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Synthesis and Transformations of 9-Substituted Imidazo[1,2-*a*]benzimidazole-2-carbaldehydes

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Abstract—Ethyl 2-formyl-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate was synthesized for the first time in a high yield by heating a solution of ethyl 2-(dibromomethyl)-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate in ethanol. Acid hydrolysis of the product gave less accessible 9-methylimidazobenzimidazole-2-carbaldehyde. Ethyl 2-formyl-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate underwent cyclization to fused oxopyridazine derivative by treatment with hydrazine hydrate, it reacted as a typical aldehyde with acetophenones, hydroxylamine hydrochloride, and malononitrile, and its reaction with acetylacetone and thiourea (Biginelli reaction) afforded the corresponding pyrimidine derivative.

Keywords: ethyl 2-formyl-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate, 9-methyl-9*H*-imidazo-[1,2-*a*]benzimidazole-2-carbaldehyde, 6-methyl-2*H*-pyridazino[4′,5′:4,5]imidazo[1,2-*a*]benzimidazol-1(6*H*)-one, ethyl 2-cyano-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate, Biginelli reaction

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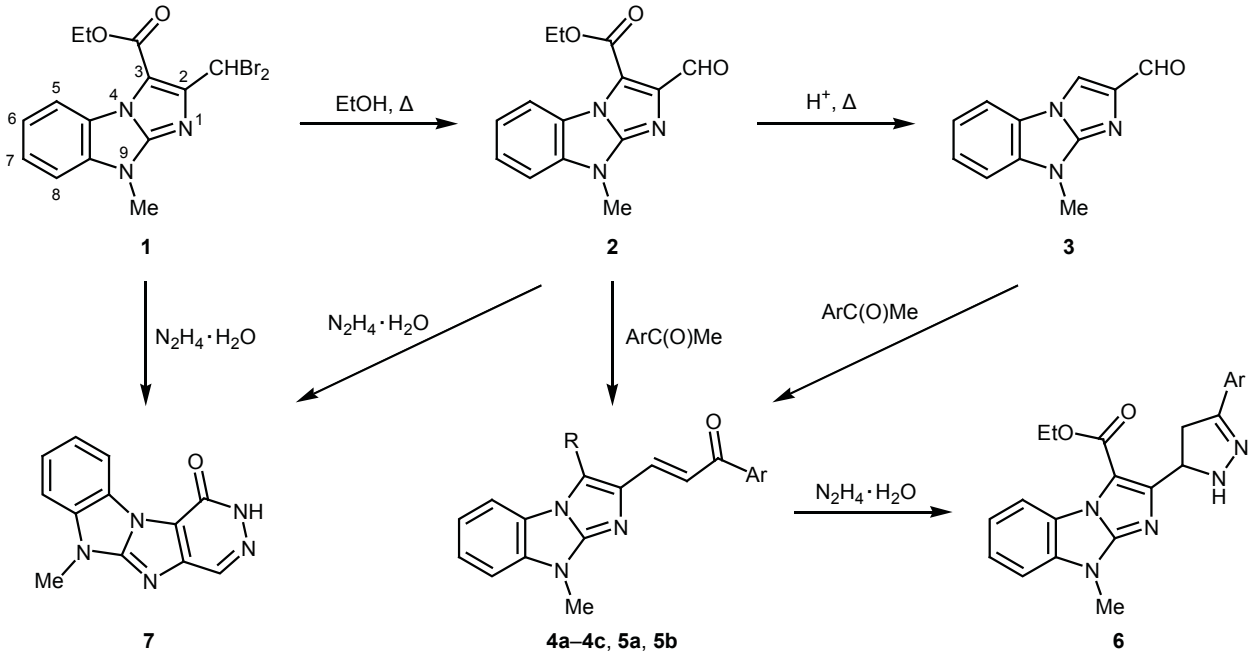
2-Formylimidazo[1,2-*a*]benzimidazoles, unlike their 3-formyl analogs, have been poorly studied. While searching for new β-lactamase inhibitors, Venkatesan et al. [1] described the synthesis of 9-methylimidazo[1,2-*a*]benzimidazole-2-carbaldehyde which was characterized only by color (brown crystals) and molecular weight. It was obtained by condensation of 1-methyl-1*H*-benzimidazol-2-amine with ethyl 3-bromopyruvate, reduction of ethyl imidazo[1,2-*a*]-benzimidazole-2-carboxylate thus formed to the corresponding alcohol, and oxidation of the latter; the overall yield did not exceed 16%.

Another approach to 2-formylimidazobenzimidazoles has been proposed, and study of their reactivity has been started, which seems important in view of various pharmacological activities of imidazo[1,2-*a*]-benzimidazole derivatives [2–5]. We used preparatively accessible ethyl 2-(dibromomethyl)-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate (**1**) as starting material. The synthesis of analogous methyl ester by the bromination of methyl 2,9-dimethylimidazo[1,2-*a*]benzimidazole with *N*-bromosuccinimide was reported in [6]. Although the hydrolysis of geminal dibromides to aldehydes is usually carried out in the presence of silver nitrate or weakly alkaline reagents, dibromomethyl derivative **1** was successfully converted to aldehyde **2** by heating in boiling ethanol (yield ~80%; Scheme 1). The acid hydrolysis of **2** was accompanied by decarboxylation of intermediate 3-carboxylic acid to produce aldehyde **3**. However, this reaction involved considerable tar formation, especially when the reaction solution was made alkaline in the isolation stage, so that the yield of **3** decreased to 42%. Presumably, the observed tar formation is related to intermolecular addition of the unsubstituted C^3 atom (which possesses the largest negative charge in imidazobenzimidazoles) to the aldehyde carbonyl group.

It is known that in the ^{1}H NMR spectra of many 2,9-disubstituted imidazobenzimidazoles ($CDCl_3$), the 3-H signal appears at a higher field (δ ~7 ppm) than the signals from the other aromatic protons (5-H–8-H) [7]. In contrast, the 3-H proton of **3** appears as the most downfield signal (δ 8.04 ppm) due to electron-withdrawing effect and magnetic anisotropy of the neighboring carbonyl group.

The condensation of 2-formylimidazobenzimidazoles **2** and **3** with acetophenones in ethanol in the presence of sodium hydroxide gave chalcone analogs **4** and **5** which were assigned exclusively *E* configuration on the basis of the ^{1}H NMR data. Like most 9-sub-

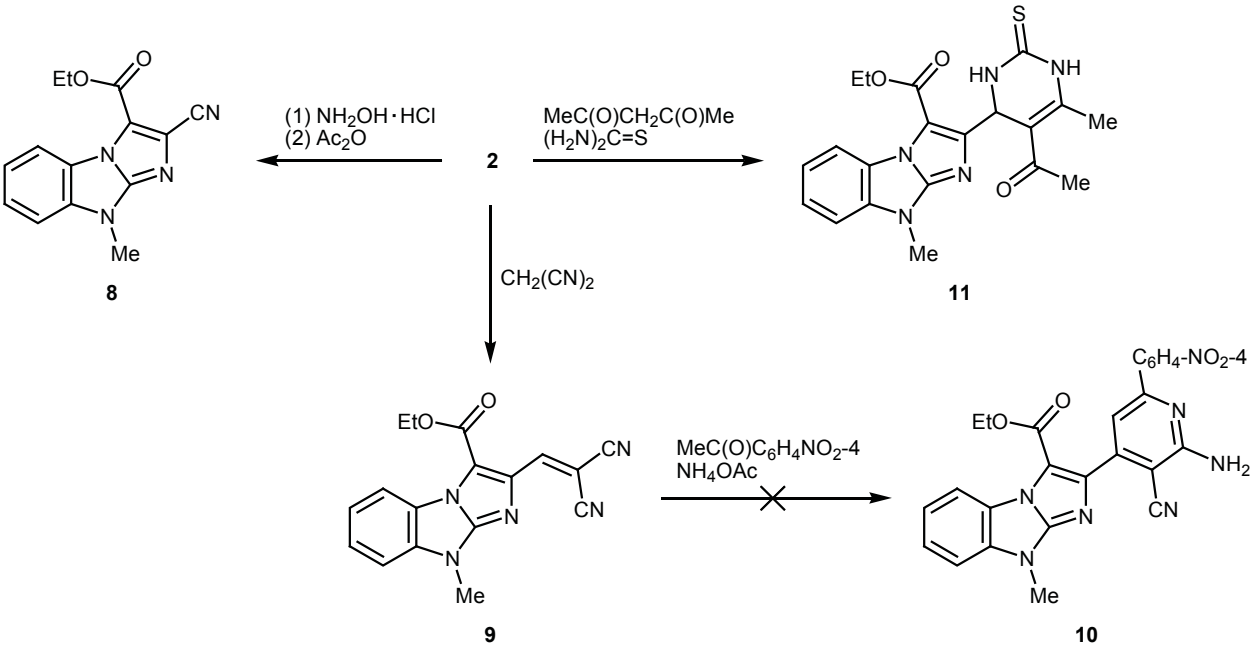
Scheme 1.



4, R = COOEt; **5**, R = H; **4**, **5**, Ar = 4-$O_2NC_6H_4$ (**a**), 1,1′-biphenyl-4-yl (**b**), naphthalen-1-yl (**c**); **6**, Ar = 1,1′-biphenyl-4-yl.

stituted imidazobenzimidazoles having no substituent on C^3, compounds **5** formed electrostatically stabilized complexes with DMSO [7]. Therefore, the 3-H signal of, e.g., **5a** shifted downfield by ~0.6 ppm in going from $CDCl_3$ to polar DMSO and was observed at δ 8.29 ppm. Unlike many α,β-unsaturated ketones which exhibit luminescence properties, imidazobenzimidazole **4** and **5** showed no luminescence. Chalcone **4b** reacted with hydrazine hydrate in boiling ethanol to give dihydropyrazole **6**. The reaction of **2** or **1** with hydrazine hydrate led to the formation of previously unknown fused oxopyridazine derivative **7**; compounds structurally related to the latter were found to exhibit cytotoxic and [8] and antimicrobial [9] activities.

Scheme 2.



Aldehyde **2** was converted to the corresponding oxime by treatment with hydroxylamine hydrochloride, and subsequent dehydration by the action of acetic anhydride on heating for a short time afforded 75% of nitrile **8** (Scheme 2). According to the data of [10], 2-(imidazo[1,2-*a*]pyridin-2-ylmethylidene)malononitrile is a good scaffold for the synthesis of various 2-hetaryl-substituted derivatives. Analogous nitrile **9** was obtained by us from aldehyde **2** and malononitrile in nearly quantitative yield. However, fusion of **9** with 4-nitroacetophenone and ammonium acetate, which was expected (by analogy with [10]) to furnish 2-pyridinylimidazobenzimidazole **10**, led to the formation of a complex mixture of products which we failed to separate and identify.

Taking into account a broad spectrum of pharmacological activity of 3,4-dihydropyrimidine-2-thione derivatives, including anticancer activity [11, 12], we synthesized pyrimidine derivative **11** by the three-component Biginelly reaction of aldehyde **2** with thiourea and acetylacetone (Scheme 2).

Thus, we have proposed a fairly convenient procedure for the synthesis of previously unknown ethyl 2-formyl-9-alkylimidazo[1,2-*a*]benzimidazole-3-carboxylates. Acid hydrolysis of such esters provides a more efficient synthetic route to 3-unsubstituted imidazobenzimidazole-2-carbaldehydes than that described in [1]. Nevertheless, these compounds still remain difficult to obtain. 2-Formylimidazo[1,2-*a*]-benzimidazoles have been shown to be promising for the synthesis of new imidazo[1,2-*a*]benzimidazole derivatives.

EXPERIMENTAL

The ^{1}H NMR spectra of compounds **1**, **3**, **5b**, **6**, and **9** were recorded on a Varian Unity-300 spectrometer at 300 MHz, and of the other compounds, on a Bruker Avance 600 spectrometer at 600 MHz; samples were dissolved in DMSO-d_6 (**6**, **7**, **4c**, **11**) or $CDCl_3$ (all other compounds); the chemical shifts were measured relative to the residual proton signal of the solvent. The IR spectra were recorded in mineral oil on a Varian Excalibur 3100 FT-IR spectrometer. The melting points were determined with a Fisher–Johns melting point apparatus. Elemental analysis was performed by classical micro analysis methods [13]. The progress of reactions and the purity of the isolated compounds were monitored by TLC on alumina plates (Brockmann activity grade III) using chloroform as eluent; spots were visualized by treatment with iodine vapor in a moist chamber.

All reagents used were commercially available.

Ethyl 2-(dibromomethyl)-9-methyl-9*H*-imidazo-[1,2-*a*]benzimidazole-3-carboxylate (1) was synthesized according to the procedure reported in [6] for analogous methyl ester. Yield 78%, colorless crystals, mp 215–216°C. ^{1}H NMR spectrum, δ, ppm: 1.50 t (3H, $CH_2C\mathbf{H}_3$, J = 7.0 Hz), 3.86 s (3H, CH_3), 4.51 q (2H, OCH_2, J = 7.1 Hz), 7.22–7.41 m (3H, 6-H, 7-H, 8-H), 7.59 s (1H, CH), 8.12 d (1H, 5-H, J = 8.4 Hz). Found, %: C 40.74; H 2.95; Br 38.24; N 10.30. $C_{14}H_{13}Br_2N_3O_2$. Calculated, %: C 40.51; H 3.16; Br 38.50; N 10.12.

Ethyl 2-formyl-9-methyl-9*H*-imidazo[1,2-*a*]-benzimidazole-3-carboxylate (2). A suspension of 4.15 g (0.01 mol) of compound **1** in 50 mL of ethanol was refluxed for 1.5 h until complete dissolution and for 0.5 h more (TLC (R_f 0.9 and 0.7 for **1** and **2**, respectively). The mixture was evaporated to 1/3 of the initial volume and neutralized with 20% aqueous sodium hydrogen carbonate, and the precipitate was filtered off and washed with water. Yield 2.25 g (83%), colorless crystals, mp 211–212°C (from EtOAc). IR spectrum, ν, cm^{-1}: 1695 s (C=O), 1681 s (C=O). ^{1}H NMR spectrum, δ, ppm: 1.46 t (3H, $CH_2C\mathbf{H}_3$, J = 7.1 Hz), 3.81 s (3H, CH_3), 4.51 q (2H, OCH_2, J = 7.1 Hz), 7.26 t (1H, 6-H or 7-H, J = 7.4 Hz), 7.29 d (1H, 8-H, J = 8.0 Hz), 7.42 t (1H, 7-H or 6-H, J = 7.4 Hz), 8.52 d (1H, 5-H, J = 8.3 Hz), 10.51 s (1H, CHO). Found, %: C 62.15; H 5.03; N 15.72. $C_{14}H_{13}N_3O_3$. Calculated, %: C 61.99; H 4.83; N 15.49.

9-Methyl-9*H*-imidazo[1,2-*a*]benzimidazole-2-carbaldehyde (3). A solution of 1.35 g (5 mmol) of aldehyde **2** in 15 mL of concentrated aqueous HCl was refluxed for 3.5 h. After completion of the reaction (TLC), the mixture was neutralized with a 20% solution of sodium hydrogen carbonate, and the dark brown mixture was extracted with chloroform (3×15 mL). The extract was evaporated, and the residue was subjected to column chromatography on alumina using chloroform as eluent; a fraction with R_f 0.6 was collected. Yield 0.42 g (42%), off-white crystals, mp 138–139°C (from isooctane–toluene, 9:1). ^{1}H NMR spectrum, δ, ppm: 3.83 s (3H, CH_3), 7.23–7.43 m (2H, 6-H, 7-H), 7.44 d (1H, 8-H, J = 8.0 Hz), 7.64 d (1H, 5-H, J = 8.1 Hz), 8.04 s (1H, 3-H), 9.93 s (1H, CHO). Found, %: C 66.12; H 4.28; N 21.30. $C_{11}H_9N_3O$. Calculated, %: C 66.32; H 4.55; N 21.09.

Chalcones 4 and 5 (*general procedure*). A solution of 2 mmol of aldehyde **2** or **3** and 2 mmol of the corresponding ketone in 5 mL of ethanol containing a catalytic amount of 40% aqueous sodium hydroxide was refluxed for 5–7 min. After cooling, the precipitate was filtered off and washed with ethanol and diethyl ether.

Ethyl 9-methyl-2-[(*E*)-3-(4-nitrophenyl)-3-oxoprop-1-en-1-yl]-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate (4a). Yield 0.69 g (83%), orange crystals, mp 226–227°C (from DMF). ^{1}H NMR spectrum, δ, ppm: 1.48 t (3H, $CH_2C\mathbf{H}_3$, *J* = 7.1 Hz), 3.84 s (3H, CH_3), 4.49 q (2H, OCH_2, *J* = 7.1 Hz), 7.26 t (1H, 6-H or 7-H, *J* = 8.1 Hz), 7.30 d (1H, 8-H, *J* = 7.9 Hz), 7.39 t (1H, 7-H or 6-H, *J* = 7.9 Hz), 7.93 d (1H, CH=, *J* = 15.2 Hz), 8.19 d and 8.31 d (2H each, $C_6H_4NO_2$, *J* = 8.9 Hz), 8.51 d (1H, CH=, *J* = 15.2 Hz), 8.54 d (1H, 5-H, *J* = 7.9 Hz). Found, %: C 63.37; H 4.12; N 13.52. $C_{22}H_{18}N_4O_5$. Calculated, %: C 63.15; H 4.34; N 13.39.

Ethyl 2-[(*E*)-3-(1,1′-biphenyl-4-yl)-3-oxoprop-1-en-1-yl]-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate (4b). Yield 0.65 g (72%), pale yellow crystals, mp 239–241°C (from DMF). ^{1}H NMR spectrum, δ, ppm: 1.50 t (3H, $CH_2C\mathbf{H}_3$, *J* = 7.1 Hz), 3.84 s (3H, CH_3), 4.49 q (2H, OCH_2, *J* = 7.1 Hz), 7.25–7.47 m (6H, 6-H or 7-H, C_6H_5), 7.63–7.65 m (2H, 7-H or 6-H, 8-H), 7.71 d (2H, 2′-H, 6′-H, *J* = 8.4 Hz), 8.04 d (1H, CH=, *J* = 15.2 Hz), 8.16 d (2H, 3′-H, 5′-H, *J* = 8.4 Hz), 8.50 d (1H, CH=, *J* = 15.2 Hz), 8.55 d (1H, 5-H, *J* = 8.0 Hz). Found, %: C 74.98; H 5.03; N 9.57. $C_{28}H_{23}N_3O_3$. Calculated, %: C 74.82; H 5.16; N 9.35.

Ethyl 9-methyl-2-[(*E*)-3-(naphthalen-1-yl)-3-oxoprop-1-en-1-yl]-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate (4c). Yield 0.60 g (70%), yellow crystals, mp 196–197°C (from BuOH). ^{1}H NMR spectrum, δ, ppm: 1.41 t (3H, $CH_2C\mathbf{H}_3$, *J* = 7.1 Hz), 3.78 s (3H, CH_3), 4.28 q (2H, OCH_2, *J* = 7.1 Hz), 7.28 t (1H, 6-H or 7-H, *J* = 7.4 Hz], 7.42 t.d (1H, 7-H or 6-H, *J* = 7.4, 1.2 Hz), 7.57 d (1H, CH=, *J* = 15.5 Hz), 7.59–7.66 m (4H, 3′-H, 5′-H, 6′-H, 7′-H), 7.84 d.d (1H, 8-H, *J* = 7.0, 1.2 Hz), 8.02–8.04 m (1H, 4′-H), 8.09 d (1H, CH=, *J* = 15.5 Hz), 8.13 d (8′-H, *J* = 8.3 Hz), 8.20–8.22 m (1H, 2′-H), 8.34 d (1H, 5-H, *J* = 8.1 Hz). Found, %: C 73.52; H 5.23; N 10.18. $C_{26}H_{21}N_3O_3$. Calculated, %: C 73.74; H 5.00; N 9.92

(*E*)-3-(9-Methyl-9*H*-imidazo[1,2-*a*]benzimidazol-2-yl)-1-(4-nitrophenyl)prop-2-en-1-one (5a). Yield 0.52 g (75%), orange crystals, mp 237–238°C (from BuOH). ^{1}H NMR spectrum, δ, ppm: in $CDCl_3$: 3.81 s (3H, CH_3), 7.22 t (1H, 6-H or 7-H, *J* = 7.8 Hz), 7.29 d (1H, 8-H, *J* = 8.0 Hz), 7.36 t (1H, 7-H or 6-H, *J* = 7.9 Hz), 7.54 d (1H, 5-H, *J* = 8.0 Hz), 7.66 s (1H, 3-H), 7.76 d and 7.85 d (1H each, CH=CH, *J* = 14.9 Hz), 8.22 d and 8.32 d (2H each, $C_6H_4NO_2$, *J* = 8.5 Hz); in DMSO-d_6: 3.74 s (3H, CH_3), 7.22 t (1H, 6-H or 7-H, *J* = 7.8 Hz), 7.36 t (1H, 7-H or 6-H, *J* = 7.8 Hz), 7.54 d (1H, 8-H, *J* = 8.1 Hz), 7.65 d and 7.78 d (1H each, CH=CH, *J* = 14.9 Hz), 7.81 d (1H, 5-H, *J* = 7.9 Hz), 8.23 d (2H, $C_6H_4NO_2$, *J* = 8.7 Hz), 8.29 s (1H, 3-H), 8.36 d (2H, $C_6H_4NO_2$, *J* = 8.7 Hz). Found, %: C 66.12; H 4.27; N 16.40. $C_{19}H_{14}N_4O_3$. Calculated, %: C 65.89; H 4.07; N 16.18.

(*E*)-1-(1,1′-Biphenyl-4-yl)-3-(9-methyl-9*H*-imidazo[1,2-*a*]benzimidazol-2-yl)prop-2-en-1-one (5b). Yield 0.51 g (69%), bright yellow crystals, mp 223–224°C (from BuOH). ^{1}H NMR spectrum, δ, ppm: 3.84 s (3H, CH_3), 7.21–7.69 m (10H, 3-H, 5-H, 6-H, 7-H, 8-H, C_6H_5), 7.73 d (2H, 2′-H, 6′-H, *J* = 8.4 Hz), 7.86 d and 7.90 d (1H each, CH=CH, *J* = 15.0 Hz), 8.22 d (2H, 3′-H, 5′-H, *J* = 8.4 Hz). Found, %: C 79.73; H 4.80; N 11.42. $C_{25}H_{19}N_3O$. Calculated, %: C 79.55; H 5.07; N 11.13.

Ethyl 2-{3-[(1,1′-biphenyl)-4-yl]-4,5-dihydro-1*H*-pyrazol-5-yl}-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate (6). A solution of 0.45 g (1 mmol) of **4b** and 0.2 mL of hydrazine hydrate in 10 mL of ethanol was refluxed for 45 min. After cooling, the colorless solid was filtered off and washed with acetone. Yield 0.32 g (69%), mp 187–189°C (from *i*-PrOH). ^{1}H NMR spectrum, δ, ppm: 1.52 t (3H, $CH_2C\mathbf{H}_3$, *J* = 7.0 Hz), 3.51–3.55 m and 3.68–3.74 m (1H each, 4′-H), 3.81 s (3H, CH_3), 4.52 q (2H, OCH_2, *J* = 7.0 Hz), 5.59–5.66 m (1H, 5′-H), 6.58 br.s (1H, NH), 7.26–7.82 (12H, H_{arom}), 8.50 d (1H, 5-H, *J* = 8.1 Hz). Found, %: C 72.68; H 5.27; N 14.88. $C_{28}H_{25}N_5O_2$. Calculated, %: C 72.55; H 5.44; N 15.11.

6-Methyl-2*H*-pyridazino[4′,5′:4,5]imidazo[1,2-*a*]benzimidazol-1(6*H*)-one (7). A solution of 0.42 g (1 mmol) of **1** in 5 mL of hydrazine hydrate was refluxed for 0.5 h. After cooling, the precipitate was filtered off and washed with water. Yield 0.21 g (88%), colorless crystals, mp > 300°C (from DMF). ^{1}H NMR spectrum, δ, ppm: 3.85 s (3H, CH_3), 7.37 t and 7.40 t (1H, 8-H, 9-H, *J* = 7.1 Hz), 7.70 d (1H, 7-H, *J* = 8.1 Hz), 8.25 d (1H, 10-H, *J* = 8.0 Hz), 8.40 s (1H, 4-H), 12.90 s (1H, NH). Found, %: C 60.12.15; H 3.95; N 29.17. $C_{12}H_9N_5O$. Calculated, %: C 60.25; H 3.79; N 29.27.

Ethyl 2-cyano-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate (8). A solution of 0.27 g (1 mmol) of aldehyde **2** and 0.14 g (2 mmol) of hydroxylamine hydrochloride in 3 mL of glacial acetic acid containing 0.17 g (2 mmol) of anhydrous sodium acetate was refluxed for 30 min. The mixture was cooled and diluted with 15 mL of water, and the precipitate (oxime) was filtered off, washed with water, and dried. Yield 0.24 g (84%). The product was dissolved in 2 mL of acetic anhydride, and the solution was refluxed for 30 min. The mixture was treated with 7 mL of water to decompose excess acetic anhydride, and the precipitate was filtered off and washed with water. Yield 0.2 g (75%, based on the initial aldehyde **2**), colorless crystals, mp 177–178°C (from EtOAc). IR spectrum, ν, cm^{-1}: 2237 s (C≡N), 1712 s (C=O). ^{1}H NMR spectrum, δ, ppm: 1.46 t (3H, $CH_2C\mathbf{H}_3$, J = 7.1 Hz), 3.79 s (3H, CH_3), 4.46 q (2H, OCH_2, J = 7.1 Hz), 7.27 t (1H, 6-H or 7-H, J = 7.4 Hz), 7.32 d (1H, 8-H, J = 8.1 Hz), 7.42 t (1H, 7-H or 6-H, J = 7.4 Hz), 8.47 d (1H, 5-H, J = 8.3 Hz). Found, %: C 62.51; H 4.67; N 20.75. $C_{14}H_{12}N_4O_2$. Calculated, %: C 62.68; H 4.51; N 20.88.

Ethyl 2-(2,2-dicyanoethenyl)-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate (9). A solution of 1.35 g (5 mmol) of aldehyde **2** and 0.35 g (5 mmol) of malononitrile in 25 mL of ethanol was refluxed for 3–5 min and was then left to stand at 25°C for 1 h. The yellow precipitate was filtered off. Yield 1.50 g (94%), mp 264–265°C (from BuOH). ^{1}H NMR spectrum, δ, ppm: 1.55 t (3H, $CH_2C\mathbf{H}_3$, J 7.2 Hz), 3.88 s (3H, CH_3), 4.57 q (2H, OCH_2, J = 7.2 Hz), 7.31 t (1H, 6-H or 7-H, J = 7.4 Hz), 7.38 d (1H, 8-H, J = 8.2 Hz), 7.48 t (1H, 6-H or 7-H, J = 7.5 Hz), 8.46 s (1H, CH=), 8.54 d (1H, 5-H, J = 8.1 Hz). Found, %: C 63.72; H 4.27; N 22.18. $C_{17}H_{13}N_5O_2$. Calculated, %: C 63.94; H 4.10; N 21.93.

Ethyl 2-(5-acetyl-6-methyl-2-sulfanylidene-1,2,3,4-tetrahydropyrimidin-4-yl)-9-methyl-9*H*-imidazo[1,2-*a*]benzimidazole-3-carboxylate (11). A suspension of 0.54 g (2 mmol) of aldehyde **2**, 0.23 g (3 mmol) of thiourea, and 0.2 mL (2 mmol) of acetylacetone in 10 mL of ethanol was heated to the boiling point, and the resulting solution was heated at 50°C for 8 h. The precipitate was filtered off and washed with ethanol. Yield 0.49 g (60%), colorless crystals, mp 284–285°C (from DMF). ^{1}H NMR spectrum, δ, ppm: 1.41 t (3H, $CH_2C\mathbf{H}_3$, J = 7.1 Hz), 2.09 s (3H, 6′-CH_3), 2.31 s (3H, $COCH_3$), 3.71 s (3H, 9-CH_3), 4.38–4.45 m (2H, OCH_2), 6.18 s (1H, 4′-H), 7.25 t (1H, J = 7.8 Hz) and 7.38 t (1H, J = 7.9 Hz) (6-H, 7-H), 7.57 d (1H, 8-H, J = 8.2 Hz), 8.33 d (1H, 5-H, J = 8.3 Hz), 9.39 s (1H, NH), 10.16 s (1H, NH). Found, %: C 58.59; H 5.27; N 16.85; S 7.51. $C_{20}H_{21}N_5O_3S$. Calculated, %: C 58.38; H 5.14; N 17.02; S 7.79.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Venkatesan, A.M., Agarwal, A., Abe, T., Ushirogochi, H., Ado, M., Tsuyoshi, T., Dos Santos, O., Li, Zh., Francisco, G., Lin, Y.I., Petersen, P.J., Yang, Y., Weiss, W.J., Shlaes, D.M., and Mansour, T.S., *Bioorg. Med. Chem*., 2008, vol. 16, p. 1890. https://doi.org/10.1016/j.bmc.2007.11.006
2. Han, X., Pin, S.S., Burris, K., Fung, L.K., Huang, S., Taber, M.T., Zhang, J., and Dubowchik, G.M., *Bioorg. Med. Chem. Lett*., 2005, vol. 15, p. 4029. https://doi.org/10.1016/ j.bmcl.2005.06.02
3. Spasov, A.A., Vassiliev, P.M., Lenskaya, K.V., Kosolapov, V.A., Babkov, D.A., Anisimova, V.A., Kuzmenko, T.A., and Morkovnik, A.S., *Pure Appl. Chem*., 2017, vol. 89, p. 1007. https://doi.org/10.1515/pac-2016-1024
4. Spasov, A.A., Grechko, O.Yu., Shtareva, D.M., Rashchenko, A.I., Eliseeva, N.V., and Anisimova, V.A., *J. Clin. Health Sci*., 2018, vol. 3, p. 13. https://doi.org/10.24191/ jchs.v3i2.7275
5. Spasov, A.A., Yakovlev, D.S., Maltsev, D.V., Zhukovskaya, O.N., Anisimova, V.A., Kovalev, G.I., Zimin, I.A., and Morkovina, Y.V., *Russ. J. Bioorg. Chem*., 2016, vol. 42, p. 397. https://doi.org/10.1134/S1068162016040178
6. Anisimova, V.A. and Lukova, O.A., *Chem. Heterocycl. Compd*., 1994, vol. 30, p. 325. https://doi.org/10.1007/BF01165699
7. Kuz'menko, T.A., Divaeva, L.N., Morkovnik, A.S., Anisimova, V.A., Borodkin, G.S., and Kuz'menko, V.V., *Russ. J. Org. Chem*., 2014, vol. 50, p. 716. https://doi.org/10.1134/S1070428014050169

8. Murineddu, G., Cignarella, G., Chelucci, G., Loriga, G., and Pinna, G.A., *Chem. Pharm. Bull*., 2002, vol. 50, p. 754. https://doi.org/10.1248/cpb.50.754
9. Avan, I., Guven, A., and Guven, K., *Turk. J. Chem*., 2013, vol. 37, p. 271. https://doi.org/10.3906/kim-1210-22
10. Haouchine, A.-L., Kabri, Y., Bakhta, S., Curti, Ch., Nedjar-Kolli, B., and Vanelle, P., *Synth. Commun*., 2018, vol. 48, p. 2159. https://doi.org/10.1080/00397911.2018.1479759
11. Kulakov, I.V., Talipov, S.A., Shulgau, Z.T., and Seilkhanov, T.M., *Chem. Heterocycl. Compd*., 2015, vol. 50, p. 1478. https://doi.org/10.1007/s10593-014-1613-1
12. Cheng, Q., Wang, Q., Tan, T., Chen, N., and Shuai, M., *J. Heterocycl. Chem*., 2012, vol. 49, p. 1352. https://doi.org/10.1002/jhet.978
13. Gel'man, N.E., Terent'eva, E.A., Shanina, T.M., and Kiparenko, L.M., *Metody kolichestvennogo organicheskogo elementnogo analiza* (Methods of Quantitative Organic Elemental Analysis), Moscow: Khimiya, 1987.