trans-5-Benzoyl-1-methyl-2-methylthio-4-(p-chlorophenyl)-2-imidazoline (XXXI). A solution of 0.02 mole of potassium hydroxide (or sodium hydroxide or a quaternary ammonium base) in 10 ml of ethanol was added to a solution of 0.01 mole of cis-5-benzoyl-1-methyl-2-methylthio-4-(p-chlorophenyl)-2-imidazoline borotrifluoride in 30 ml of ethanol, and the mixture was allowed to stand at room temperature for 0.5 h. The ethanol was evaporated at reduced pressure, the residue was dissolved in 40-50 ml of ether, the solution was passed through a 2-3-cm layer of silica gel on a Schott filter, and the ether was removed by distillation to dryness.

Deuterium Exchange of Stereoisomeric 5-Benzoyl-1-methyl-2-methylthio-4-(p-chlorophenyl)-2-imidazolines XXIX and XXXI. A 0.1-g sample of the 2-imidazoline, 1 ml of $d_4$-methanol, and 0.01 g of sodium methoxide were placed in a PMR ampul, and the mixture was allowed to stand at room temperature. According to the PMR data, 90% deuterium exchange of the 5-H proton occurs in the case of XXIX after 5 min, as compared with 90% deuterium exchange in the case of XXXI after 25 min.

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# SYNTHESIS AND TAUTOMERISM OF 5,7-DIARYL-4,7(6,7)-DIHYDROTETRAZOLO[1,5a]PYRIMIDINES

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5,7-Diaryl-4,7(6,7)-dihydrotetrazolo[1,5-a]pyrimidines were synthesized by the cyclocondensation of 5-aminotetrazole with chalcones. The tautomerism of the compounds obtained is discussed.

Azolopyrimidine derivatives have attracted attention as a consequence of their potential physiological activity, but their dihydrogenated derivatives until recently [1] have remained virtually uninvestigated and have been examined only as intermediates in the synthesis of heteroaromatic systems [2].

The aim of the present research was to obtain and study the properties of aromatic substituted 4,7-dihydrotetrazolo[1,5-a]pyrimidines. We have previously reported [1] the synthesis of 4,7-dihydrotriazolo[1,5-a]pyrimidine derivatives by condensation of 3-amino-1,2,4-triazole with 1,3-diaryl-1-propen-3-ones (chalcones). The synthesis of the desired IIIa-h was accomplished by a similar method — by refluxing solutions of 5-aminotetrazole (I) and chalcones IIa-h in dimethylformamide (DMF):

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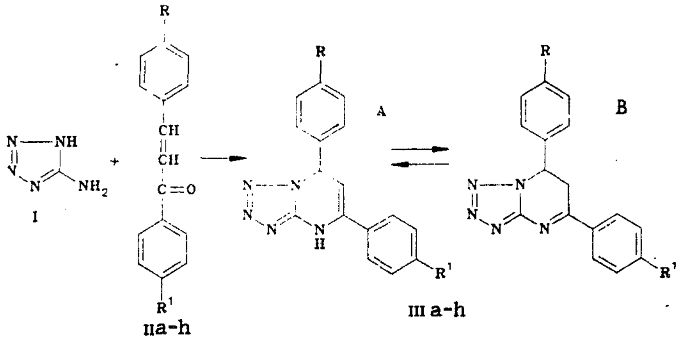


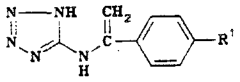
II, III a–f R=H, g R=$CH_3$, h R=Br; a,g,h R¹=H, b R¹=$CH_3$, c R¹=$CH_3O$;
d R¹=$(CH_3)_2N$, e R¹=Br, f R¹=$NO_2$

Compound I could not be condensed with 4-nitro- and 4-dimethylaminochalcones [II, R = $NO_2$ or $(CH_3)_2N$, $R^1$ = H] under these conditions; the low reactivities of these chalcones with respect to amino azoles has also been previously noted [1].

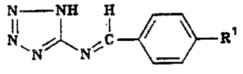
Compounds IIIa-h were identified by means of UV, IR, and NMR spectroscopy, and their formation was confirmed by the results of elementary analysis for nitrogen (Table 1). The IR spectra of IIIa-c, e-h contain $\nu_{C=C}$ bands at 1653-1658 $cm^{-1}$; in the case of IIId there is an intense broad band at 1620 $cm^{-1}$ in the region of $\nu_{C=C}$ and $\nu_{C=N}$ frequencies. The $\nu_{NH}$ bands cannot be identified unambiguously in measurements of the IR spectra of KBr pellets of IIIa-h. On the other hand, in the spectra measured for solutions in CCl4 the $\nu_{NH}$ absorption shows up in the form of a narrow ($\Delta\nu_{\frac{1}{2}}$ ~ 50 $cm^{-1}$) band of medium intensity at 3440-3448 $cm^{-1}$. Compound IIId, in the IR spectra of which a $\nu_{NH}$ band is absent, regardless of the conditions used to measure them, constitutes an exception.

Differences are also observed in the electronic absorption spectra of the investigated compounds. Thus, the spectra of IIIa-c, e-h contain two absorption bands with $\lambda_{max}$ 240-270 and 278-335 nm, while an intense absorption band in the longer-wave region ($\lambda_{max}$ 390 nm) is observed in the spectrum of IIId. The spectrum of a methanol solution of IIIc also contains a low-intensity band in the long-wave region. A similar effect of substituents on the spectra of aromatic substituted dihydro-1,2,4-triazolo[1,5-a]pyrimidines has been previously noted [1]; this was explained by the existence of a tautomeric equilibrium between the 4,7- and 6,7-dihydro forms of these compounds.

To interpret the nature of the absorption spectra of the investigated substances we calculated the electronic characteristics of the ground and excited states of planar models of the principal chromophore groupings of IIIa, c, d. We selected structures IVa, c, d as models for the A tautomers and structures Va, c, d as models for the B tautomers.



IVa,c,d



Va,c,d

IV, V a R¹=H, c R¹=$OCH_3$, d R¹=$N(CH_3)_2$

The calculation was carried out by the MO LCAO SCF CI (molecular-orbital linear-combination-of-atomic-orbitals self-consistent-field configuration-interaction) method in the PPP (Pariser—Parr—Pople) variant with the standard set of parameters [3]. The results of calculation of $\lambda_{max}$ and the oscillator forces (f) of the absorption bands, which are presented in Table 2, show that as IIIa, c, d pass from A form to the B form the long-wave absorption bands of these compounds should undergo a substantial increase in their intensities and be shifted 33-48 nm to the red region. Good agreement between the calculated and experimental spectra is observed if it is assumed that IIIa exists in the A form in methanol solution and IIId exists in the B form. Compound IIIc probably exists in the form of a mixture of two tautomeric forms; the band with $\lambda_{max}$ 278 nm corresponds to the A form, and the band with $\lambda_{max}$ 325 nm corresponds to the B form (see Table 2).

The tautomeric equilibria are sensitive to a change in the acidity of the medium. Measurements of the UV spectra of IIIc in methanol solutions with different amounts of $CF_3COOH$ (Fig. 1) show that the intensity of the longer-wave band increases and the intensity of the band with $\lambda_{max}$ 278 nm decreases with an increase in the $CF_3COOH$ concentration. The isobestic point is retained over the range of acid concentrations from 0 to 20% (by volume). In our opinion, these results reflect a change in the ratio of the concentrations of the tautomeric forms of IIIc: the percentage of the B form increases with an increase in the $CF_3COOH$

TABLE 1. Characteristics of IIIa-h

| Compound | mp, °C (dec.) | IR spectrum, cm$^{-1}$ (KBR) | | UV spectrum, $\lambda_{max}$, nm ($\varepsilon \cdot 10^{-3}$) | N found, % | Empirical formula | Calc., % | Yield, % |
|---|---|---|---|---|---|---|---|---|
| | | $\nu_{C=C}$ | $\nu_{NH}$* | | | | | |
| IIIa | 232...233 | 1655 | 3444 | 242 (20,4), 278 (6,1) | 25,4 | $C_{16}H_{13}N_5$ | 25,5 | 54 |
| IIIb | 239 | 1656 | 3440 | 244 (19,3), 279 (6,0) | 24,0 | $C_{17}H_{15}N_5$ | 24,3 | 50 |
| IIIc | 220 | 1658 | 3448 | 250, 278, 325† | 22,9 | $C_{17}H_{15}N_5O$ | 22,9 | 60 |
| IIId | 210...212 | — | — | 252 (8,0), 312 (2,6), 390 (24,6) | 26,2 | $C_{18}H_{18}N_6$ | 26,4 | 52 |
| IIIe | 242 | 1650 | 3442 | 247 (17,3), 282 (7,5) | 19,8 | $C_{16}H_{12}BrN_5$ | 19,8 | 70 |
| IIIf | 239...241 | 1653 | 3443 | 268 (14,1), 335 (6,0) | 26,3 | $C_{16}H_{12}N_6O_2$ | 26,2 | 63 |
| IIIg | 230...231 | 1659 | 3445 | 247 (16,8), 278 (6,0) | 24,2 | $C_{17}H_{15}N_5$ | 24,3 | 56 |
| IIIh | 238...240 | 1655 | 3443 | 242 (22,0), 280 (5,8) | 19,6 | $C_{16}H_{12}BrN_5$ | 19,8 | 65 |

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*In $CCl_4$.

†The determination of ε was difficult in connection with the unknown tautomeric composition of the solution of IIIc.

TABLE 2. Data from the Calculation of the Electronic Absorption Spectra of Tautomeric Forms A and B of IIIa, c, d

| Compound | Exptl. | | Calc. | | | |
|---|---|---|---|---|---|---|
| | | | A | | B | |
| | $\lambda_{max}$, nm | f | $\lambda_{max}$, nm | f | $\lambda_{max}$, nm | f |
| IIIa | 278 | 0,07 | 279 | 0,07 | 279, 308 | 0,25, 1,05 |
| IIIb | 278 | —* | 280 | 0,11 | — | — |
| | 325 | — | — | — | 316 | 1,17 |
| IIId | 312 | 0,07 | 302 | 0,86 | 329 | 0,12 |
| | 390 | 0,53 | 330 | 0,07 | 378 | 1,14 |

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*The determination of f for the absorption bands of IIIc was difficult, since the concentration of each of the tautomers in solution is unknown.

concentration. At acid concentrations above 20% the spectral pattern changes substantially, probably as a consequence of protonation.

The PMR spectra of IIIa-h measured in $d_6$-DMSO and $CF_3COOH$ provide substantial information regarding their structures (Table 3). The spectra of IIIa, b, e-h in both solvents contain, in addition to a multiplet of aromatic protons, two doublets of CH protons, while the spectra in $d_6$-DMSO also contain a singlet of the proton of an imino group. The absence in the spectra of signals that are typical for the protons of a $CH-CH_2$ group constitutes evidence for the absence of the 6,7-dihydro form B in solutions of these compounds (within the limits of the sensitivity of PMR spectroscopy). The situation is somewhat different in the case of IIIc, d. The PMR spectrum of IIIc in $d_6$-DMSO is similar to the spectra of IIIa, b, e-h (Table 3). However, in $CF_3COOH$, in addition to signals of protons of the A tautomer, signals of protons of the $A_2X$ system that belong to the 6,7-dihydro form B of IIIc also show up, and the signal of the protons of the $CH_3O$ group is split (δ 3.65 and 3.73 ppm). According to data on the integral intensities of the corresponding signals, the ratio between the concentrations of tautomeric forms A and B is ~1:1. Signals of both tautomers appear in the spectrum of IIId measured in $d_6$-DMSO (Table 3) with a ratio of the concentrations of the A and B forms of ~2:3; the $\delta_{N(CH_3)_2}$ values of these tautomers are 2.93 and 3.06 ppm, respectively. Signals of only the protons of the A tautomer appear in the PMR spectrum of IIId in $CF_3COOH$ (Table 3); the signal of the protons of the dimethylamino group is broadened because of its protonation in $CF_3COOH$ [$\delta_{N(CH_3)_2}$ = 3.14 ppm].

Thus, the results of the spectral studies show that IIIa, b, e, h exist in 4,7-dihydro form A (in solutions in $CCl_4$, $CH_3OH$, $d_6$-DMSO, and $CF_3COOH$), that IIIc can form a mixture of tautomers (in $CH_3OH$ and $CF_3COOH$), and that 6,7-dihydro form B is preferable for IIId (this explains the peculiarities of its IR spectrum). In IIIc, d the aromatic substituent in the 5 position of the two-ring system contains a methoxy or dimethylamino group, the electronic character of which evidently promotes stabilization of the B tautomer. The dimethylamino

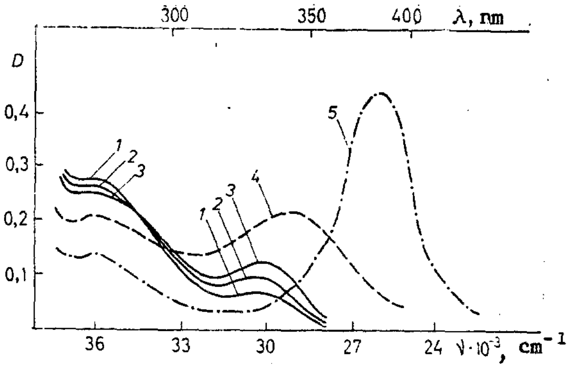


Fig. 1. UV spectra of IIIc (c = $4.5 \cdot 10^{-5}$ M) in methanol–$CF_3COOH$ mixtures percent by volume): 1) 0; 2) 8; 3) 20; 4) 50; 5) 100.

TABLE 3. PMR Spectra (δ, ppm) of IIIa-h

| Compound | In $d_6$-DMSO | | | | In $CF_3COOH$ | | |
|---|---|---|---|---|---|---|---|
| | 6-CH*, d | 7-CH*, d | aromatic protons, m | NH, s | 6-CH*, d | 7-CH*, d | Aromatic protons, m |
| IIIa | 5,32 | 6,65 | 7,15...7,90 | 10,52 | 5,21 | 6,25 | 6,96...7,41 |
| IIIb | 5,30 | 6,58 | 7,10...7,88 | 10,55 | 5,09 | 6,14 | 6,85...7,30 |
| IIIc† | 5,24 | 6,62 | 6,92...7,80 | 10,52 | 5,16 | 6,21 | 6,70...7,41 |
| IIId† | 5,15 | 6,57 | 6,65...7,77 | 10,40 | 5,31 | 6,25 | 6,96...7,79 |
| IIIe | 5,39 | 6,60 | 7,31...8,37 | 10,79 | 5,36 | 6,26 | 7,06...7,46 |
| IIIf | 5,58 | 6,60 | 7,31...8,37 | 10,56 | 5,26 | 6,20 | 7,10...8,16 |
| IIIg | 5,30 | 6,61 | 7,12...7,79 | 10,56 | 5,15 | 6,20 | 6,90...7,32 |
| IIIh | 5,35 | 6,70 | 7,20...8,05 | 10,68 | 5,11 | 6,15 | 6,90...7,45 |

*The spin–spin coupling constants (SSCC) range from 2.5 to 3.0 Hz.

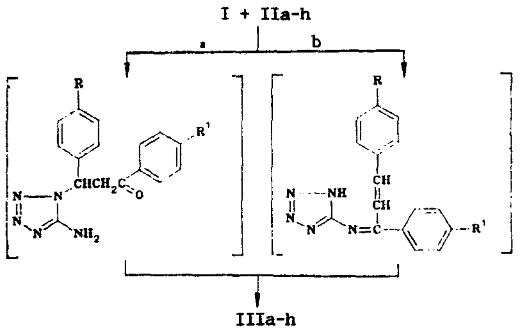
†The spectra of IIIc in $CF_3COOH$ and IIId in $d_6$-DMSO also contain signals of the protons of the CH–$CH_2$ group of the B tautomers: IIIc 5.80 (t, CH), 3.95 (d, $CH_2$), J = 6 Hz; IIId 5.76 (t, CH), 3.61 (d, $CH_2$), J = 7 Hz.

group loses electron-donor character on protonation; this is the reason that IIId exists in the A form in solution in $CF_3COOH$.

We measured the mass spectrum of IIIa; in addition to the molecular ion, $(M - 1)^+$, $(M - 28)^+$, and $(M - 77)^+$ ions, which reflect the principal pathways of primary fragmentation, appear in its mass spectrum.

In the condensation of arylamines with enones (the Skraup reaction) the amino group reacts with the β-cation atom of the ketone [4]. The specificity of the reaction may be different in similar condensations with the participation of hetarylamines [5, 6]. The structures of IIIa-h correspond to a specificity of condensation of I with chalcones in which the endocyclic atom of 5-aminotetrazole reacts with the β-carbon atom of the enone, while the amino group reacts with the keto group. This sort of specificity has been previously demonstrated for the cyclocondensation of chalcones with 3-amino-1,2,4-triazole [1]. Thus, the mechanism of the Skraup reaction is not realized in the reactions of chalcones with 3-amino-1,2,4-triazole and 5-aminotetrazole.

The change in the specificity of the cyclocondensation on passing from aniline to 3-amino-1,2,4-triazole [1] and 5-aminotetrazole is probably due to the change in the direction of alkylation of the amine in the first step of the reaction and its occurrence not at the amino group, but rather at the endocyclic atom (pathway a):



This conclusion is in agreement with data on the primary alkylation of 5-aminotetrazole at the endocyclic $N_{(1)}$ atom [4]. Since chalcones on reaction with arylamines generally do not form azomethine systems but only β-amination products [7], the probability of the formation of an azomethine in the first step (pathway b) is low.

## EXPERIMENTAL

The IR spectra of KBr pellets and solutions in $CCl_4$ with concentrations of $(4\text{-}6)\cdot10^{-4}$ M of IIIa-h were measured with a Specord IR-75 spectrometer. The electronic absorption spectra of solutions in methanol [$(3\text{-}5)\cdot10^{-5}$ M] were obtained with a Specord UV-vis spectrophotometer. The PMR spectra were recorded with a Tesla BS-2487-B spectrometer with tetramethylsilane (TMS) as the internal standard. The mass spectrum of IIIa was recorded with a Varian MAT CH-6 spectrometer at an ionizing voltage of 70 eV.

The individuality of IIIa-h was monitored by TLC on Silufol UV-254 plates with elution by chloroform.

5,7-Diphenyl-4,7-dihydrotetrazolo[1,5-a]pyrimidine (IIIa). A solution of 0.34 g (4 mmoles) of 5-aminotetrazole and 0.83 g (4 mmoles) of chalcone in 1 ml of DMF was refluxed for 2 h, after which the reaction mixture was cooled, and the precipitated crystals were removed by filtration to give 0.6 g (54%) of IIIa with mp 232-233°C [dec., benzene–dimethylformamide (3:1)]. Mass spectrum: 275 (31), 274 (13), 247 (35), 246 (65), 198 (70), 197 (21), 191 (16), 170 (26), 144 (28), 129 (27), 128 (57), 116 (20), 115 (21), 104 (100), 103 (21), 102 (19), 89 (20), 78 (16), 77 (67).

Compounds IIIb-h were similarly obtained.

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