Chemistry of Heterocyclic Compounds, Vol. 46, No. 7, 2010

3-[2(4)-PYRIMIDINYL]COUMARINS AND THEIR CONDENSED ANALOGS

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3-Pyrimidinylcoumarins have been synthesized by interacting 2- and 4-pyrimidinylacetonitriles with substituted salicylic aldehydes, but 9-pyrimidinylpyrano[2,3-f]chromene-4,8-diones were obtained with 8-formyl-7-hydroxychromones. Modification of the corresponding 7-hydroxycoumarins was carried out by acylation and aminomethylation.

Keywords: 7-acyloxy-3-pyrimidinylcoumarins, 8-dimethylaminomethyl-7-hydroxy-3-pyrimidinylcoumarins, pyrimidinylacetonitriles, 3-(2-pyrimidinyl)coumarins, 3-(4-pyrimidinyl)coumarins, 9-pyrimidinyl-4H,8H-pyrano[2,3-*f*]chromene-4,8-diones.

The chemistry of hetaryl-substituted coumarins has developed intensively in the last decades [1], however 3-pyrimidinylcoumarins have been described in only a few studies [2-6]. 3-(2- and 4-Pyrimidinyl)-coumarins were synthesized previously by building a pyrimidine fragment onto an already existing coumarin [2-5]. On interacting 5,6-benzocoumarin-3-carboxylic acid chloride with the dimethyl ester of dithiomalondiimido acid, 3-(4,6-dimethylthiopyrimidin-2-yl)coumarin was obtained [2], but on heterocyclization of the chalcones with amidines or thiourea, derivatives of 3-(4-pyrimidinyl)coumarin were synthesized [3-5], possessing antibacterial activity [5]. A different approach was proposed for the synthesis of 3-(5-pyrimidinyl)coumarins, *viz*. to construct the coumarin system on reaction with pyrimidine derivatives, particularly on condensation of 2-hydroxyacetophenones with pyrimidine-5-acetic acid [6].

With the aim of expanding the circle of pyrimidinyl-substituted coumarins we took advantage of the second approach. The subjects of our investigation were 4,6-dimethylpyrimidin-2-ylacetonitrile (**1a**) and 2,6-dimethylpyrimidin-4-ylacetonitrile (**1b**), which were introduced into a Knoevenagel reaction with substituted salicylic aldehydes **2-5** in 2-propanol in the presence of a catalytic amount of piperidine. As a result of reacting nitrile **1a** with aldehyde **3** in pure water 6-chloro-3-(4,6-dimethylpyrimidin-2-yl)-2-iminocoumarin (**6a**) was isolated, which was confirmed by the presence in its ^{1}H NMR spectrum, taken in DMSO-d_6, of a low field singlet for the NH proton at 10.79 ppm. The singlet of the proton at position 4 of the **6a** molecule was found in the region of 8.57 ppm.

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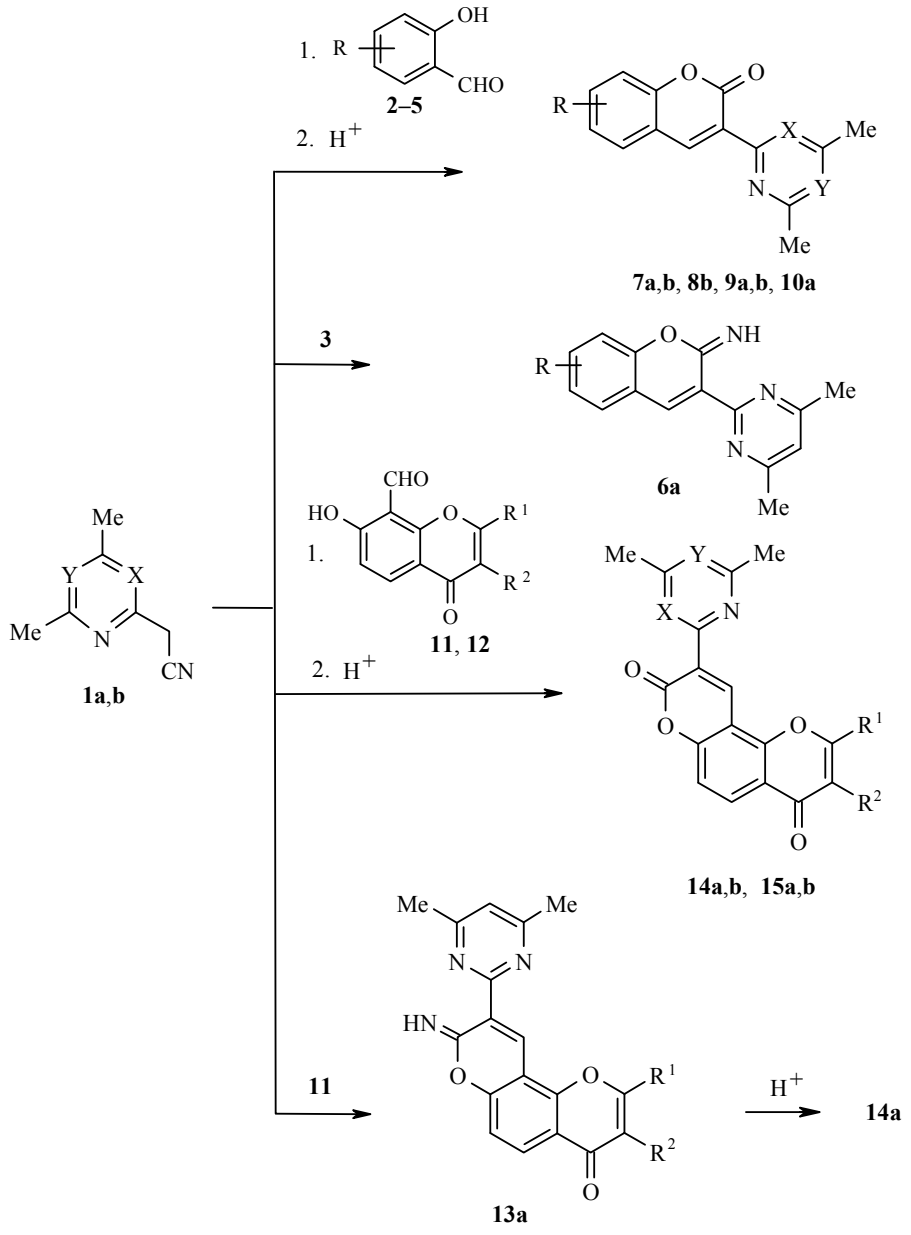
Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 7, pp. 1027-1038, July, 2010. Original article submitted October 5, 2009.



1,**7**,**9**,**10**,**14**,**15 a** X = N, Y = CH; **1**, **7-9**,**14**,**15 b** X = CH, Y = N; **2**,**7a**,**b** R = H, **3** R = 5-Cl, **6a**, **8b** R = 6-Cl, **4** R = 4-OH, **5** R = 3-MeO, **9a**,**b** R = 7-OH, **10a** R = 8-MeO; **11**, **13a**, **14a**,**b** R^1 = Me, R^2 = 4-ClC_6H_4O, **12**, **15a**,**b** R^1 = H, R^2 = 4-ClC_6H_4

In the remaining cases the reaction mixture was contaminated by the product of hydrolysis and it was further hydrolyzed with 3% H_2SO_4 or MeCOOH to the corresponding coumarins **7-10**. In their IR spectra intense bands were present for the stretching vibrations of the lactone carbonyl at 1712-1729 cm^{-1}. In the ^1H NMR spectra of 3-(4,6-dimethylpyrimidin-2-yl)coumarins **7a**, **9a**, and **10a**, recorded in DMSO-d_6, signals were observed for the pyrimidine fragment, *viz*. a six-proton singlet for the symmetrical methyl groups fell into the absorption region of DMSO and the H-5' proton at 7.09-7.20 ppm. The signals of the aromatic protons of the coumarin portion of the molecule, the most low field of which belonged to the H-4 proton singlet at 8.34-8.42 ppm, and signals for substituents were also observed.

TABLE 1. Characteristics of Compounds **6-10**, **12-18**

Compound	Empirical formula	Found, %, N / Calculated, %, N	mp,°C*	Yield, %
6a	$C_{15}H_{12}ClN_3O$	14.61 / 14.71	198	80
7a	$C_{15}H_{12}N_2O_2$	11.23 / 11.11	138	86
7b	$C_{15}H_{12}N_2O_2$	11.10 / 11.11	184	75
8b	$C_{15}H_{11}ClN_2O_2$	10.01 / 9.77	220	70
9a	$C_{15}H_{12}N_2O_3$	10.49 / 10.44	207	92
9b	$C_{15}H_{12}N_2O_3$	10.57 / 10.44	>300	87
10a	$C_{16}H_{14}N_2O_3$	9.97 / 9.92	181	75
12	$C_{16}H_9ClO_4$	—*[2]	144	68
13a	$C_{25}H_{18}ClN_3O_4$	9.17 / 9.14	252	67
14a	$C_{25}H_{17}ClN_2O_5$	6.12 / 6.08	288	78
14b	$C_{25}H_{17}ClN_2O_5$	6.15 / 6.08	268	51
15a	$C_{24}H_{15}ClN_2O_4$	6.74 / 6.50	215	55
15b	$C_{24}H_{15}ClN_2O_4$	6.44 / 6.50	292	42
16a	$C_{17}H_{14}N_2O_4$	8.91 / 9.03	165	68
16b	$C_{17}H_{14}N_2O_4$	9.27 / 9.03	158	90
17b	$C_{22}H_{16}N_2O_4$	7.39 / 7.52	178	65
18a	$C_{20}H_{23}N_3O_3$	12.12 / 11.89	128	53
18b	$C_{20}H_{23}N_3O_3$	11.80 / 11.89	164	57

*Solvents for recrystallization: 2-propanol (compounds **6a**, **8b**, **13a**), ethanol (compounds **7a**,**b**, **12**, **17b**), DMF–ethanol (compound **9a**), DMF (compound **9b**), methanol (compounds **10a**, **16a**,**b**), AcOH (compounds **14a**,**b**, **15a**,**b**), ethyl acetate (compounds **18a**,**b**).

*[2]Found, Cl, %: 11.91. Calculated, Cl, %: 11.79.

In the spectra of 3-(2,6-dimethylpyrimidin-4-yl)coumarins **7b-9b** the signals of the aromatic protons of the benzene portion of the benzopyrones were observed in the same regions as in products **7a**, **9a**, and **10a**, but the singlet of the H-4 proton underwent a paramagnetic displacement of 0.6 ppm (8.97-9.04 ppm), the same as for the singlet of the H-5' pyrimidine proton (7.94-8.04 ppm). Signals of the protons of the unsymmetrical methyl groups appeared as two three-proton singlets at 2.5 and 2.7 ppm. The most low field singlet of products **9a** (10.60 ppm) and **9b** (10.69 ppm) belongs to the proton of the OH group at position 7 of the coumarin nucleus.

If the effect of the structure of the compounds on the values of the chemical shifts in the ^1H spectra of the isomeric compounds **7a**,**b** and **9a**,**b** is considered, then the most characteristic of their differences is the significant change of chemical shift of the H-4 proton signal of the coumarin nucleus. In products **7a** and **9a** this signal absorbs close to 8.4 ppm and in compounds **7b** and **9b** its chemical shift is found close to 8.9 ppm. So

TABLE 2. IR and ^{1}H NMR Spectra of Compounds **6-10**, **12-18**

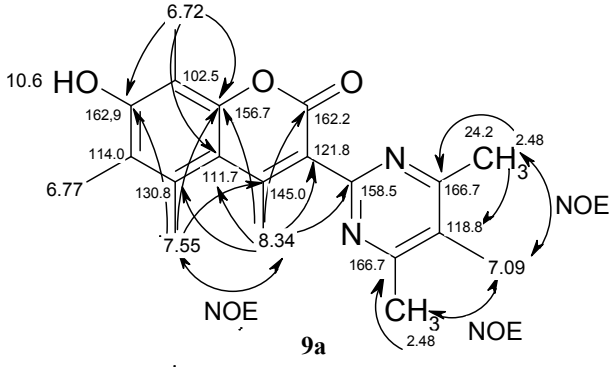
Com-pound	IR spectrum, $\nu_{C=O}$, cm^{-1}	^{1}H NMR spectrum, δ, ppm (*J*,Hz)*
6a	1643*[2]	2.57 (6H, s, 4',6'-CH_3); 7.22 (1H, d, *J* = 8.8, H-8); 7.26 (1H, s, H-5'); 7.47 (1H, dd, $J_{7,8}$ = 8.8, $J_{7,5}$ = 2.4, H-7); 7.70 (1H, d, *J* = 2.4, H-5); 8.57 (1H, s, H-4); 10.79 (1H, s, NH)
7a	1727	2.50 (6H, s, 4',6'-CH_3); 7.19 (1H, s, H-5'); 7.35 (1H, t, *J* = 7.6, H-6); 7.40 (1H, d, *J* = 7.6, H-8); 7.63 (1H, t, *J* =7.6, H-7); 7.80 (1H, d, *J* = 7.6, H-5); 8.42 (1H, s, H-4)
7b	1719	2.53 (3H, s, 6'-CH_3); 2.68 (3H, s, 2'-CH_3); 7.38-7.43 (2H, m, H-6,8); 7.69 (1H, m, H-7); 7.90 (1H, dd, $J_{5,6}$ = 7.6, $J_{5,7}$ = 1.2, H-5); 8.04 (1H, s, H-5'); 9.04 (1H, s, H-4)
8b	1724	2.53 (3H, s, 6'-CH_3); 2.68 (3H, s, 2'-CH_3); 7.46 (1H, d, *J* = 8.8, H-8); 7.66 (1H, dd, $J_{7,8}$ = 8.8, $J_{7,5}$ = 2.4, H-7); 8.01 (2H, s, H-5,5'); 9.01 (1H, s, H-4)
9a	1712	2.48 (6H, s, 4',6'-CH_3); 6.72 (1H, d, *J* = 2.0, H-8); 6.77 (1H, dd, $J_{6,8}$ = 2.0, $J_{6,5}$ = 8.4, H-6); 7.09 (1H, s, H-5'); 7.55 (1H, d, *J* = 8.4, H-5); 8.34 (1H, s, H-4); 10.60 (1H, s, 7-OH)
9b	1729	2.41 (3H, s, 6'-CH_3); 2.57 (3H, s, 2'-CH_3); 6.72 (1H, d, *J* = 2.0, H-8); 6.81 (1H, dd, $J_{6,8}$ = 2.0, $J_{6,5}$ = 8.4, H-6); 7.74 (1H, d, *J* = 8.4, H-5); 7.94 (1H, s, H-5'); 8.90 (1H, s, H-4); 10.69 (1H, s, 7-OH)
10a	1729	2.50 (6H, s, 4',6'-CH_3); 3.97 (3H, s, 8-CH_3O); 7.18 (1H, s, H-5'); 7.26-7.32 (3H, m, H-5,6,7); 8.39 (1H, s, H-4)
12	1636	7.09 (1H, d, *J* = 9.2, H-6); 7.43 (2H, d, *J* = 8.4, H-2',6'); 7.62 (2H, d, *J* = 8.4, H-3',5'); 8.26 (1H, d, *J* = 9.2, H-5); 8.48 (1H, s, H-2); 10.53 (1H, s, CHO); 12.24 (1H, br. s, 7-OH)
13a	1630	2.72 (3H, s, 2-CH_3); 3.04 (6H, s, 4",6"-CH_3); 6.92 (2H, d, *J* = 8.8, H-2',6'); 7.33 (2H, d, *J* = 8.8, H-3',5'); 7.90 (2H, m, H-5",6); 9.01 (1H, d, *J* = 9.2, H-5); 10.21 (1H, s, H-10)
14a	1744[α], 1651[γ]	2.74 (3H, s, 2-CH_3); 3.03 (6H, s, 4",6"-CH_3); 6.94 (2H, d, *J* = 8.8, H-2',6'); 7.32 (2H, d, *J* = 8.8, H-3',5'); 7.79 (1H, d, *J* = 9.2, H-6); 7.84 (1H, s, H-5"); 8.87 (1H, d, *J* = 9.2, H-5); 10.34 (1H, s, H-10)
14b	1742[α], 1651[γ]	2.75 (3H, s, 2-CH_3); 3.02 (3H, s, 6"-CH_3); 3.16 (3H, s, 2"-CH_3); 6.95 (2H, d, *J* = 8.8, H-2',6'); 7.35 (2H, d, *J* = 8.8, H-3',5'); 7.73 (1H, d, *J* = 9.2, H-6); 8.80 (1H, d, *J* = 9.2, H-5); 9.07 (1H, s, H-5"); 10.20 (1H, s, H-10)
15a	1749[α], 1648[γ]	[3.02 (6H, s, 4",6"-CH_3); 7.48 (2H, d, *J* = 8.4, H-2',6'); 7.53 (2H, d, *J* = 8.4, H-3',5'); 7.79 (1H, d, *J* = 9.2, H-6); 7.83 (1H, s, H-5"); 8.50 (1H, s, H-2); 8.93 (1H, d, *J* = 9.2, H-5); 10.34 (1H, s, H-10)] 2.49 (6H, s, 4",6"-CH_3); 6.98 (1H, s, H-5"); 7.39 (2H, d, *J* = 8.4, H-2',6'); 7.51 (1H, d, *J* = 9.2, H-6); 7.63 (2H, d, *J* = 8.4, H-3',5'); 8.35 (1H, d, *J* = 9.2, H-5); 8.60 (1H, s, H-2); 8.81 (1H, s, H-10)
15b		2.59 (3H, s, 6"-CH_3); 2.75 (3H, s, 2"-CH_3); 7.46 (2H, d, *J* = 8.4, H-2',6'); 7.55 (1H, d, *J* = 9.2, H-6); 7.64 (2H, d, *J* = 8.4, H-3',5'); 8.15 (1H, s, H-5"); 8.42 (1H, d, *J* = 9.2, H-5); 8.68 (1H, s, H-2); 9.45 (1H, s, H-10)
16a	1752	2.34 (3H, s, CH_3CO); 2.50 (6H, s, 4′,6′-CH_3); 7.11 (1H, dd, $J_{6,8}$ = 2.0, $J_{6,5}$ = 8.4, H-6); 7.18 (1H, s, H-5′); 7.22 (1H, d, *J* = 2.0, H-8); 7.85 (1H, d, *J* = 8.4, H-5); 8.45 (1H, s, H-4)
16b	1762, 1734	2.34 (3H, s, CH_3CO); 2.53 (3H, s, CH_3-6'); 2.68 (3H, s, 2'-CH_3); 7.17 (1H, dd, $J_{6,8}$ = 2.0, $J_{6,5}$ = 8.4, H-6); 7.27 (1H, d, *J* = 2.0, H-8); 7.96 (1H, d, *J* = 8.4, H-5); 8.03 (1H, s, H-5'); 9.07 (1H, s, H-4)
17b	1729	2.53 (3H, s, 6'-CH_3); 2.68 (3H, s, 2'-CH_3); 7.32 (1H, dd, $J_{6,8}$ = 1.6, $J_{6,5}$ = 8.4, H-6); 7.43 (1H, d, *J* = 1.6, H-8); 7.60 (2H, t, *J* = 7.6, H-2",6"); 7.74 (1H, t, *J* = 7.6, H-4"); 8.03 (1H, d, *J* = 8.4, H-5); 8.04 (1H, s, H-5'); 8.18 (2H, d, *J* = 7.6, H-3",5"); 9.09 (1H, s, H-4)
18a	1734	1.17 (6H, t, *J* = 7.2, 2C$\underline{H_3}$$CH_2$); 2.50 (6H, s, 4',6'-$CH_3$); 2.74 (4H, q, *J* = 7.2, 2CH_3C$\underline{H_2}$); 4.09 (2H, s, 8-CH_2); 6.64 (1H, d, *J* = 8.4, H-6); 7.11 (1H, s, H-5'); 7.50 (1H, d, *J* = 8.4, H-5); 8.35 (1H, s, H-4); (OH exchanged with D_2O)
18b	1732	1.19 (6H, t, *J* = 7.2, 2C$\underline{H_3}$$CH_2$); 2.50 (3H, s, 6'-$CH_3$); 2.63 (3H, s, 2'-$CH_3$); 2.78 (4H, q, *J* = 7.2, 2CH_3C$\underline{H_2}$); 4.12 (2H, s, 8-CH_2); 6.66 (1H, d, *J* = 8.4, H-6); 7.57 (1H, d, *J* = 8.4, H-5); 8.01 (1H, s, H-5'); 8.35 (1H, s, H-4); (OH exchanged with D_2O)

*^{1}H NMR spectra of compounds **13a**, **14a**,**b**, and **15a** (given in square brackets) were recorded in CF_3CO_2D, the remainder in DMSO-d_6.

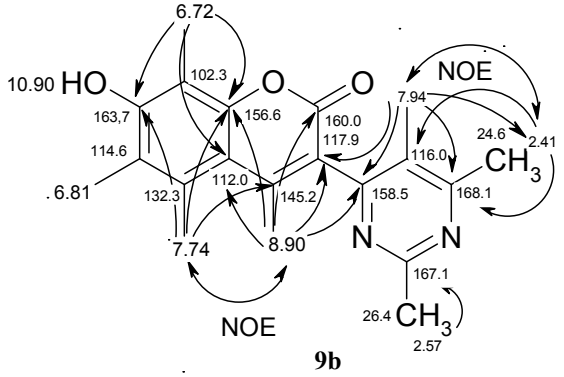
significant a change of chemical shift may only be linked with a different conformation of these substances. The sole parameter influencing the chemical shift, which may change from one compound to another, is the torsion angle between the heterocyclic fragments of the molecule. On the basis of the data of NMR spectra given above the conclusion may be drawn that the H-5' atom of the pyrimidine ring in compounds **7b-9b** experiences a strong nonbonding interaction with the carbonyl oxygen atom, and the H-4 atom of the coumarin nucleus undergoes a deshielding influence from the unshared pair of electrons of the nitrogen atom of the pyridine ring. A planar conformation is therefore established in which the similarly charged atoms of nitrogen and oxygen are removed furthest from one another. On the other hand, in compounds **7a**, **9a**, and **10a** the pyrimidine nucleus is removed from the plane of the coumarin, as is indicated by the diamagnetic displacement of the H-4 proton signal by 0.6 ppm.

With the aim of a more detailed investigation of the structure of isomers **a** and **b** we studied the NMR spectra of compounds **9a**,**b**. In addition to the proton spectra we also measured heteronuclear $^{1}H–^{13}C$ HMQC and HMBC spectral correlations. Measurement of these spectra enabled reliable assignments of carbon signals and afforded the possibility of comparing values of chemical shifts of carbon atoms in isomeric compounds. In such investigations assignment of the signals of protonated carbon atoms may be made on the basis of HMQC spectra, and assignment of the signals of quaternary carbon atoms on the basis of heteronuclear correlations through 2-3 chemical bonds in HMBC spectra.

The most important of the correlations found in the HMBC spectra are shown below with pointers, the found values of the chemical shifts of protons and carbon atoms are shown near the appropriate atoms.



9a



9b

Conclusions on the conformation of molecules **9a**,**b** may be made on the basis of the values of the chemical shifts of atom C(3). In compound **9a** its chemical shift is 121.8 and in product **9b** 117.9 ppm. The chemical shift of this carbon atom is therefore reduced by almost 4 ppm. The diamagnetic displacement of the signal indicates that in compound **9b** conjugation between the heterocyclic fragments of the molecule is significantly stronger. This is possible by reducing the torsion angle between them on going from product **9a** to **9b**.

Additional information on the relative orientation of the heterocyclic fragments was given by NOESY spectra. Analysis of the available correlations in the NOESY spectrum of compound **9b** shows the absence of a significant effect between the H-4 atom of the coumarin fragment and H-5' of the pyrimidine nucleus. This indicates their spatial separation. The conclusion may therefore be drawn as to the existence of this molecule in the planar (*E*)-conformation, or in a canted conformation with a small angle between the heterocyclic fragments. For compound **9a** the NOESY method was uninformative in view of the absence of protons in the pyrimidine nucleus which might have been close to the coumarin proton.

The NMR data therefore indicate that isomers **9a** and **9b** differ significantly in the torsion angle between the heterocyclic fragments. If the **9b** molecule is practically planar then in **9a** the torsion angle between the heterocyclic fragments has a significant value.

To confirm this conclusion quantum-chemical calculations were carried out of the optimized geometry of the **9a**,**b** molecules and the NMR spectra were calculated. The orientation of the pyrimidine ring in the planar structure **9b** is given in Fig. 1. Stabilization occurs as a result of intramolecular interactions of two H atoms with O and N atoms. In spite of the fact that the O···H distance is shorter (Fig. 1) and the charges on both H atoms are the same (0.132), the mean value of the diagonal elements of the magnetic shielding tensor (σ_{iso}) is less for the hydrogen atom of the coumarin fragment (H_c) σ_{iso} = 22.67 ppm (which corresponds to the chemical shift $\delta_{H,iso}$ = 9.35 ppm, determined relative to σ_{iso} for H atoms in the TMS molecule, calculated by the same method and on the same basis), than for H of the pyrimidine fragment (H_p) σ_{iso} = 23.37 ppm ($\delta_{H,iso}$ = 8.65 ppm). The calculated values of δ_H were slightly overstated in comparison with the experimental δ_H = 8.90 (H_c) and 7.94 ppm (H_p), which may be caused both by errors of calculation and by the fact that a portion of the molecules are found in a less stable state (Fig. 2) (the difference in energies of the two structures (Figs. 1 and 2) corresponds to $E_{1,pl} - E_{1,nonpl}$ = -29.4 kJ/mol, which, as calculations within the framework of DFT by the B3LYP/6-31(d, p) method showed, is close to the energy of a medium strength H bond), which is characterized by a smaller value of δ_H for H_c (7.02 ppm). It should be noted that the value of the anisotropy σ_{ii} is less for H_c (10.08 ppm) than for H_p (12.04 ppm) (Fig. 1). It may be concluded that for the planar structure (Fig. 1) the π-electron current shows up in the value of δ_H for H_c more strongly than for H_p. This is also indicated by the significant delocalization of π-orbitals (for example in Fig. 1 the localization of the highest occupied MO is given).

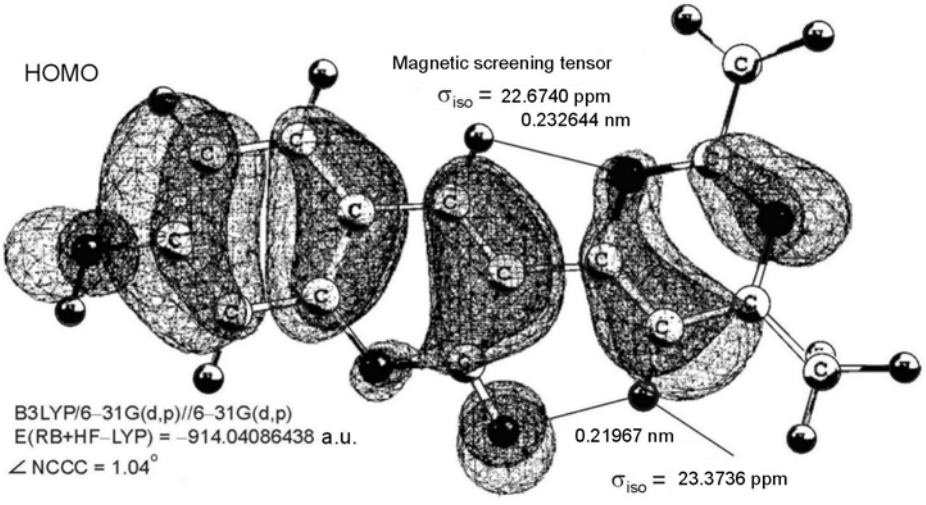


Fig. 1. Most stable, practically planar structure of compound **9b**.

A planar structure was unstable for isomer **9a** (Fig. 3), optimization of the geometry by the HF/6-31G(d, p) method gives an angle of about 35° between the planes of the two fragments of this isomer. For H_c the calculated value of δ_H = 8.02 ppm, which is somewhat less than the experimental value of δ_H = 8.34 ppm as a

result of errors of calculation or the presence in the system of molecules with a more planar structure. Consequently additional calculations were carried out with optimization of the geometry within the framework of DFT by the B3LYP/6-31G(d, p) method, which gave an angle between the planes of about 23° and a value of δ_H = 8.66 ppm for atom H_c. The mean value of the two calculations of δ_H corresponds to the experimental value of δ_H.

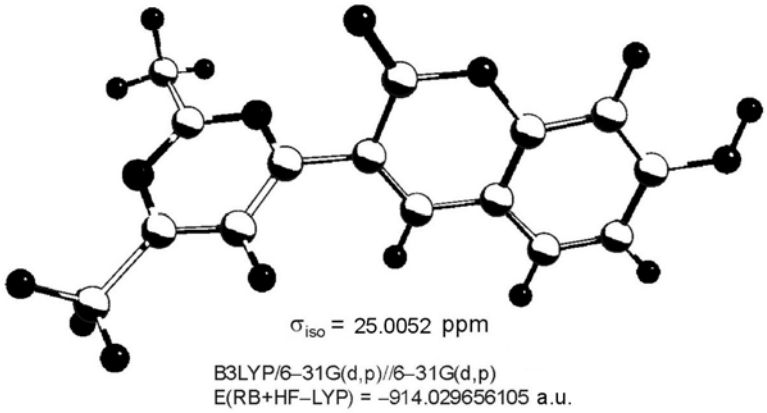


Fig. 2. Less stable structure for isomer **9b** (on optimization of the geometry a local minimum was found on the potential energy surface) with a turn of the pyrimidine fragment by 57.1° (HF/6-31G(d, p)) or 45.4° (B3LYP/6-31G(d, p)).

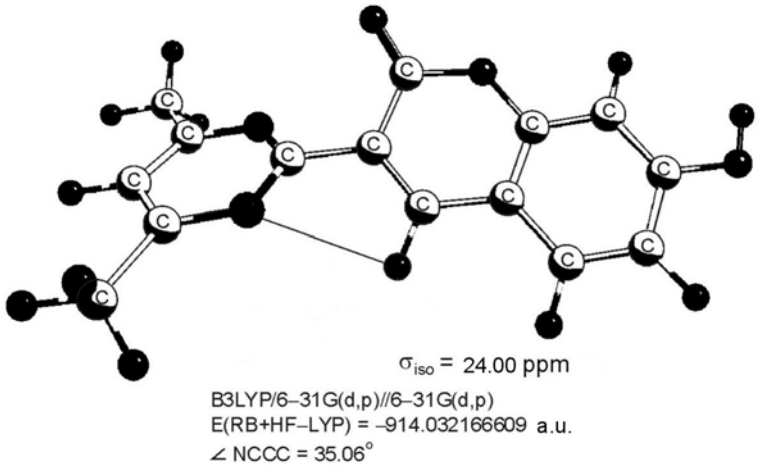


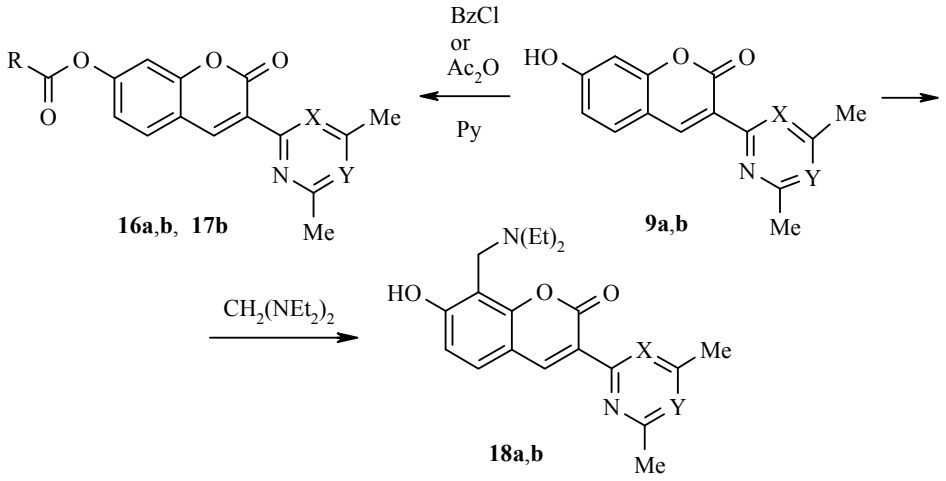
Fig. 3. Most stable structure for isomer **9a** with a turn of the pyrimidine fragment through an angle of 35° (HF/6-31G(d, p)) or 23° (B3LYP/6-31G(d, p)).

We also investigated the interaction of pyrimidinylacetonitriles **1a**,**b** with condensed *ortho*-hydroxybenzaldehydes, in particular with 8-formyl-7-hydroxychromones **11**, **12** obtained by the Daff reaction from the corresponding 7-hydroxychromones. The condensation was carried out under the same conditions as for compounds **1** and **2-5**. As a result of the reaction of nitrile **1a** with aldehyde **11** the intermediate 3-(4-chlorophenoxy)-9-(4,6-dimethylpyrimidin-2-yl)-8-imino-2-methyl-4H,8H-pyrano[2,3-*f*]chromen-4-one (**13a**) was isolated. Its hydrolysis to the corresponding condensed coumarin **14a** was carried out in acetic acid. The pyrimidine derivatives 4H,8H-pyrano[2,3-*f*]chromene-4,8-diones **14b** and **15a**,**b** were synthesized by the analogous hydrolysis of partially hydrolyzed condensation products of **1a**,**b** and **11**, **12.**

A strong absorption band was present in the IR spectrum of product **13a** for the chromone C=O at 1630 cm^{-1}, and in the spectra of compounds **14a**,**b** and **15a**,**b** there were bands for the stretching vibrations of the C=O of the γ and α pyrone fragments at 1648-1651 and 1742-1749 cm^{-1} respectively. For the ^{1}H NMR spectra of these compounds recorded in CF_3CO_2D the presence of the most low field singlet of the H-10 proton at 10.20-10.34 ppm was characteristic. In the spectrum of imino derivative **13a** it resonated at 10.21 ppm and in the corresponding coumarin **14a** it was displaced to 10.34 ppm at low field.

The presence of a hydroxyl group at position 7 of coumarins **9a**,**b** made their modification possible. On acylating products **9a**,**b** with acetic anhydride or benzoyl chloride in pyridine their acetyl (**16a**,**b**) and benzoyl (**17b**) derivatives were obtained.

The ^{1}H NMR spectra of these derivatives were characterized by the display of signals of the acetyl group protons at 2.34 ppm (**16a**,**b**) or of the aromatic protons of the benzoyl group (**17b**) and an insignificant displacement of the protons of the coumarin nucleus towards low field compared with the signals of the initial products **9a**,**b**. It should be noted that unlike the initial compounds the doublet of the H-8 proton is found at lower field than the signal of the H-6 proton.



16a,**b** R = Me; **17b** R = Ph; **16a**, **18a** X = N, Y = CH; **16–18 b** X = CH, Y = N

On aminomethylating 7-hydroxy-3-pyrimidinylcoumarins **9a**,**b** with *bis*-diethylaminomethane in dioxane the 8-diethylaminomethyl derivatives **18a**,**b** were synthesized, which was indicated by the absence of a signal for the H-8 proton at 6.73 ppm observed in the spectra of the initial compounds **9a**,**b**, and the appearance of a methylene group signal at 4.1 ppm and signals of the ethyl group protons.

Solutions of the synthesized 3-pyrimidinylcoumarins in organic solvents possessed blue fluorescence in UV light. The most intense fluorescence was observed for the Mannich bases **18a**,**b**.

Previously unknown 3-pyrimidinylcoumarins and their condensed analogs 9-pyrimidinylpyrano-[2,3-*f*]chromene-4,8-diones have therefore been synthesized from 2- and 4-pyrimidinylacetonitriles and substituted salicylic aldehydes. The presence of a hydroxyl group in position 7 of the coumarins made it possible to modify them by acylation and aminomethylation.

EXPERIMENTAL

The IR spectra were taken on a Perkin-Elmer instrument in KBr disks. The ^{1}H NMR spectra were recorded in DMSO-d_6 and CF_3CO_2D on a Varian Mercury 400 (400 MHz) spectrometer, internal standard was

TMS. Calculations of the optimized geometry were carried out by the HF/6-31G(d, p) or B3LYP/6-31G(d, p) method, and calculations of the NMR spectra by the GIAO/B3LYP/6-31G(d, p) method using the Gaussian 03 set of programs [7]. A portion of the calculations by the HF/6-31G(d, p) method were carried out using the GAMESS (version 7.15) set of programs [8, 9]. The purity of the synthesized compounds was checked by TLC on Silufol UV-254 plates, eluent was chloroform–methanol, 9:1.

6-Chloro-3-(4,6-dimethylpyrimidin-2-yl)-2-iminocoumarin (6a). 5-Chloro-2-hydroxybenzaldehyde (**3**) (0.15 g, 1.5 mmol) and piperidine (2 drops) were added to a solution of 4,6-dimethylpyrimidin-2-yl-acetonitrile (**1a**) (0.16 g, 1.5 mmol) in 2-propanol (1 ml) with heating. The mixture was maintained at room temperature for 1 day, the precipitated solid was filtered off, and washed with 2-propanol.

3-Pyrimidinylcoumarins 7-10. Condensation of the appropriate pyrimidinylacetonitrile **1a**,**b** and substituted 2-hydroxybenzaldehydes **2-5** was carried out analogously to the synthesis of compound **6a**. Hydrolysis of the condensation products to the corresponding coumarins **7a**,**b**, **8b**, **9a,b**, and **10a** was carried out by boiling (4-6 h) the reaction mixture with 3% aqueous H_2SO_4 solution (10 ml) (check by TLC), the mixture was cooled, neutralized with ammonia solution, and the solid filtered off. The partially hydrolyzed condensation product (0.47 g) of compounds **1a** and **5b** was dissolved in acetic acid (1 ml), maintained at room temperature for 1 day, triturated with water (5 ml), the solid was filtered off, and recrystallized from a suitable solvent.

3-(4-Chlorophenyl)-8-formyl-7-hydroxychromone (12). A solution of 3-(4-chlorophenyl)-7-hydroxy-chromone (1.09 g, 4 mmol) and hexamethylenetetramine (5.6 g, 40 mmol) in acetic acid (20 ml) was heated on a water bath for 8 h, poured into a boiling mixture (24 ml) of HCl–H_2O, 1:2, diluted with water (40 ml), and after several hours the precipitated solid was filtered off.

3-(4-Chlorophenoxy)-9-(4,6-dimethylpyrimidin-2-yl)-8-imino-2-methyl-4H,8H-pyrano[2,3-*f*]chromen-4-one (13a) was obtained by the condensation of compound **1a** (0.33 g, 1 mmol) and 3-(4-chlorophenoxy)-8-formyl-7-hydroxy-2-methylchromone (**11**) (0.15 g, 1 mmol) in 2-propanol (25 ml) by the procedure for compound **6a**.

9-Pyrimidinyl-4H,8H-pyrano[2,3-*f*]chromene-4,8-diones 14a,b, 15a,b. A solution of compound **13a** (0.46 g, 1 mmol) or the partially hydrolyzed products of compounds **1a**,**b** and **12**, **1b** and **11** in acetic acid (3 ml) was boiled for 5 min, cooled, the precipitated solid was filtered off, and washed with ethanol.

7-Acetoxy-3-pyrimidinylcoumarins 16a,b. Acetic anhydride (0.12 g, 1.1 mmol) was added to a suspension of the appropriate 7-hydroxy-3-pyrimidinylcoumarin **9a**,**b** (0.27 g, 1 mmol) in pyridine (1.5 ml), heated to solution, and maintained for 2 day at room temperature. The precipitated solid was filtered off, washed with water, and with methanol.

7-Benzoyloxy-3-(2,6-dimethylpyrimidin-4-yl)coumarin (17b). Benzoyl chloride (0.28 g, 2 mmol) was added to a solution of 3-(2,6-dimethylpyrimidin-4-yl)-7-hydroxycoumarin (**9b**) (0.27 g, 1 mmol) in pyridine (2 ml), maintained for 1 day at room temperature, the precipitated solid was filtered off, and washed with ethanol.

8-Diethylaminomethyl-7-hydroxy-3-pyrimidinylcoumarins 18a,b. *Bis*-diethylaminomethane (0.2 g, 1.3 mmol) was added to a suspension of 7-hydroxy-3-pyrimidinylcoumarin (0.27 g, 1 mmol) in dioxane (3 ml) and boiled for 5-6 h (check by TLC). The solvent was evaporated in vacuum, the oily residue was triturated under ethyl acetate, and the solid filtered off.

The constants and yields of compounds **6-10**, **12-18** are given in Table 1, and data of IR and ^{1}H NMR spectra in Table 2.

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