A NEW APPROACH TO IMIDAZO[1,5-*a*]INDOLE DERIVATIVES

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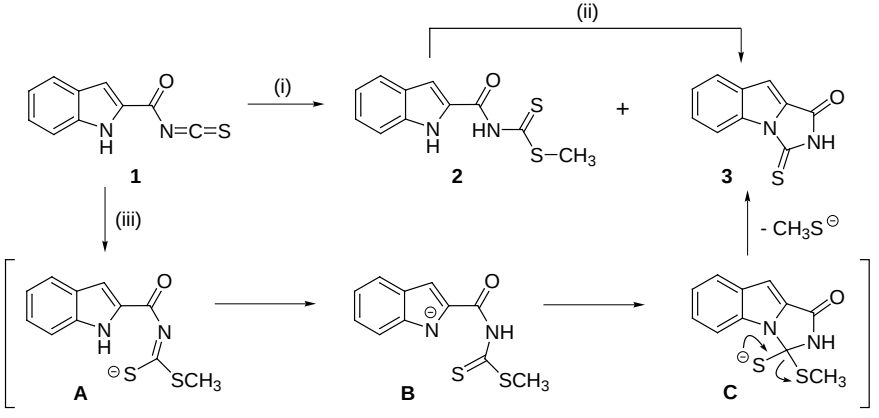
Reaction of indole-2-carbonyl isothiocyanate (**1**) with sodium methanethiolate afforded 1-thioxo-1*H*-imidazo[1,5-*a*]indol-3(2*H*)-one (**3**). Its methylation with methyl iodide in the presence of lithium hydride in dimethylformamide, or potassium carbonate in acetone resulted in the formation of corresponding *S*- and *N*-methyl derivatives **4** and **5**. *N*-(Indole-2-carbonyl)thiocarbamates and *N*-(indole-2-carbonyl)thioureas prepared by treatment of isothiocyanate **1** with corresponding nucleophilic reagents were *S*-methylated with methyl iodide in acetone in the presence of potassium carbonate. The obtained *N*-(indole-2-carbonyl) substituted thiocarbonimidates **15**, **16** and isothioureas **17**–**20** afforded by treatment with lithium hydride in dimethylformamide the derivatives of imidazo[1,5-*a*]-indol-3-one **23**–**28** in 49–87% yields. Antifungal activity of the prepared compounds has been examined, using the fungus *Bipolaris leersiae*. 1-Methylsulfanyl-3*H*-imidazo-[1,5-*a*]-indol-3-one (**4**) exhibited the highest antifungal activity.

Key words: Imidazoles; Indoles; Phytoalexins; Cyclization; Isothiocyanates; Antifungal activity.

The imidazo[1,5-*a*]indole derivatives are an interesting group of compounds, due to their central nervous depressant and analgesic activity[1,2]. Previously, this infrequent tricyclic system was prepared by the reaction of (indol-2-ylmethyl)amine with 1,1′-carbonyldiimidazole[1], indole-2-carboxanilide with phenyl isocyanate[2], ethyl indole-2-carboxylate with phenyl[2] or methyl[3a,3b] isocyanate, methyl indole-2-carboxylate with methyl isothiocyanate[3c], 3-arylindole-2-carbonyl chlorides with *N*-ethyl carbamate[4], thionyl-chloride-mediated ring contraction of [1,2,4]triazino[4,5-*a*]indoles[5] and by aza-Wittig reaction of 2′-{2-(azidomethyl)-2-[*tert*-butyl(dimethyl)-silyloxy]vinyl}trifluoroacetanilide with dimethyl 4-ethyl-4-formylheptane-

dioate[6]. Recently, 2-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-1*H*-imidazo-[1,5-*a*]indole-1,3(2*H*)-dione has been prepared by desulfurization-cyclocondensation reaction of tetra-*O*-acetyl-β-D-glucopyranosyl isothiocyanate with indole-2-carboxylic acid in the presence of silver trifluoroacetate and triethylamine[7]. Mesoionic imidazo[1,5-*a*]indolium hydroxides were obtained by treatment of 1-acetylindol-3(2*H*)-one with sodium hydride, carbon disulfide and primary amines[8].

With continuing interest in the synthesis of indole phytoalexins and related compounds[9], we have recently studied the synthesis of methyl *N*-(indole-2-carbonyl)dithiocarbamate (isooxobrassinin, **2**, Scheme 1) by treatment of indole-2-carbonyl isothiocyanate (**1**), prepared from indole-2-carboxylic acid, with sodium hydrogensulfide in the presence of methyl iodide[10]. Unexpectedly, we have isolated the 1-thioxo-1*H*-imidazo[1,5-*a*]indol-3(2*H*)-one (**3**) as a side product in 9% overall yield. This finding initiated our interest in this new cyclization reaction.



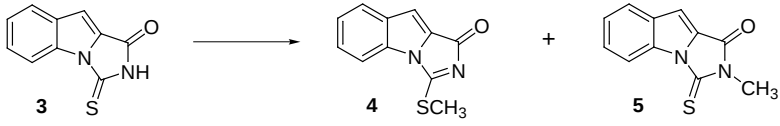
(i) NaSH, CH_3I (ref.[10]) (19% of **2** and 9% of **3**); (ii) LiH, DMF (99%); (iii) CH_3SNa, acetone–methanol, r.t. (39%)

SCHEME 1

The unexpected formation of compound **3** can be explained by instability of dithiocarbamate **2** in the slightly alkaline reaction medium during its preparation. This assumption was confirmed by independent cyclization of **2** to **3** by lithium hydride in dimethylformamide in 99% yield[10], indicating the effective intramolecular substitution of dithiocarbamate methylsulfanyl group by indole nitrogen. Despite of the high yield of this cyclization, the overall yield is low. To obtain product **3** in a reasonable yield from indole-2-carboxylic acid, it was decided to generate the anion of dithiocarbamate **2**

by nucleophilic addition of sodium methanethiolate to isothiocyanate **1** (Scheme 1). The reaction proceeded smoothly at room temperature and imidazoindole **3** was isolated in 39% overall yield. Most probably, in the first step, the anion **A** is formed, which can be transformed by proton transfer to intermediate **B**. The reaction is terminated by nucleophilic attack of deprotonated indole nitrogen to the thiocarbonyl group, followed by splitting off the methanethiolate ion from intermediate **C**. Accordingly, the reaction proceeds with the same yield when **1** is treated with only 0.2 equivalents of sodium methanethiolate. Direct cyclization of isothiocyanate **1** in alkaline reaction medium can be excluded, because its treatment with lithium or sodium hydride in acetonitrile or dimethylformamide did not afford product **3**. An attempt to trap any intermediate by carrying out the reaction of isothiocyanate **1** with sodium methanethiolate in the presence of up to ten-fold excess of methyl iodide was unsuccessful, whereas the yield of product **3** remained unchanged.

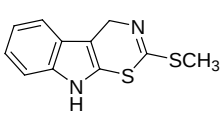
With the aim to obtain a compound with expected antifungal activity, we have studied the methylation of compound **3** to 1-(methylsulfanyl-3*H*-imidazo[1,5-*a*]indol-3-one (**4**, Scheme 2) possessing the N=C–SCH_3



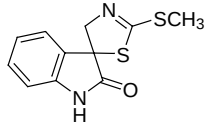
Method	Experimental conditions	% of **4**	% of **5**
A	LiH, CH_3I/DMF, r.t.	7	81
B	K_2CO_3, CH_3I/acetone, r.t.	18	37
C	K_2CO_3, CH_3I/acetone, reflux	31	23

SCHEME 2

grouping, which is also present in antifungal phytoalexins cyclobrassinin (**6**, ref.[11]) and spirobrassinin (**7**, ref.[12]).



Cyclobrassinin (**6**)

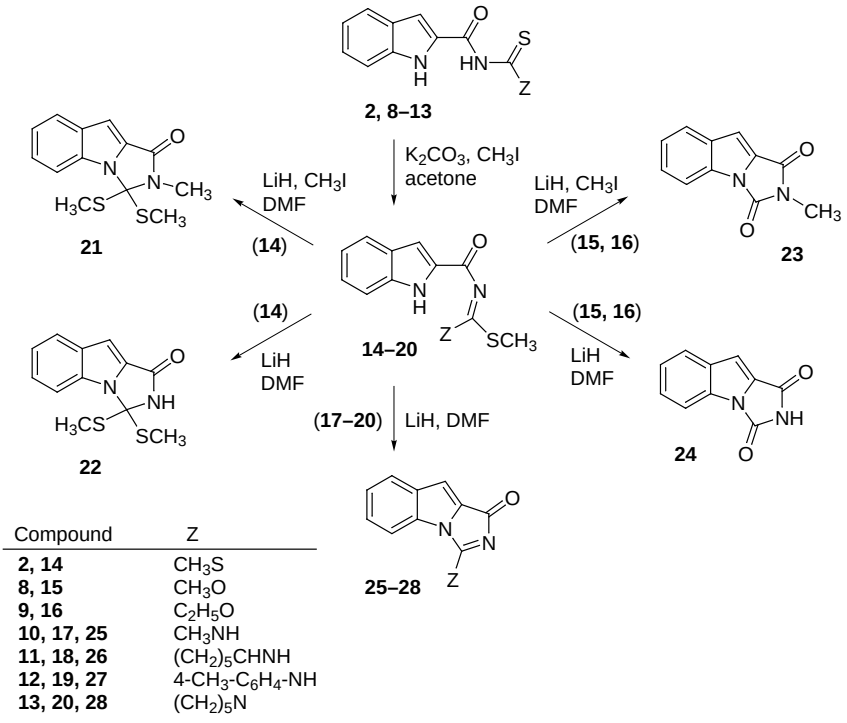


Spirobrassinin (**7**)

Methylation of imidazoindole **3** with methyl iodide in dimethylformamide in the presence of lithium hydride, or in acetone in the pres-

ence of powdered potassium carbonate afforded *S*-methyl derivative **4** (7–31%) in a mixture with *N*-methyl derivative **5** (23–81%).

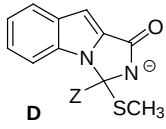
To investigate the scope and limitation of the cyclization depicted in Scheme 1, the reactions of monothiocarbamates **8** and **9**, and thioureas **10**–**13**, prepared by addition of alcohols and amines, respectively, to isothiocyanate **1**, with lithium hydride in dimethylformamide were examined. In these cases, no cyclization took place and starting compounds were recovered, thus indicating, that the presence of methylsulfanyl leaving group in dithiocarbamate **2** is essential for the success of cyclization. The reaction of dithiocarbamate **2** with methyl iodide in dry acetone in the presence of potassium carbonate did not result in cyclization, and isobrassenin B (**14**) was obtained in 83% yield[10]. Probably, the potassium salt of **2** is insoluble in acetone and, therefore, the cyclization cannot occur. Instead, the *S*-anion is effectively trapped by methyl iodide and isobrassenin B (**14**) is selectively formed in high yield. However, attempted *N*-methylation of **14** with methyl iodide and lithium hydride in dimethylformamide resulted in cyclization to 2-methyl-1,1-bis(methylsulfanyl)-1*H*-imidazo[1,5-*a*]indol-3(2*H*)-one (**21**) in 90% yield[10]. In this case, the cyclization proceeded *via* intramolecular nucleophilic attack of the deprotonated indole nitrogen on the highly electrophilic carbon atom of the enamide C=N bond and the transiently formed N-2 anion was methylated with methyl iodide under the formation of product **21**. When the reaction was quenched with water instead of methyl iodide, the corresponding non-methylated bis(methylsulfanyl) derivative **22** (Scheme 3) was obtained in 79% yield. The high reactivity of (methylsulfanyl)formimidothioate **14** in the studied cyclization turned our attention to the preparation of thiocarbonimidates **15** and **16**, and isothioureas **17**–**20**, and to their behaviour under the treatment with lithium hydride in dimethylformamide. Compounds **15**–**20** were obtained by methylation of monothiocarbamates **8** and **9**, and thioureas **10**–**13** with methyl iodide in dry acetone in the presence of potassium carbonate in 68–86% yields. The lithium-hydride-mediated cyclization of compounds **15**–**20** in dimethylformamide proceeded with the formation of imidazo[1,5-*a*]indol-1-one derivatives **23**–**28** in 50–87% yield, with the structures strongly dependent on the nature of the group Z (Scheme 3). Cyclization of compounds **14**–**20** can be also performed in the same yields with sodium hydride in dry dimethylformamide. The use of less reactive lithium hydride is, however, more convenient because dimethylformamide does not need to be dried and can be used in commercial quality.



Compound	Z
2, 14	CH_3S
8, 15	CH_3O
9, 16	C_2H_5O
10, 17, 25	CH_3NH
11, 18, 26	$(CH_2)_5CHNH$
12, 19, 27	4-CH_3-C_6H_4-NH
13, 20, 28	$(CH_2)_5N$

SCHEME 3

We assume that the cyclization of compounds **14**–**20** proceeds *via* the common intermediate **D**. If Z = SCH_3, the stable anion **D** can be methylated or protonated with the formation of 1,1-bis(methylsulfanyl) derivatives **21** and **22**. In the case of Z = OCH_3 and OC_2H_5, the situation is similar, how-



ever, the instability of the 1-alkoxy derivatives under the hydrolytic work-up conditions results in the formation of 1-oxo derivatives **23**, **24**. Attempts in obtaining 2-methyl derivatives, analogous to **21** and **23**, from isothioureas **17**–**20** were unsuccessful, even in the presence of ten-fold excess of methyl iodide.

Antifungal activity of synthesized compounds was examined by TLC bioassay, using the fungus *Bipolaris leersiae*. The compounds showing a dis-

tinct antifungal spots were tested quantitatively and compared with brassinin, which completely inhibited the conidial germination at a concentration of 0.1 mmol l^{-1}. The highest activity exhibited 1-methylsulfanyl derivative **4**, which completely inhibited the germination at 0.025 mmol l^{-1}. Compound **3** exhibited antifungal activity on the level of brassinin, whereas all the other substances showed lower activity.

EXPERIMENTAL

The infrared absorption spectra were recorded on an IR-75 spectrometer (Zeiss, Jena) in chloroform except for compounds **3**, **18** and **25**, which were measured in KBr discs; the wavenumbers are given in cm^{-1}. ^{1}H NMR spectra were measured on a Tesla BS 487A (80 MHz) spectrometer in deuteriochloroform (compounds **4**, **5**, **15**–**17**, **19**–**20**, **22**, **23** and **27**), hexadeuteriodimethyl sulfoxide (compounds **3**, **24** and **26**), hexadeuterioacetone (compounds **9** and **18**) and in a mixture of deuteriochloroform and hexadeuteriodimethyl sulfoxide (compounds **25** and **28**). ^{13}C NMR spectra were measured on a Jeol Gemini 2000 (75 MHz) spectrometer in hexadeuteriodimethyl sulfoxide (compound **3**) and deuteriochloroform (compounds **22** and **27**). Chemical shifts (δ) are reported in ppm downfield from tetramethylsilane, coupling constants (*J*) in Hz. The electron impact mass spectra were recorded on a Finigan SSQ 700 spectrometer at ionization energy 70 eV. UV absorption spectra were measured on a Varian SuperScan 3 spectrometer in methanol solutions. The reaction course was monitored by thin-layer chromatography, using Silufol plates (Kavalier). The preparative column chromatography was performed on Kieselgel Merck, type 9385, 230–400 mesh. Antifungal activity was examined by the previously described procedure[9a]. Compounds **1**, **2**, **8** and **10**–**14** were prepared according to previously described procedures[10].

1-Thioxo-1*H*-imidazo[1,5-*a*]indol-3(2*H*)-one (**3**)

To a stirred acetone solution of isothiocyanate **1**, prepared from 5 mmol of indole-2-carboxylic acid[10], was added dropwise a solution of sodium methanethiolate (210 mg, 3 mmol) in methanol (6 ml) at room temperature within 15 min. The reaction mixture was then poured into 200 ml of cold water, neutralized with dilute hydrochloric acid (1 : 5) and, after standing for 1 h, the separated precipitate was filtered off with suction, washed with water and dried. Yield 395 mg (39%, based on indole-2-carboxylic acid), m.p. 256–259 °C (acetone–hexane). IR, ^{1}H NMR and MS spectra of the obtained product are identical with the previously described data[10]. UV, λ_{max} (ε_{max}): 212 (7 100), 260 (6 350), 294 (2 850). ^{13}C NMR: 108.25, 131.21, 124.56, 124.79, 129.12, 129.64, 132.77, 132.84; 159.97 (C=O); 174.32 (C=S).

1-(Methylsulfanyl)-3*H*-imidazo[1,5-*a*]indol-3-one (**4**) and
2-Methyl-1-thioxo-1*H*-imidazo[1,5-*a*]indol-3(2*H*)-one (**5**)

Method A. To a stirred suspension of lithium hydride (32 mg, 4 mmol) in dimethylformamide (20 ml), imidazoindole **3** (404 mg, 2 mmol) was added at room temperature. After 25 min, methyl iodide (568 mg, 0.249 ml, 4 mmol) was added and stirring was continued at the same temperature for 75 min. The reaction mixture was poured into 150 ml of cold wa-

ter with intensive stirring, the precipitated product **5** was filtered off with suction, washed with water and dried. Yield 350 mg (81%). The filtrate was extracted with diethyl ether (4 × 20 ml), the extract dried with anhydrous sodium sulfate, concentrated to approximately 10 ml and diluted with 10 ml of hexane. After standing at 10 °C overnight, the separated product **4** was filtered off and dried. Yield 32 mg (7%).

Method B. To a solution of imidazoindole **3** (190 mg, 0.94 mmol) in dry acetone (8 ml), methyl iodide (324 mg, 0.124 ml, 2.28 mmol) and powdered anhydrous potassium carbonate (129 mg, 0.93 mmol) were added and the mixture was stirred under reflux for 2 h. After cooling to room temperature, the insoluble material was filtered off, the filtrate evaporated to dryness and the residue chromatographed on 30 g of silica gel, using a mixture acetone–cyclohexane (2 : 1) as eluent. Yield 37 mg (18%) of **4** and 75 mg (37%) of **5**.

Method C. Analogous methylation as in the previous case performed at room temperature during 4 days afforded 63 mg (31%) of **4** and 47 mg (23%) of **5**.

1-(Methylsulfanyl)-3H-imidazo[1,5-a]indol-3-one (**4**). M.p. 141–143 °C (acetone–cyclohexane). For $C_{11}H_8N_2OS$ (216.3) calculated: 61.09% C, 3.73% H, 12.95% N; found: 61.18% C, 3.60% H, 12.73% N. UV, λ_{max} (ε_{max}): 215 (11 600), 277 (7 000), 293 (8 200). IR: 1 720 (C=O). ^{1}H NMR: 2.85 s, 3 H (SCH_3); 7.11 s, 1 H and 7.46 m, 4 H (arom. H).

2-Methyl-1-thioxo-1H-imidazo[1,5-a]indol-3(2H)-one (**5**). M.p. 192–194 °C, ref.[3c] 188 °C (acetone–water). For $C_{11}H_8N_2OS$ (216.3) calculated: 61.09% C, 3.73% H, 12.95% N; found: 61.16% C, 3.52% H, 12.70% N. UV, λ_{max} (ε_{max}): 212 (7 000), 262 (6 000), 295 (3 350). IR: 1 736 (C=O). ^{1}H NMR: 3.35 s, 3 H (NCH_3); 7.05 s, 1 H, 7.45 m, 3 H and 8.32 m, 1 H (arom. H).

Ethyl *N*-(Indole-2-carbonyl)thiocarbamate (**9**)

Crude isothiocyanate **1**, prepared from indole-2-carboxylic acid (5 mmol), was dissolved in dry ethanol (25 ml) and the obtained solution was stirred at 65 °C (bath temperature) for 15 min. The mixture was poured into 150 ml of cold water and, after standing overnight, the separated precipitate was filtered off with suction, dried and crystallized from ethanol–water. Yield 409 mg (33%, based on indole-2-carboxylic acid), m.p. 188–190 °C. For $C_{12}H_{12}N_2O_2S$ (248.3) calculated: 58.05% C, 4.87% H, 11.28% N; found: 57.86% C, 5.01% H, 11.46% N. IR: 3 453 (NH), 1 700 (C=O), 1 495 (NHCS). ^{1}H NMR: 1.40 t, 3 H, J = 7 (CH_3); 4.61 q, 2 H, J = 7 (CH_2); 7.00–7.85 m, 5 H (arom. H).

Substituted (Methylsulfanyl)formimidates **15**, **16** and Isothioureas **17**–**20**. General Procedure

To a solution of corresponding thiocarbamate **8**, **9**, or thiourea **10**–**13** (1 mmol) in dry acetone (10 ml), methyl iodide (426 mg, 0.187 ml, 3 mmol) and powdered anhydrous potassium carbonate (138 mg, 1 mmol) were added. The reaction mixture was stirred at room temperature for 1 h (**8**, **9**), 8 h (**11**) or 3 h (**13**); at 80 °C for 1.5 h (**10**) or at 65 °C for 45 min (**12**). The reaction mixture was poured into 100 ml of cold water (with **10** and **12**, after cooling to room temperature), the precipitate separated after 2 h was filtered off with suction, dried and crystallized from an appropriate solvent. In the case of **10**, **12**, or **11**, the product was filtered off after 3 or 12 h standing at 5 °C. In the case of **13**, no precipitate separated and therefore the product was extracted with dichloromethane (3 × 25 ml), and the extract dried with anhydrous sodium sulfate. After evaporation of the solvent, the residue was chromatographed on 35 g of silica gel, using benzene–acetone (5 : 2) as eluent.

Methyl N-(indole-2-carbonyl)(methylsulfanyl)formimidate (**15**). Yield 72%, m.p. 145–147 °C (acetone–water). For $C_{12}H_{12}N_2O_2S$ (248.3) calculated: 58.05% C, 4.87% H, 11.28% N; found: 58.18% C, 4.63% H, 11.02% N. IR: 3 464 (NH), 1 620 (C=N–C=O). ^{1}H NMR: 2.45 s, 3 H (SCH_3); 4.17 s, 3 H (OCH_3); 7.00–7.85 m, 5 H (arom. H); 9.35 s, 1 H (NH).

Ethyl N-(indole-2-carbonyl)(methylsulfanyl)formimidate (**16**). Yield 77%, m.p. 147–149 °C (acetone–water). For $C_{13}H_{14}N_2O_2S$ (262.3) calculated: 59.37% C, 5.38% H, 10.68% N; found: 59.37% C, 5.60% H, 10.54% N. IR: 3 463 (NH), 1 620 (C=N–C=O). ^{1}H NMR: 1.48 t, 3 H, J = 7 (CH_3); 2.45 s, 3 H (SCH_3); 4.76 q, 2 H, J = 7 (CH_2); 7.02–7.78 m, 5 H (arom. H); 9.38 s, 1 H (NH).

3-(Indole-2-carbonyl)-1,2-dimethylisothiourea (**17**). Yield 82%, m.p. 174–175 °C (acetone–water). For $C_{12}H_{13}N_3OS$ (247.3) calculated: 58.28% C, 5.30% H, 16.99% N; found: 58.45% C, 5.02% H, 17.19% N. IR: 3 473 (NH), 1 560 (C=N–C=O). ^{1}H NMR: 2.63 s, 3 H (SCH_3); 3.05 d, 3 H, J = 6 (NHC**H**$_3$); 7.00–7.80 m, 5 H (arom. H); 9.21 s, 1 H and 10.92 s, 1 H (NH).

1-Cyclohexyl-3-(indole-2-carbonyl)-2-methylisothiourea (**18**). Yield 86%, m.p. 159–161 °C (acetone–water). For $C_{17}H_{21}N_3OS$ (315.4) calculated: 64.73% C, 6.71% H, 13.32% N; found: 64.89% C, 6.48% H, 13.57% N. IR: 1 570 (C=N–C=O). ^{1}H NMR: 1.60 m, 10 H [$(CH_2)_5$]; 2.65 s, 3 H (SCH_3); 3.68 m, 1 H (CH); 6.90–7.75 m, 5 H (arom. H); 10.55 s, 1 H and 11.34 s, 1 H (NH).

3-(Indole-2-carbonyl)-2-methyl-1-(4-tolyl)isothiourea (**19**). Yield 76%, m.p. 145–147 °C (acetone–water). For $C_{18}H_{17}N_3OS$ (323.4) calculated: 66.85% C, 5.30% H, 12.99% N; found: 66.59% C, 5.59% H, 12.70% N. IR: 3 463 (NH), 1 540 (C=N–O=C). ^{1}H NMR: 2.40 s, 3 H (CH_3); 2.62 s, 3 H (SCH_3); 7.00–7.82 m, 9 H (arom. H); 9.25 s, 1 H (NH).

Methyl N-(indole-2-carbonyl)piperidine-1-carbothioimidate (**20**). Yield 62%, m.p. 158–159 °C (dichloromethane–hexane). For $C_{16}H_{19}N_3OS$ (301.4) calculated: 63.76% C, 6.35% H, 13.94% N; found: 63.91% C, 6.52% H, 13.78% N. IR: 3 460 (NH), 1 577 (C=N–C=O). ^{1}H NMR: 1.71 m, 6 H [$(CH_2)_3$]; 2.39 s, 3 H (SCH_3); 3.75 m, 4 H [$(CH_2)_2$]; 6.99–7.72 m, 5 H (arom. H); 9.33 s, 1 H (NH).

Preparation of 1-Substituted Imidazo[1,5-*a*]indol-3-ones (**22**, **24**–**28**).
General Procedure

To a suspension of lithium hydride (10.4 mg, 1.3 mmol) in dimethylformamide (6 ml), corresponding dithiocarbonimidate **14**, thiocarbonimidate **15**, **16**, or isothiourea **17**–**20** (0.6 mmol) was added and the mixture was stirred at room temperature for 0.5 h (**14**), 1.5 h (**15**, **16**, **18**), 2 h (**17**), 5.5 h (**19**) or 3 h (**20**). After pouring into 70 ml of cold water and standing overnight at 5 °C, the separated precipitate was filtered off with suction, dried and crystallized from an appropriate solvent. In the case of **17**, the reaction mixture was neutralized with several drops of dilute HCl (1 : 1), extracted with dichloromethane (1 × 60, 1 × 40 and 1 × 20 ml) and the extract was dried with anhydrous sodium sulfate. After evaporation of the solvent, the product was precipitated with water and filtered off after standing overnight at 5 °C.

1,1-Bis(methylsulfanyl)-1H-imidazo[1,5-a]indol-3(2H)-one (**22**). Yield 78%, m.p. 154–156 °C (acetone–water). For $C_{12}H_{12}N_2OS_2$ (264.4) calculated: 54.52% C, 4.58% H, 10.60% N; found: 54.71% C, 4.40% H, 10.83% N. UV, λ_{max} (ε_{max}): 216 (8 600), 276 (5 200), 295 (5 850). IR: 3 461 (NH), 1 717 (C=O). ^{1}H NMR: 1.74 s, 6 H (2 × SCH_3); 7.02 s, 1 H, 7.25 m, 2 H and 7.85 m, 2 H (arom. H). ^{13}C NMR: 12.89 (SCH_3); 87.21 (C-1); 101.22, 113.19, 123.06, 124.58, 126.12, 132.19, 132.88, 133.01; 161.64 (C=O). MS, *m/z* (%): 264 (M^+, 4), 217 (100), 143 (51), 115 (31), 89 (16).

1H-Imidazo[1,5-a]indole-1,3(2H)-dione (**24**). Yield 50% (from **15**), 54% (from **16**); m.p. 257–260 °C (acetone–water), ref.[5] 270 °C (sublimed). For $C_{10}H_6N_2O_2$ (186.2) calculated: 64.52% C, 3.25% H, 15.05% N; found: 64.28% C, 3.42% H, 14.87% N. UV, λ_{max} (ε_{max}): 230 (4 600), 275 (3 070), 301 (2 920). IR: 3 448 (NH), 1 780 and 1 743 (CO–NH–CO). ^{1}H NMR: 7.10–7.94 m, 5 H (arom. H); 10.62 s, 1 H (NH).

1-(Methylamino)-3H-imidazo[1,5-a]indol-3-one (**25**). Yield 57%, m.p. 280–282 °C (dimethylformamide–water). For $C_{11}H_9N_3O$ (199.2) calculated: 66.32% C, 4.55% H, 21.09% N; found: 66.61% C, 4.33% H, 21.35% N. UV, λ_{max} (ε_{max}): 253 (4 670), 275 (3 000), 316 (2 900). IR: 1 707 (C=O), 1 613 (C=N). ^{1}H NMR: 3.23 s, 3 H (CH_3); 6.98 s, 1 H and 7.21–8.03 m, 4 H (arom. H); 8.10 s, 1 H (NH). MS, *m/z* (%): 199 (M^+, 100), 143 (78), 115 (32).

1-(Cyclohexylamino)-3H-imidazo[1,5-a]indol-3-one (**26**). Yield 87%, m.p. 259–261 °C (acetone–water). For $C_{16}H_{17}N_3O$ (267.3) calculated: 71.89% C, 6.41% H, 15.72% N; found: 72.07% C, 6.66% H, 15.95% N. UV, λ_{max} (ε_{max}): 233 (7 500), 260 (6 200), 307 (5 250). IR: 1 703 (C=O), 1 613 (C=N). ^{1}H NMR: 1.25–2.00 m, 10 H [$(CH_2)_5$]; 3.59 m, 1 H (CH); 7.03 s, 1 H and 7.15–8.13 m, 4 H (arom. H). MS, *m/z* (%): 267 (M^+, 78), 239 (17), 224 (43), 185 (28), 143 (100), 115 (42).

1-(4-Methylanilino)-3H-imidazo[1,5-a]indol-3-one (**27**). Yield 68%, m.p. 210–212 °C (acetone–water). For $C_{17}H_{13}N_3O$ (275.3) calculated: 74.17% C, 4.76% H, 15.26% N; found: 73.92% C, 4.49% H, 15.06% N. UV, λ_{max} (ε_{max}): 210 (5 700), 244 (5 950), 317 (3 600). IR: 1 706 (C=O), 1 603 (C=N). ^{1}H NMR: 2.36 s, 3 H (CH_3); 6.97 d, 2 H, J = 8; 7.09 s, 1 H, 7.19 d, 2 H, J = 8 and 7.26–8.11 m, 5 H (arom. H and NH). ^{13}C NMR: 21.13 (CH_3); 106.03, 114.31, 121.80, 123.68, 124.08, 127.82, 129.03, 130.49, 132.50, 132.87, 134.64, 138.24; 143.62 (C=N); 159.44 (C=O). MS, *m/z* (%): 275 (M^+, 35), 144 (100), 115 (7).

1-Piperidino-3H-imidazo[1,5-a]indol-3-one (**28**). Yield 50%, m.p. 261–263 °C (acetone–water). For $C_{15}H_{15}N_3O$ (253.3) calculated: 71.13% C, 5.98% H, 16.59% N; found: 71.32% C, 6.19% H, 16.78% N. UV, λ_{max} (ε_{max}): 221 (15 400), 275 (14 400), 288 (11 400). IR: 1 687 (C=O), 1 687 (C=N). ^{1}H NMR: 2.78 m, 6 H and 3.87 m, 4 H [$(CH_2)_5$]; 7.16 s, 1 H and 7.25–7.83 m, 4 H (arom. H). MS, *m/z* (%): 253 (M^+, 27), 143 (100), 115 (31).

2-Methyl-1*H*-imidazo[1,5-*a*]indole-1,3(2*H*)-dione (**23**)

To a stirred suspension of lithium hydride (16 mg, 2 mmol) in dimethylformamide (10 ml) was added thiocarbonimidate **15** or **16** (0.96 mmol). After 1.5 h, methyl iodide (567 mg, 0.294 ml, 4 mmol) was added and stirring was continued for 20 min. The mixture was then poured into cold water (80 ml) with intensive stirring and set aside at 5 °C for 30 min. The precipitate was filtered off with suction, washed with water and dried. Yield 50% (from **15**), 49% (from **16**); m.p. 182–184 °C (acetone–water), ref.[3b] 184 °C (benzene or ethanol). For $C_{11}H_8N_2O_2$ (200.2) calculated: 65.99% C, 4.23% H, 13.99% N; found: 65.73% C, 4.41% H, 14.20% N. UV, λ_{max} (ε_{max}): 223 (4 220), 261 (3 620), 304 (2 750). IR: 1 783 and 1 727 (C=O). ^{1}H NMR: 3.20 s, 3 H (CH_3); 7.13 s, 1 H and 7.28–7.96 m, 4 H (arom. H).

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