-hydroxy-3-(4-ethoxycarbonylphenylamino)furan-2(5*H*)-one was obtained previously and characterized in [8]. However we failed to isolate this cyclic form of compounds **III** as individual substances.

We established that acids **Ia–Ig** and 2-hydroxy-5,5-dimethyl-4-oxohex-2-enoic acid did not react with the sterically hindered 2,6-dibromo-4-chloroaniline, 3,5-dimethyl-2,6-dicyanoaniline, and 4,6-dibromo-2-{[cyclohexyl(methyl)amino]methyl}aniline (the base of a drug bromhexine).

The spectral characteristics of compounds **II** show that at introducing electron-withdrawing substituents into the aromatic ring attached to the nitrogen and electron-donor substituents to the aromatic ring in the aroyl part of the molecule it is possible if not to achieve the formation of *Z*-enimino-enol form **E** of compounds **II**, then to have a sufficiently strong intramolecular hydrogen bond favoring the formation of such *Z*-enimino-enol structure at insignificant energy supply.



This suggestion is confirmed not only by published data [9] but also by the formation of 3-(4-ethoxycarbonylphenyl)imino-5-(4-ethoxyphenyl)-3*H*-furan-2-one (**IV**) at heating compound **IIn** at 140°C. Compound **IIn** unlike compounds **IIa–IIm** eliminated water at heating providing compound **IV**. The latter was also obtained by intramolecular cyclization of compound **IIn** in acetic anhydride.

It is not inconceivable that a similar heterocyclization through form **E** may occur also with compounds **III** although in the latter case the cyclization mechanism through intermediate furanones **D** by water elimination also seems possible.

EXPERIMENTAL

IR spectra were recorded on a spectrophotometer FSM-1201 from mulls in mineral oil. ^{1}H NMR spectra were registered on spectrometers Bruker DRX-500 (500.13 MHz) and Varian Mercury Plus-300 (300.05 MHz) in DMSO-d_6 and $CDCl_3$, internal reference HMDS. The reaction progress was monitored and the purity of compounds obtained was checked by TLC on Silufol UV-254 or Sorbfil plates, eluent ether–benzene–acetone, 10:9:1, spots were visualized under iodine vapor.

4-Aryl-2-arylamino-4-oxobut-2-enoic acids IIa–IIn. To a solution of 0.01 mol of 4-aryl-2-hydroxy-4-oxobut-2-enoic acid **Ia–Ig** in 20 ml of ethanol was added a solution of 0.01 mol of amine in 20 ml of ethanol, and the mixture was left standing for 24 h at 20–25°C. The

mixture was cooled to 0°C, the separated precipitate was filtered off and recrystallized.

2-(2,4-Dimethylphenylamino)-4-oxo-4-phenylbut-2-enoic acid (IIa). Yield 2.01 g (68%), yellow crystals, mp 180–181°C (benzene–hexane). IR spectrum, ν, cm^{-1}: 3256 (NH), 1730 (COOH). ^1H NMR spectrum, δ, ppm, form **A** (76%): 2.27 s (6H, Me), 6.29 s (1H, CH), 6.76–7.92 m (8H, Ph, C_6H_3), 11.98 s (1H, NH); form **B** (24%): 2.16 s (6H, Me), 5.62 s (1H, CH), 6.76–7.92 m (8H, Ph, C_6H_3), 9.90 s (1H, NH). Found, %: C 73.28; H 5.73; N 4.81. $C_{18}H_{17}NO_3$. Calculated, %: C 73.20; H 5.80; N 4.74.

2-(2,6-Dimethylphenylamino)-4-oxo-4-phenylbut-2-enoic acid (IIb). Yield 1.71 g (58%), yellow crystals, mp 164-165°C (benzene–hexane). IR spectrum, ν, cm^{-1}: 3192 (NH), 1700 (COOH). ^1H NMR spectrum, δ, ppm, form **A** (63%): 2.19 s (6H, 2Me), 6.29 s (1H, CH), 7.01–7.92 m (8H, Ph, C_6H_3), 11.60 s (1H, NH); form **B** (24%): 2.16 s (6H, 2Me), 5.26 s (1H, CH), 7.01–7.92 m (8H, Ph, C_6H_3), 9.90 (1H, NH), 11.60 s (1H, NH). Found, %: C 73.31; H 5.86; N 4.77. $C_{18}H_{17}NO_3$. Calculated, %: C 73.20; H 5.80; N 4.74.

4-Oxo-2-(2,4,6-trimethylphenylamino)-4-phenylbut-2-enoic acid (IIc). Yield 2.75 d (89%), yellow crystals, mp 187–189°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 3200 (NH), 1645 sh (COOH). ^1H NMR spectrum, δ, ppm, form **A** (64%): 2.11–2.20 group of signals (9H, 3Me), 6.24 s (1H, CH), 6.83–7.91 m (7H, Ph, C_6H_2), 11.54 s (1H, NH); form **B** (36%): 2.11– 2.20 group of signals (9H, 3Me), 5.29 s (1H, CH), 6.83–7.91 m (7H, Ph, C_6H_2), 9.85 s (1H, NH). Found, %: C 73.69; H 6.24; N 4.59. $C_{19}H_{19}NO_3$. Calculated, %: C 73.77; H 6.19; N 4.53.

4-Oxo-2-(3-trifluoromethylphenylamino)-4-phenylbut-2-enoic acid (IId), form **A.** Yield 2.70 g (81%), yellow crystals, mp 168–169°C (EtOH). IR spectrum, ν, cm^{-1}: 3244 (NH), 1661 (COOH). ^1H NMR spectrum, δ, ppm: 6.48 s (1H, CH), 7.42–7.94 m (9H, Ph, C_6H_4), 11.66 s (1H, NH). Found, %: C 60.94; H 3.62; N 4.19. $C_{17}H_{12}F_3NO_3$. Calculated, %: C 60.90; H 3.61; N 4.17.

2-(2-Methyl-5-nitrophenylamino)-4-oxo-4-phenylbut-2-enoic acid (IIe), form **A.** Yield 2.74 g (84%), yellow crystals, mp 185–186°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 1731 (COOH). ^1H NMR spectrum, δ, ppm: 2.38 s (3H, Me), 6.49 s (1H, CH), 7.38–7.90 m (8H, Ph, C_6H_3), 11.81 s (1H, NH). Found, %: C 62.51; H 4.38; N 8.67. $C_{17}H_{14}N_2O_5$. Calculated, %: C 62.57; H 4.32; N 8.59.

2-[4-(2-*N*,*N*-Diethylaminoethoxycarbonyl)-phenylamino]-4-oxo-4-phenylbut-2-enoic acid (IIf). Yield 3.28 g (80%), yellow crystals, mp 207.5–209.5°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 3150 sh (NH), 1713 (COOH, COOEt). ^1H NMR spectrum, δ, ppm, form **A** (80%): 1.20 group of signals (6H, Me), 3.12 q (4H, $2CH_2$), 3.37 group of signals (2H, CH_2), 3.42 group of signals (2H, CH_2), 5.97 s (1H, CH), 7.2–7.9 m (9H, Ph, C_6H_4), 12.48 s (1H, NH); form **B** (20%): 1.20 group of signals (6H, Me), 3.12 q (4H, $2CH_2$), 3.37 group of signals (2H, CH_2), 3.42 group of signals (2H, CH_2), 5.20 s (1H, CH), 7.2–7.9 m (9H, Ph, C_6H_4), 9.80 s (1H, NH). Found, %: C 67.32; H 6.42; N 6.80. $C_{23}H_{26}N_2O_5$. Calculated, %: C 67.30; H 6.38; N 6.82.

2-(2-Methyl-5-nitrophenylamino)-4-(4-methylphenyl)-4-oxobut-2-enoic acid (IIg), form **A.** Yield 2.58 g (76%), yellow crystals, mp 176–177°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 1731 (COOH). ^1H NMR spectrum, δ, ppm: 2.31 s (3H, Me), 2.37 s (3H, Me), 6.46 s (1H, CH), 6.92–7.82 m (7H, C_6H_4, C_6H_3), 11.83 s (1H, NH). Found, %: C 63.59; H 4.78; N 8.19. $C_{18}H_{16}N_2O_5$. Calculated, %: C 63.52; H 4.74; N 8.23.

4-Oxo-4-(4-fluorophenyl)-2-[*N*-(4-ethoxycarbonylphenyl)]aminobut-2-enoic acid (IIh), form **A**. Yield 3.14 g (88%), yellow crystals, mp 148–149°C (toluene). IR spectrum, ν, cm^{-1}: 3194 (NH), 1709, 1727 (COOH, COOEt). ^1H NMR spectrum ($CDCl_3$), δ, ppm: 1.41 t (3H, CH_3CH_2), 4.33 q (2H, CH_3CH_2), 6.71 s (1H, CH), 7.04–8.14 m (8H, $2C_6H_4$), 8.90 s (1H, NH). Found, %: C 63.85; H 4.53; N 3.93. $C_{19}H_{16}FNO_5$. Calculated, %: C 63.86; H 4.51; N 3.92.

4-(4-Bromophenyl)-4-oxo-2-[*N*-(4-ethoxycarbonylphenyl)]aminobut-2-enoic acid (IIj), form **A.** Yield 1.84 d (44%), yellow crystals, mp 144–146°C (MeCN). IR spectrum, ν, cm^{-1}: 3204 (NH), 1719 (COOH, COOEt). ^1H NMR spectrum, δ, ppm: 1.23 t (3H, CH_3CH_2), 4.22 q (2H, CH_3CH_2), 7.03 s (1H, CH), 7.65 m (8H, $2C_6H_4$), 11.76 s (1H, NH). Found, %: C 54.59; H 3.88; N 3.39. $C_{19}H_{16}BrNO_5$. Calculated, %: C 54.56; H 3.86; N 3.35.

4-Oxo-4-(4-chlorophenyl)-2-[*N*-(4-ethoxycarbonylphenyl)]aminobut-2-enoic acid (IIk). Yield 2.91 g (78%), yellow crystals, mp 154–156°C (MeCN) (mp 177–178°C [10]). IR spectrum, ν, cm^{-1}: 3204 (NH), 1722 (COOH, COOEt). Found, %: C 61.09; H 4.34; N 3.79. $C_{19}H_{16}ClNO_5$. Calculated, %: C 61.05; H 4.31; N 3.75.

4-(4-Methylphenyl)-4-oxo-2-[N-(4-ethoxycarbonylphenyl)]aminobut-2-enoic acid (III), form **A**.

Yield 2.93 g (83%), yellow crystals, mp 155–156°C (MeCN). IR spectrum, ν, cm^{-1}: 3100 (NH), 1707, 1726 (COOH, COOEt). ^{1}H NMR spectrum, δ, ppm: 1.26 t (3H, CH_3CH_2), 2.33 s (3H, $CH_3C_6H_4$), 4.23 q (2H, CH_3CH_2), 6.53 s (1H, CH), 7.50 m (8H, $2C_6H_4$), 11.75 s (1H, NH). Found, %: C 67.96; H 5.48; N 3.92. $C_{20}H_{19}NO_5$. Calculated, %: C 67.98; H 5.42; N 3.96.

4-(4-Methoxyphenyl)-4-oxo-2-[*N*-(4-ethoxycarbonylphenyl)]aminobut-2-enoic acid (IIm), form **A**. Yield 3.17 g (86%), yellow crystals, mp 159–160°C (MeCN). IR spectrum, ν, cm^{-1}: 3192 (NH), 1729 (COOH, COOEt). Found, %: C 65.06; H 5.18; N 3.72. $C_{20}H_{19}NO_6$. Calculated, %: C 65.03; H 5.18; N 3.79.

4-Oxo-2-[N-(4-ethoxycarbonylphenyl)]amino-4-(4-ethoxyphenyl)but-2-enoic acid (IIn), form **A**. Yield 3.52 g (92%), yellow crystals, mp 150– 151°C (MeCN). IR spectrum, ν, cm^{-1}: 3114 (NH), 1726 (COOH, COOEt). ^{1}H NMR spectrum, δ, ppm: 1.28 m (6H, CH_3CH_2OCO, CH_3CH_2O), 4.06 q (2H, CH_3CH_2O), 4.23 q (2H, CH_3CH_2OCO), 6.53 s (1H, CH), 7.50 m (8H, $2C_6H_4$), 11.72 s (1H, NH). Found, %: C 67.76; H 5.56; N 3.62. $C_{21}H_{21}NO_6$. Calculated, %: C 65.79; H 5.52; N 3.65.

2-Arylamino-5,5-dimethyl-4-oxohex-2-enoic acids IIIa–IIIk. To a solution of 1.72 g (0.01 mol) of 2-hydroxy-5,5-dimethyl-4-oxohex-2-enoic acid in 15 ml of ethanol (or benzene) was added a solution of 0.01 mol of arylamine in 20–30 ml of ethanol, the mixture was heated for 3–4 min and left standing for 24 h at 20–25°C. The precipitate was filtered off and recrystallized.

5,5-Dimethyl-2-(2,4-dimethylphenylamino)-4-oxohex-2-enoic acid (IIIa). Yield 1.84 g (67%), yellow crystals, mp 129–130°C (benzene–hexane). IR spectrum, ν, cm^{-1}: 3240 (NH), 1695, 1665 (COOH). ^{1}H NMR spectrum, δ, ppm, form **A** (76%): 1.12 s (9H, CMe_3), 2.21 s (6H, 2Me), 5.73 s (1H, CH), 6.65–7.07 m (3H, C_6H_3), 11.40 s (1H, NH); form **B** (24%): 0.96 s (9H, CMe_3), 2.21 s (6H, 2Me), 5.18 s (1H, CH), 6.65–7.07 m (3H, C_6H_3), 9.65 s (1H, NH). Mass spectrum, *m/z* (I_{rel}, %): 275 (12.0) $[M]^+$, 230 (5.0) $[M - COOH]^+$, 218 (33) $[M - CMe_3]^+$, 200 (7.5) $[M - H_2O - Me_3C]^+$, 172 (100) $[M - H_2O - Me_3CCO]^+$, 144 (28) $[M - H_2O - Me_3CCO - CO]^+$, 57 (49) $[Me_3C]^+$. Found, %: C 69.85; H 7.63; N 5.15. $C_{16}H_{21}NO_3$. Calculated, %: C 69.79; H 7.69; N 5.09.

5,5-Dimethyl-2-(2,6-dimethylphenylamino)-4-oxohex-2-enoic acid (IIIb). Yield 2.01 g (73%), yellow crystals, mp 128–129°C (benzene–hexane). IR spectrum, ν, cm^{-1}: 3256 (NH), 1690, 1670 (COOH). ^{1}H NMR spectrum, δ, ppm, form **A** (59%): 1.13 s (9H, CMe_3), 2.05–2.21 group of signals (6H, 2Me), 5.71 s (1H, CH), 6.89–7.11 m (3H, C_6H_3), 11.05 br.s (1H, NH); form **B** (48%): 1.13 s (9H, CMe_3), 2.05–2.21 group of signals (6H, 2Me), 4.88 s (1H, CH), 6.89–7.11 m (3H, C_6H_3), 9.67 br.s (1H, NH). Found, %: C 69.73; H 7.74; N 5.01. $C_{16}H_{21}NO_3$. Calculated, %: C 69.79; H 7.69; N 5.09.

5,5-Dimethyl-2-(2,4,6-trimethylphenylamino)-4-oxohex-2-enoic acid (IIIc). Yield 1.73 g (60%), colorless crystals, mp 104–105°C (hexane). IR spectrum, ν, cm^{-1}: 3232 (NH), 1670 (COOH). ^{1}H NMR spectrum, δ, ppm, form **A** (52%): 1.12 s [9H, $C(CH_3)_3$], 2.04–2.24 group of signals (9H, $3CH_3$), 5.66 s (1H,CH), 6.71 s, 6.92 s (2H, C_6H_2), 10.99 br.s (1H, NH); form **B**: 0.93 s [9H, $C(CH_3)_3$], 2.04–2.24 group of signals (9H, $3CH_3$), 4.90 s (1H, CH), 6.71 s, 6.92 s (2H, C_6H_2), 9.66 br.s (1H, NH). Found, %: C 70.64; H 8.09; N 4.78. $C_{17}H_{23}NO_3$. Calculated, %: C 70.56; H 8.01; N 4.84.

2-(2-Bromophenylamino)-5,5-dimethyl-4-oxohex-2-enoic acid (IIId). Yield 3.10 g (95%), colorless crystals, mp 143–145°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 3328 (NH), 1728, 1672 (COOH). ^{1}H NMR spectrum, δ, ppm, form **A** (82%): 1.13 s (9H, CMe_3), 5.95 s (1H, CH), 6.81–7.61 m (4H, C_6H_4), 11,26 br.s (1H, NH); form **D** (18%): 0.98 s (9H, CMe_3), 6.43 s (1H, CH), 6.73 s (1H, OH), 6.81–7.61 m (5H, NH, C_6H_4). Found, %: C 51.51; H 4.90; N 4.32. $C_{14}H_{16}BrNO_3$. Calculated, %: C 51.55; H 4.94; N 4.29.

2-(2-Iodophenylamino)-5,5-dimethyl-4-oxohex-2-enoic acid (IIIe). Yield 2.83 g (76%), yellow crystals, mp 145–146°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 3336 (NH), 1728, 1673 (COOH). ^{1}H NMR spectrum, δ, ppm, form **A** (83%): 1.14 s (9H, CMe_3), 5.94 s (1H, CH), 6.72–7.80 m (4H, C_6H_4), 11.26 br.s (1H, NH); form **B**: 0.98 s (9H, CMe_3), 5.20 s (1H, CH), 6.7–7.80 m (4H, C_6H_4). Found, %: C 45.12; H 4.38; N 3.68. $C_{14}H_{16}INO_3$. Calculated, %: C 45.06; H 4.32; N 3.75.

2-(4-Bromophenylamino)-5,5-dimethyl-4-oxohex-2-enoic acid (IIIf). Yield 2.67 g (82%), yellow crystals, mp 127–128°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 3316, 3375 (NH), 1748, 1680 (COOH). ^{1}H NMR spectrum, δ, ppm, form **A** (26%): 1.13 s (9H, CMe_3), 5.90 s (1H, CH), 7.0 d (2H, C_6H_4), 7.48 d (2H, C_6H_4), 11.33 s (1H, NH); form **D** (74%): 0.98 s (9H, CMe_3), 6.38 s (1H,CH), 7.11 s (1H, OH), 7.25 d (2H, C_6H_4), 7.43 d (2H, C_6H_4), 8.49 s (1H, NH). Mass spectrum,

m/z (I_{rel}, %): 325 (6.0) $[M]^+$, 282 (2.0) $[M - COOH]^+$, 270 (28.0), 268 (28.5) $[M - CMe_3]^+$, 222 (50), 224 (55) $[M - H_2O - Me_3CCO]^+$, 196 (8.5) $[M - H_2O - Me_3CCO - CO]^+$, 189 (42.5) $[M - Br - Me_3C]^+$, 171 (19.0) $[BrC_6H_4NH]^+$, 157 (13), 155 (13) $[BrC_6H_4]^+$, 143 (28) $[M - H_2O - Me_3CCO - Br]^+$, 85 (6) $[Me_3CCO]^+$, 57 (97) $[Me_3C]^+$. Found, %: C 51.49; H 4.98; N 4.23. $C_{14}H_{16}BrNO_3$. Calculated, %: C 51.55; H 4.94; N 4.29. *M* 326.19.

2-(2,4-Dibromophenylamino)-5,5-dimethyl-4-oxohex-2-enoic acid (IIIg). Yield 2.51 g (62%), yellow crystals, mp 156–157°C (benzene–hexane). IR spectrum, ν, cm^{-1}: 1708 (COOH). ^1H NMR spectrum, δ, ppm, form **A** (81%): 1.18 s (9H, CMe_3), 6.06 s (1H, CH), 6.85–7.83 m (3H, C_6H_3), 11.37 s (1H, NH); form **D** (19%): 1.03 s (9H, CMe_3), 6.47 s (1H,CH), 6.85–7.83 m (4H, NH, C_6H_3), 7.10 s (1H, OH). Found, %: C 41.47; H 3.81; N 3.41. $C_{14}H_{15}Br_2NO_3$. Calculated, %: C 41.51; H 3.73; N 3.46.

5,5-Dimethyl-2-(2,4-dichlorophenylamino)-4-oxohex-2-enoic acid (IIIh). Yield 2.18 d (69%), yellow crystals, mp 150–151°C (benzene–hexane). IR spectrum, ν, cm^{-1}: 1712 (COOH). ^1H NMR spectrum, δ, ppm, form **A** (69%): 1.15 s (9H, CMe_3), 6.09 s (1H, CH), 7.02–7.64 m (3H, C_6H_3), 11.46 s (1H, NH); form **D** (31%): 0.99 s (9H, CMe_3), 6.41 s (1H, CH), 7.02–7.64 m (4H, NH, C_6H_3), 7.18 s (1H, OH). Found, %: C 53.26; H 4.71; N 4.49. $C_{14}H_{15}Cl_2NO_3$. Calculated, %: C 53.18; H 4.78; N 4.43.

5,5-Dimethyl-2-(2-methyl-5-nitrophenylamino)-4-oxohex-2-enoic acid (IIIi). Yield 1.81 g (59%), yellow crystals, mp 180–181°C (benzene–hexane). IR spectrum, ν, cm^{-1}: 3235(NH), 1700 (COOH). ^1H NMR spectrum, δ, ppm form **A** (28%): 1.10 s (9H, CMe_3), 2.32 s (3H, CH_3), 7.33 s (1H, CH), 7.40–7.72 m (3H, C_6H_3), 11.27 s (1H, NH); form **B** (72%): 0.93 s (9H, CMe_3), 2.29 s (3H, CH_3), 5.97 s (1H, CH), 7.40–7.72 m (3H, C_6H_3). Mass spectrum, *m/z* (I_{rel}, %): 306 (3.0) $[M]^+$, 249 (22.0) $[M - CMe_3]^+$, 221 (5) $[M - Me_3CCO]^+$, 203 (100) $[M - H_2O - Me_3CCO]^+$, 175 (12) $[M - H_2O - Me_3CCO - CO]^+$, 57 (81) $[Me_3C]^+$. Found, %: C 58.76; H 5.98; N 9.09. $C_{15}H_{18}N_2O_5$. Calculated, %: C 58.82; H 5.92; N 9.15. *M* 306.32

5,5-Dimethyl-4-oxo-2-(4-ethoxycarbonylphenylamino)hex-2-enoic acid (IIIj). Yield 2.42 g (76%), yellow crystals, mp 161–162°C (*i*-PrOH). IR spectrum, ν, cm^{-1}: 3198, 3327 (NH), 1661, 1684, 1726 (COOH, COOEt). ^1H NMR spectrum, δ, ppm, form **A** (22%): 1.13 s (9H, CMe_3), 1.43 t (3H, CH_3CH_2), 4.29 q (2H, CH_3CH_2), 5.95 s (1H, CH), 6.94–7.87 m (4H, C_6H_4), 11.20 s (1H, NH); form **D** (78%): 0.98 C (9H, CMe_3), 1.43 t (3H, CH_3CH_2), 4.29 q (2H, CH_3CH_2), 6.49 s (1H, CH), 7.24 s (1H, OH), 7.3–7.87 m (4H, C_6H_4), 8.68 s (1H, NH). Found, %: C 63.87; H 6.68; N 4.24. $C_{17}H_{21}NO_5$. Calculated, %: C 63.94; H 6.63; N 4.19.

5,5-Dimethyl-2-[4-(2-*N*,*N*-diethylamino)-ethoxycarbonylphenylamino]-4-oxohex-2-enoic acid (IIIk). Yield 3.35 d (86%), yellow crystals, mp 203–204°C (EtOH). IR spectrum, ν, cm^{-1}: 1712 (COOH, COOEt). ^1H NMR spectrum, δ, ppm, form **A** (47%): 1.10 group of signals (15H, 5Me), 2.88–3.41 m (6H, $3CH_2$), 4.30 group of signals (2H, CH_2), 6.52 s (1H,CH), 7.19–7.78 m (4H, C_6H_4), 12.00 s (1H, NH); form **B** (53%): 1.10 group of signals (15H, 5Me), 2.88–3.41 m (6H, $3CH_2$), 4.30 group of signals (2H, CH_2), 5.41 s (1H, CH), 7.19–7.78 m (4H, C_6H_4). Found, %: C 64.53; H 7.79; N 7.25. $C_{21}H_{30}N_2O_5$. Calculated, %: C 64.59; H 7.74; N 7.17.

3-(4-Ethoxycarbonylphenyl)imino-5-(4-ethoxyphenyl)-3*H*-furan-2-one (IV). *a*. A solution of 3.83 g (0.01 mol) of acid **IIn** in 8 ml of acetic anhydride was heated for 1 h at 70°C. The precipitate separated on cooling was filtered off, washed with anhydrous ether, and recrystallized from anhydrous toluene . Yield 1.5 g (41%).

b. Acid **IIn** (3.83 g, 0.01 mol) was heated for 10 min at 140°C. The residue was recrystallized. Yield 2.19 g (60%), orange crystals, mp 149.5–151°C (toluene). IR spectrum, ν, cm^{-1}: 1813 (CO_{lact}), 1709 (COOEt). ^1H NMR spectrum, δ, ppm: 1.37 m (6H, CH_3CH_2OCO, CH_3CH_2O), 4.05 q (2H, CH_3CH_2OCO), 4.35 q (2H, CH_3CH_2), 6.23 s (1H, CH), 7.48 m (8H, $2C_6H_4$). Found, %: C 69.08; H 5.25; N 3.81. $C_{21}H_{19}NO_5$. Calculated, %: C 69.03; H 5.24; N 3.83.

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