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CYCLOCONDENSATION OF 2-FLUORO-5-NITROBENZALDEHYDE WITH AMIDINES. NEW SYNTHESIS OF ISOQUINOLINES*

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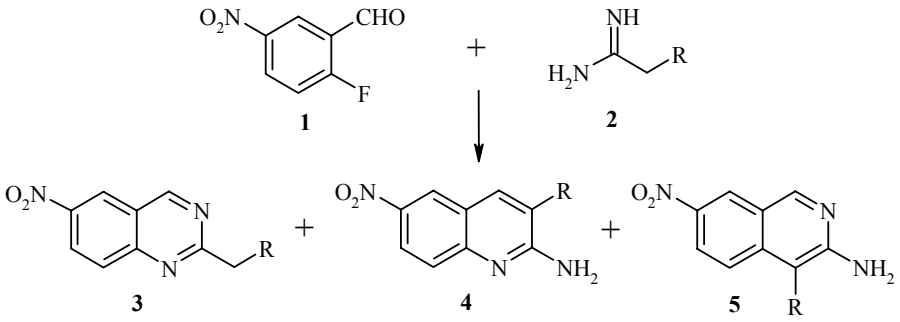
The direction of the cyclocondensation of 2-fluoro-5-nitrobenzaldehyde with five amidines having α-hydrogen atoms has been studied. It was established that depending on the structure of the amidine the main products of the reaction may be not only quinazolines but also 3-aminoisoquinolines. A new convenient route has been found for the synthesis of 3-aminoisoquinolines consisting of the cyclocondensation of α-acylacetamidines with 2-fluoro-5-nitrobenzaldehyde.

Keywords: amidines as N,N- and C,N-dinucleophiles, isoquinolines, 2-fluoro-5-nitrobenzaldehyde, cyclocondensation.

The cyclocondensation of amidines with activated *ortho*-fluorobenzaldehydes was discovered recently, and is a simple and convenient method for synthesizing 4-unsubstituted quinazolines. Amidines, the behavior of which was studied in this reaction, react as N,N'-dinucleophiles [2].

In addition it is known that amidines having a hydrogen atom in the α-position to the amidine fragment may also act as N,C-dinucleophiles in reactions with 1,3-dielectrophiles [3]. In reactions with activated *ortho*-fluorobenzaldehydes such amidines might form 2-aminoquinolines **4** or 3-aminoisoquinolines **5**, together with quinazolines **3** isomeric with them.



a R = H; **b** R = Ph; **c** R = $CONH_2$; **d** R = COPh; **e** R = CO_2Et

We have investigated the reaction of substituted acetamidines **2a-e,** differing in the nature of the substituent at the α-carbon atom and consequently in the reactivity of the carbon nucleophilic center, with aldehyde **1**.

* For the preliminary communication see [1].

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Amidines **2a-c** were reacted as the hydrochlorides as we used the conditions described in [2]. Potassium carbonate was used as base. Amidines **2d** and **2e** were reacted as the free bases. Judging by the ^{1}H NMR spectra they exist in the enediamine form $(NH_2)_2C{=}CHR$ (R = COPh and CO_2Et).

In the reaction of aldehyde **1** with acetamidine **2a**, with the least ability to display C-nucleophilic properties, the main product, as expected, proved to be 2-methyl-6-nitroquinazoline (**3a**), isolated in 58% yield. 2-Amino-6-nitroquinoline (**4a**), resulting from participation of the carbon nucleophilic center of acetamidine, was also successfully isolated from the reaction mixture in ~1.5% yield. The structures of quinazoline **3a** and aminoquinoline **4a** were confirmed by their ^{1}H NMR spectra. Compound **4a** may be assigned a quinoline structure and not the isomeric isoquinoline, since in its ^{1}H NMR spectrum a spin-spin interaction is observed between the protons at positions 3 and 4 with a coupling constant of 9.0 Hz (doublets at 6.89 and 8.13 ppm), which corresponds to their *ortho* disposition. Aminoquinoline **4a** has been repeatedly described in the literature [4-6]. Various authors give its melting point in the range 255-265°C. The sample obtained by us decomposed at ~250°C.

Two isomeric compounds were isolated in the reaction with phenylacetamidine (**2b**). These were 2-benzyl-6-nitroquinazoline (**3b**) in 18% yield and 2-amino-6-nitro-3-phenylquinoline (**4b**), purified through the picrate and isolated in 6% yield. The structures of quinazoline **3b** and aminoquinoline **4b** were confirmed by their ^{1}H NMR spectra. To prove the structure of aminoquinoline **4b** a NOESY spectrum was taken in which a cross peak was observed between the signals of the 4-H proton of the heterocycle and the *ortho*-protons of the benzene ring, which indicates the relatively close disposition of them both, which occurs only in the quinoline structure.

In the reaction with carbamoylacetamidine (**2c**) we isolated only 3-amino-4-carbamoyl-7-nitroisoquinoline (**5c**) in 63% yield. It is not possible to draw an unequivocal conclusion between the quinoline **4c** and isoquinoline **5c** structures on the basis of the ^{1}H NMR spectrum of this compound, since the expected difference of chemical shifts of the protons for these structures is small, and the character of the spin-spin interactions is the same. Consequently to demonstrate the structure of this compound the spin-spin interactions between the ^{1}H and ^{13}C nuclei were studied. A complete assignment of the signals in the ^{13}C NMR spectrum was carried out on the basis of unidimensional ^{13}C NMR spectra without proton decoupling and DEPT-135 and of two-dimensional COLOC correlation spectra (with optimization of sensitivity at J = 8 Hz) and HSQC without broadband decoupling from the ^{13}C nuclei [7]. The chemical shift (156.1 ppm) detected for the signal of the $C_{(1)}$ atom (or $C_{(4)}$ for quinoline) served to indicate the isoquinoline structure, since the values of the chemical shifts for unsubstituted structures were 152.0 ppm for $C_{(1)}$ in isoquinoline and 136.1 for $C_{(4)}$ in quinoline [8]. In addition, from the ^{13}C spectrum without proton decoupling we obtained a value for the direct coupling constant $^1J(C_{(1)}–H)$ = 181.5 Hz, at corresponding values for the unsubstituted compounds $^1J(C_{(1)}\text{-}H)$ = 178 Hz (isoquinoline), and $^1J(C_{(4)}–H)$ = 162 Hz (quinoline) [8]. The chemical shift of the $C_{(1)}$ atom signal and the value of its direct coupling constant are adequately weighty, but indirect arguments in favor of the fact that the compound obtained is an isoquinoline. For a direct demonstration, a so-called relay INEPT-INADEQUATE experiment [9] was carried out, designed to clarify spin systems of the form $^1H–^{13}C–^{13}C$ and including the sequential transfer of polarization from the proton to the geminal carbon atom through the $^1J_{H\text{-}C}$ and $^1J_{C\text{-}C}$ coupling constants.

In the INEPT-INADEQUATE spectrum (Fig. 1) signals of the quaternary carbon atoms linked in both structures with methine carbon atoms ($C_{(4a)}$, $C_{(7)}$, and $C_{(8a)}$ for isoquinoline and $C_{(4a)}$, $C_{(6)}$, and $C_{(8a)}$ for quinoline), were observed, as might have been expected, in the form of antiphase doublets with coupling constants $^1J_{C\text{-}C}$ ~65 Hz. In the structure of the $C_{(4)}$ atom signal ($C_{(3)}$ for quinoline) at 104.3 ppm the indicated doublet splitting was absent. In the structure of quinoline **4c** the $C_{(3)}$ atom has a vicinal proton (4-H) and the signal of this atom should be represented as an antiphase doublet. In the structure of isoquinoline **5c** the $C_{(4)}$ atom does not have vicinal protons. On the basis of the shape of the signal at 104 ppm we may confidently assign the structure of isoquinoline **5c** to the compound being investigated.

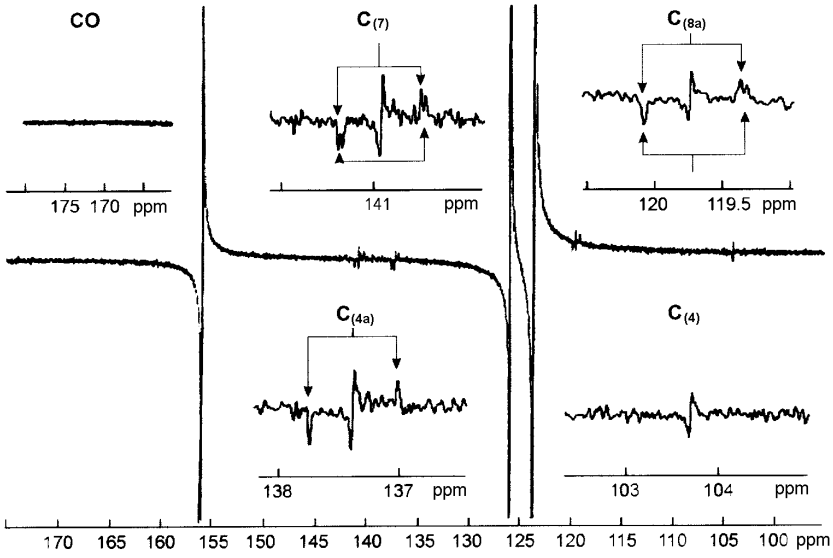


Fig. 1. INEPT-INADEQUATE spectrum of compound **5c**.

In addition to the signals of the main substance, a group of low intensity signals was observed in the ^{1}H NMR spectrum of isoquinoline **5c,** which may belong to the isomeric aminoquinoline **4c**, the content of which in the reaction product was less than 1%.

On carrying out the reaction of benzoylacetamidine (**2d**) with aldehyde **1** under the conditions used for amidines **2a-c**, we isolated a reaction mixture with a low content of the main substance strongly contaminated with side products. On carrying out this reaction without base (method A) the main reaction product was 3-amino-4-benzoyl-7-nitroisoquinoline (**5d**), isolated in 47% yield. The structure of aminoisoquinoline **5d** was confirmed by its ^{1}H and ^{13}C NMR spectra. In the ^{1}H NMR spectrum the signals of the 1-H, 6-H, and 8-H protons and the protons of the amino group have chemical shifts close to the signals of the analogous protons of isoquinoline **5c**. The exception was the signal for the proton at position 5 (doublet with coupling constant 9.3 Hz), the displacement of which into the low frequency region by 0.64 ppm in comparison with the signal for 5-H of isoquinoline **5c** may be explained by the shielding action of the benzene ring. Assignment of the signals of the methine carbon atoms in the ^{13}C spectrum was carried out using DEPT and HSQC spectra and the

TABLE 1. Yield of Products from the Reaction of Aldehyde **1** with Amidines **2a-e**

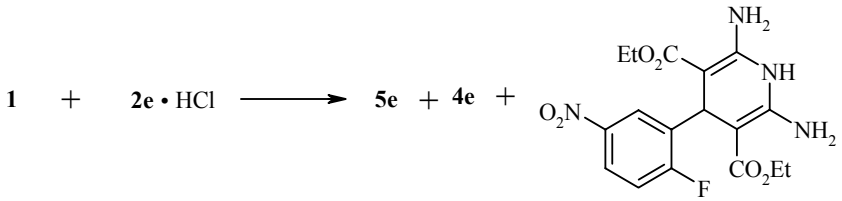
Amidine	Yield, %		
	3	**4**	**5**
2a	58	1.5	0
2b	18	6	0
2c	0	0.5*	63
2d	0	2.5*	47
2e	0	2*	37

* Not isolated.

quaternary atoms were assigned by comparison with the position of the signals of the analogous atoms in the spectrum of aminoisoquinoline **5c**. The signal of the $C_{(1)}$ atom was located at 157.8 ppm and the coupling constant $^1J(C_{(1)}–H)$ = 186.8 Hz, which corresponds to the value expected for an isoquinoline.

On carrying out the same reaction in the presence of triethylamine (method B) aminoisoquinoline **5d** is formed in somewhat lower yield. Signals were detected in the ^{1}H NMR spectrum of the main product which may be assigned to the isomeric 2-amino-3-benzoyl-6-nitroquinoline (**4d**), present at 5%. In the HSQC spectrum, without decoupling from the ^{13}C nuclei, appropriate cross peaks are also observed belonging to monomeric aminoquinoline **4d**, among which may be isolated a cross peak between the signal of the 4-H proton (8.60 ppm) and the signal of the $C_{(4)}$ atom at 147.5 ppm. The value $^1J(C_{(4)}–H)$ = 166.2 Hz observed at this cross peak corresponds to that expected for quinoline.

On carrying out the reaction of aldehyde **1** with amidine **2e** under the same conditions as in the case of amidines **2a-c**, the main product proved to be dihydropyridine **6e**, containing as contaminants 3-amino-4-ethoxycarbonyl-7-nitroisoquinoline (**5e**) and 2-amino-3-ethoxycarbonyl-6-nitroquinoline (**4e**).



6e

A satisfactory yield of isoquinoline **5e** was achieved by gradually adding a solution of amidine **2e** as the free base to the solution of aldehyde **1** (method A). In this way isoquinoline **5e** was isolated in 40% yield, containing, judging by the ^{1}H NMR spectrum, quinoline **4e** (6%). The structure of isoquinoline **5e** was demonstrated by a chemical method. Acid **5f** (R = CO_2H) was obtained by the hydrolysis of ester **5e**, the decarboxylation of which led to isoquinoline **5a**. Pure dihydropyridine **6e** was obtained in 74% yield by method B.

The direction of the process as a function of amidine structure may therefore be demonstrated by the summary Table 1.

The reaction discovered by us represents a new scheme for assembling the isoquinoline ring and broadens the possibility of synthesizing substituted isoquinolines.

EXPERIMENTAL

The NMR spectra were obtained on a Bruker DPX-300 (300 MHz) instrument in DMSO-d_6.

Reaction of Aldehyde 1 with Acetamidine (2a). A mixture of aldehyde **1** [10] (0.84 g, 5 mmol), acetamidine hydrochloride (0.77 g, 7.5 mmol), potassium carbonate (1.03 g, 7.5 mmol), and molecular sieves 4E (1.5 g) in dry acetonitrile (40 ml) was boiled with stirring for 4 h. The solid was filtered off and washed with ethyl acetate. The filtrate was evaporated, and the residue chromatographed on a column. Initially as eluent hexane–ether was used, gradually increasing the proportion of ether from 20 to 75%. **2-Methyl-6-nitroquinazoline (3a)** (0.55 g, 58%) of mp 150-154°C was isolated. A sample pure for analysis was obtained by recrystallization from methanol–acetonitrile, 3:1. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 2.84 (3H, s, CH_3); 8.05 (1H, d, *J* = 9.1, 8-H); 8.61 (1H, m, *J* = 9.1, *J* = 2.5, 7-H); 9.12 (1H, d, *J* = 2.5, 5-H); 9.78 (1H, s, 4-H). Found, %: C 57.21; H 3.72; N 22.10. $C_9H_7N_3O_2$. Calculated, %: C 57.14; H 3.73; N 22.21. The column was then eluted with hexane–ether–ethyl acetate, 1:3:1, as a result of which the second reaction product, **2-amino-6-nitroquinoline (4a)**, was isolated in a yield of 0.011 g (1.5%) having mp 250°C (decomp.). (Lit. mp 261°C [4],

265°C [5], 256°C [6]). A sample pure for analysis was obtained by sublimation at 150°C (1 mm Hg). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 6.89 (1H, d, *J* = 9.0, 3-H); 7.23 (2H, NH_2); 7.50 (1H, d, *J* = 9.3, 8-H); 8.13 (1H, d, *J* = 9.0, 4-H); 8.22 (1H, m, *J* = 9.3, *J* = 2.5, 7-H); 8.68 (1H, d, *J* = 2.5, 5-H).

Reaction of Aldehyde 1 with Phenylacetamidine (2b). A mixture of aldehyde **1** (0.68 g, 4 mmol), phenylacetamidine hydrochloride [11] (1.1 g, 6.6 mmol), K_2CO_3 (0.92 g, 6.6 mmol), and molecular sieves 4E (1.3 g) in dry acetonitrile (40 ml) was boiled with stirring for 5 h. The solid was filtered off, washed with ethyl acetate, and the solvent evaporated. The residue was chromatographed on a column, which was eluted with hexane–ether gradually increasing the proportion of ether (5:1, 4:1, 3:1, 2:1, 1:1). **2-Benzyl-6-nitroquinazoline (3b)** was isolated in a yield of 0.19 g (18%) having mp 128-130°C. A sample pure for analysis was obtained by recrystallization from methanol. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 4.43 (2H, s, CH_2); 7.20-7.40 (5H, m, C_6H_5); 8.15 (1H, d, *J* = 9.2, 8-H); 8.64 (1H, d, *J* = 9.2, 7-H); 9.27 (1H, s, 5-H); 9.86 (1H, s, 4-H). Found, %: C 67.93; H 4.26; N 15.70. $C_{15}H_{11}N_3O_2$. Calculated, %: C 67.92; H 4.18; N 15.84. **2-Amino-6-nitro-3-phenyl-quinoline (4b)** (0.18 g) was isolated heavily contaminated and after recrystallization from methanol–acetonitrile 3:1, it contained impurities. The preparation was purified through the picrate. Yield (calculated on aldehyde **1**) 6%; mp 270°C (acetonitrile). Found, %: C 50.45; H 2.87; N 16.52. $C_{15}H_{11}N_3 \cdot C_6H_3N_3O_7$. Calculated, %: C 51.02; H 2.85; N 16.99. Pure aminoquinoline **4b** of mp 184-188°C was obtained by treating aminoquinoline **4b** picrate with an excess of aqueous KOH solution. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 6.83 (2H, NH_2); 7.44-7.53 (5H, m, C_6H_5); 7.57 (1H, d, *J* = 9.3, 8-H); 8.10 (1H, s, 4-H); 8.23 (1H, m, *J* = 9.3, *J* = 3.0, 7-H); 8.73 (1H, d, *J* = 3.0, 5-H).

Reaction of Aldehyde 1 with Carbamoylacetamidine (2c). A mixture of aldehyde **1** (0.57 g, 3.4 mmol), amidine hydrochloride **2c** (0.7 g, 5.1 mmol), K_2CO_3 (0.7 g, 5.1 mmol), and molecular sieves 4E (0.8 g) in dry acetonitrile (40 ml) was boiled for 45 min, then cooled to ~10°C, the solid was filtered off, washed with ethanol, and with hot water, after which it was stirred with hot DMF (10 ml), the sieves filtered off, and the reaction product reprecipitated from the filtrate with ethanol–ether, 1:1. **3-Amino-4-carbamoyl-7-nitroisoquinoline (5c)** (0.5 g, 63%) was obtained with mp >300°C. A sample pure for analysis was obtained by recrystallization from DMF, sequentially boiling in water, ethanol, and acetonitrile, then subliming at 220°C (1 mm Hg). ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 6.86 (2H, 3-NH_2); 7.83 (1H, d, *J* = 9.3, 5-H); 7.85 (1H, CONH); 8.06 (1H, CONH); 8.24 (1H, m, *J* = 9.3, *J* = 2.5, 6-H); 8.93 (1H, d, *J* = 2.5, 8-H); 9.19 (1H, s, 1-H). ^{13}C NMR spectrum, δ, ppm: 104.4 ($C_{(4)}$), 119.8 ($C_{(8a)}$); 123.83 ($C_{(5)}$); 123.85 ($C_{(6)}$); 126.1 ($C_{(8)}$); 137.4 ($C_{(4a)}$); 141.0 ($C_{(7)}$); 156.0 ($C_{(3)}$); 156.1($C_{(1)}$, ^1J(C-H) = 182 Hz); 168.1 (CO). Found, %: C 51.66; H 3.52; N 24.19. $C_{10}H_8N_4O_3$. Calculated, %: C 51.73; H 3.47; N 24.13.

Reaction of Aldehyde 1 with Benzoylacetamidine (2d). Amidine **2d** was obtained by the procedure of [13], ^{1}H NMR spectrum, δ, ppm: 5.15 (1H, s, =CH); 6.3 (2H, NH_2); 6.6 (1H, NH); 7.30-7.70 (5H, C_6H_5); 10.0 (1H, NH).

A. A mixture of aldehyde **1** (0.61 g, 3.6 mmol), amidine **2d** (0.48 g, 3.0 mmol), and molecular sieves 4E (0.8 g) in dry acetonitrile (20 ml) was boiled with stirring for 3 h. The sieves were filtered off, the solvent evaporated, and the residue crystallized from methanol–acetonitrile, 1:1. Yield of compound **5d** was 0.41 g (47%) of mp 192-194°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 7.13 (2H, NH_2); 7.19 (1H, d, *J* = 9.3, 5-H); 7.53 (2H, t, *m*-H); 7.68 (1H, t, *p*-H); 7.76 (2H, d, *o*-H); 8.07 (1H, m, *J* = 9.3, *J* = 2.5, 6-H); 8.95 (1H, d, *J* = 2.5, 8-H); 9.33 (1H, s, 1-H). ^{13}C NMR spectrum, δ, ppm: 104.8 ($C_{(4)}$); 119.9 ($C_{(8a)}$); 123.4 ($C_{(5)}$); 124.2 ($C_{(6)}$); 126.3 ($C_{(8)}$); 129.0 (*m*-C_6H_5); 129.4 (*o*-C_6H_5); 133.7 (*p*-C_6H_5); 137.72, 138.6 ($C_{(4a)}$, *ipso*-C_6H_5); 141.2 ($C_{(7)}$); 156.6 ($C_{(3)}$); 157.9 ($C_{(1)}$, ^1J(C–H) = 186.8 Hz); 195.8 (CO). Found, %: C 65.36; H 3.79; N 14.29. $C_{16}H_{11}N_3O_3$. Calculated, %: C 65.53; H 3.78; N 14,33.

B. A mixture of aldehyde **1** (0.34 g, 2 mmol), amidine **2d** (0.27 g, 1.7 mmol), and triethylamine (0.22 g, 2.2 mmol) in dry acetonitrile (30 ml) was boiled for 2 h. The solvent was evaporated, and the residue resolved on a chromatographic column. This was eluted with a hexane–ether mixture, gradually increasing the proportion of ether (4:1, 3:1, 2:1, 1:1, 1:2). **3-Amino-4-benzoyl-7-nitroisoquinoline (5d)** was isolated in this way, and

after recrystallization from methanol–acetonitrile, 3:1, contained the isomeric reaction product **2-amino-3-benzoyl-6-nitroquinoline (4d)** (5%). The yield of compound **5d** was 0.185 g (37%); mp 192-194°C.

Reaction of Aldehyde 1 with Ethyl Amidinoacetate (2e). Amidine **2e** was obtained as the free base by extracting an aqueous solution of amidine hydrochloride **2e** [12] and a 50% excess of potassium carbonate with ethyl acetate. ^{1}H NMR spectrum, δ, ppm: 1.09 (3H, t, CH_3); 3.78 (1H, s, =CH); 3.86 (2H, q, CH_2); 5.79 (2H, s, NH_2); 6.9 (2H, NH_2).

A. A solution of amidine **2e** (0.27 g, 2.1 mmol) in DMF (8 ml) was added dropwise with heating (50°C) and stirring during 1 h to a mixture of aldehyde **1** (0.39 g, 2.3 mmol), molecular sieves 4E (0.5 g), and acetonitrile (6 ml). After a further 1 h at 50°C the reaction mixture was poured into water (50 ml), and the resulting crystals recrystallized from methanol–acetonitrile, 4:1. The yield of **3-amino-4-ethoxycarbonyl-7-nitroisoquinoline (5e)** (containing ~5% **2-amino-3-ethoxycarbonyl-6-nitroquinoline (4e)**) was 0.22 g (40%); mp 174-177°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.39 (3H, t, CH_3); 4.42 (2H, q, CH_2); 7.92 (2H, NH_2); 8.28 (1H, m, *J* = 9.3, *J* = 2.5, 6-H); 8.51 (1H, d, *J* = 9.3, 5-H); 8.89 (1H, d, *J* = 2.5, 8-H); 9.30 (1H, s, 1-H). Found, %: C 55.19; H 4.17; N 16.03. $C_{12}H_{11}N_3O_4$. Calculated, %: C 55.17; H 4.24; N 16.08.

B. Potassium carbonate (0.61 g, 4.4 mmol) was added to a solution of aldehyde **1** (0.37 g, 2.2 mmol) and amidine hydrochloride **2e** (0.73 g, 4.4 mmol) in DMF (10 ml) and the mixture stirred for 1 h 30 min at ~20°C. The reaction mixture was then poured into water (40 ml) and the resulting crystals of **diethyl 2,6-diamino-4-(2-fluoro-5-nitrophenyl)-4,5-dihydropyridine-3,5-dicarboxylate (6e)** were filtered off, dried, and recrystallized from dichloromethane. Yield was 0.64 g (74%); mp 178-182°C. ^{1}H NMR spectrum, δ, ppm: 1.02 (6H, t, CH_3); 3.84 (4H, m, CH_2); 4.91 (1H, s, 4-CH); 7.12 (4H, NH_2); 7.27 (1H, t, 3-H_{ar}); 7.99 (2H, m, 4-H_{ar} and 6-H_{ar}); 8.62 (1H, s, NH). The picrate of **6e** was isolated analytically pure, mp 205-207°C. Found, %: C 44.29; H 3.57; N 15.75. $C_{17}H_{19}FN_4O_6 \cdot C_6H_3N_3O_7$. Calculated, %: C 44.31; H 3.56; N 15.73.

3-Amino-7-nitroisoquinoline (5a). Solutions of isoquinoline **5e** (0.2 g, 0.77 mmol) and KOH (0.14 g, 2.5 mmol) in ethanol were mixed and boiled for 2 h 30 min, the solution was cooled, and the precipitated dark-red crystals filtered off. The potassium salt of 3-amino-7-nitroisoquinoline-3-carboxylic acid (0.12 g, 57%) was obtained. A solution of the salt (0.1 g) in water (3 ml) was acidified with dilute hydrochloric acid, the precipitated yellow crystals were filtered off, and dried. Acid **5f** (0.06 g, 70%) was obtained; mp >250°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 8.10 (2H, br. s, NH_2); 8.33 (1H, m, *J* = 9.3, *J* = 2.5, 6-H); 8.72 (1H, d, *J* = 9.3, 5-H); 8.91 (1H, d, *J* = 2.5, 8-H); 9.29 (1H, s, 1-H); 13.6 (1H, COOH). The obtained acid (0.03 g) was triturated thoroughly with CaO (0.05 g) and heated at 220°C and 1 mm Hg in a sublimation apparatus. **3-Amino-7-nitroisoquinoline (5a)** (0.01 g, 42%) was isolated with mp 236-238°C (decomp.). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 4.86 (2H, NH_2); 6.78 (1H, s, 4-H); 7.61 (1H, d, *J* = 9.3, 5-H); 8.27 (1H, m, *J* = 9.3, *J* = 2.5, 6-H); 8.78 (1H, d, *J* = 2.5, 8-H); 9.05 (1H, s, 1-H).

REFERENCES

1. D. V. Dar'in, S. I. Selivanov, P. S. Lobanov, and A. A. Potekhin, *Khim. Geterotsikl. Soedin.*, 1155 (2002).
2. H. Kotsuki, H. Sakai, H. Morimoto, and H. Suenaga, *Synlett*, 1993 (1999).
3. D. G. Batt and G. C. Hoghton, *J. Heterocycl. Chem.*, **32**, 963 (1995).
4. A. E. Tschitschibabin, D. P. Witkovsky, and M. I. Lapschin, *Chem. Ber.*, **58**, 803 (1925).
5. O. Fischer and U. Guthmann, *J. Prakt. Chem.*, **93**, 378 (1916).
6. J. C. E. Simpson and P. H. Wright, *J. Chem. Soc.*, 1707 (1948).
7. E. Deroum, *Contemporary Methods of NMR for Chemical Investigations* [Russian translation], Mir, Moscow (1992).
8. H.-O. Kalinowsky, S. Berger, and S. Braun, *^{13}C-NMR Spektroskopie*, Georg Thieme Verlag, Stuttgart-New York (1984).

9. H. Kessler, W. Bermel, and C. Griesinger, *J. Magn. Reson.*, **62**, 573 (1985).
10. D. J. Gale and J. F. K. Wilshire, *Aust. J. Chem.*, **23**, 1063 (1970).
11. P. E. Fanta and E. H. Hedman, *J. Am. Chem. Soc.*, **78**, 1434 (1956).
12. S. M. McElvain and B. E. Tate, *J. Am. Chem. Soc.*, **73**, 2760 (1951).
13. B. Roth and J. M. Smith, Jr., *J. Am. Chem. Soc.*, **71**, 616 (1949).