

5-Aminouracil as a Building Block in Heterocyclic Synthesis: Part IV. One-pot Synthesis of 1*H*-Pyrrolo[2,3-*d*]pyrimidine-2,4(3*H*,7*H*)-dione Derivatives Using Controlled Microwave Heating

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An efficient and direct procedure for the synthesis of pyrrolo[2,3-*d*]pyrimidine-2,4-dione derivatives using controlled microwave heating has been described. The products were characterized by elemental analyses, IR, ¹H NMR, ¹³C NMR and MS spectra.

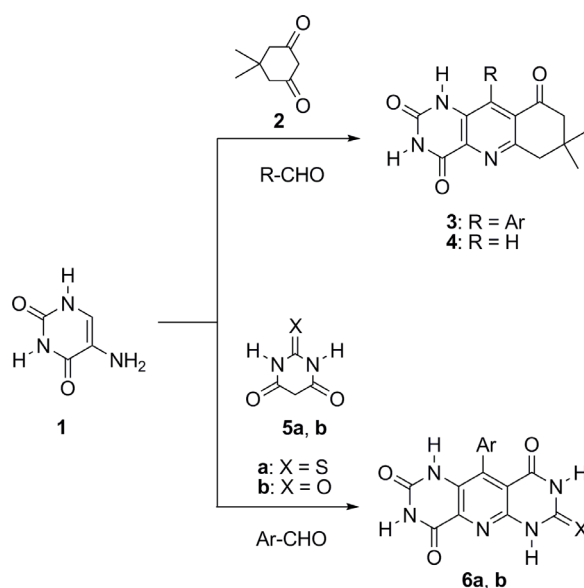
Key words: 5-Aminouracil, Dimedone, Barbituric Acid, Thiobarbituric Acid, Controlled Microwave Heating, One-pot Synthesis, Pyrrolo[2,3-*d*]pyrimidine-2,4-dione

Introduction

Fused pyrimidinone derivatives have attracted the attention of numerous researchers over many years due to their important biological activities [1–3]. Among them, pyrrolo[2,3-*d*]pyrimidines, a class of 7-deazapurine analog, exhibit interesting biological activity in part due to their resemblance to pyrimidines and purines. For example, they have recently been reported as enzyme inhibitors [4], cytotoxic [5], anti-inflammatory [6], anti-microbial [6], antibacterial [7], antifungal [7], anticancer [8], antitumor [9], antifolate [10], antiviral [11], vascular endothelial growth factor receptor-2 inhibitors [12], and antiangiogenic agents [12]. They also possess anti-HCV, anti-HIV type 1, anti-HSV, adenosine kinase inhibition, Aurora-A kinase inhibition and cAMP phosphodiesterase inhibition activity [13–15].

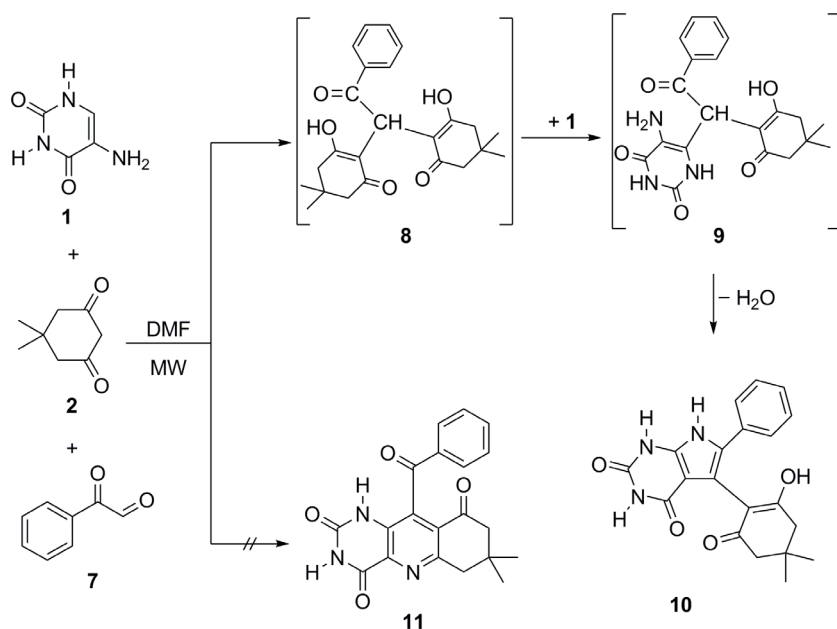
Recently, we have reported a simple and efficient synthesis of pyrimido[5,4-*b*]quinoline-2,4,9-triones **3** [16], **4** [17] and pyrido[3,2-*d*:6,5-*d'*]dipyrimidines **6** [18] *via* the reaction of 5-aminouracil (**1**), aldehydes and dimedone (**2**) or barbituric acid derivatives **5** under microwave irradiation without catalyst, which could have interesting effects on biological targets (Scheme 1).

Considering the above reports and in continuation of our interest in the development of new and sim-

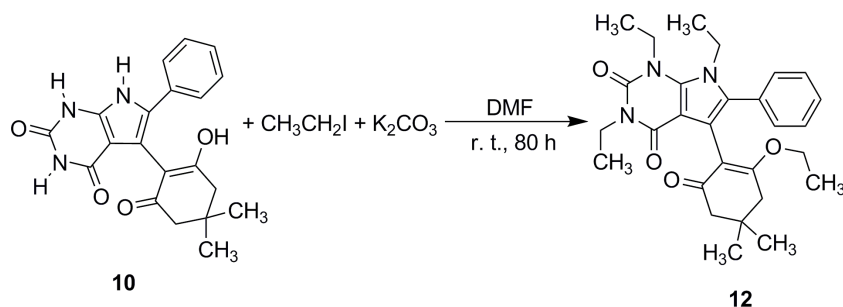


Scheme 1. Synthesis of pyrimido[5,4-*b*]quinolines **3**, **4** and pyrido[3,2-*d*:6,5-*d'*]dipyrimidines **6**.

ple methods for the synthesis of polyfunctionally substituted heterocyclic compounds [16–28], we wish to report a novel and efficient one-pot method for the synthesis of pyrrolo[2,3-*d*]pyrimidine-2,4-dione and pyrimido[5,4-*b*]quinoline-2,4,9-trione derivatives with expected interesting biological activity.



Scheme 2. Synthesis of 1H-pyrrolo[2,3-d]pyrimidine-2,4(3H,7H)-dione (**10**).



Scheme 3. Ethylation of **10**.

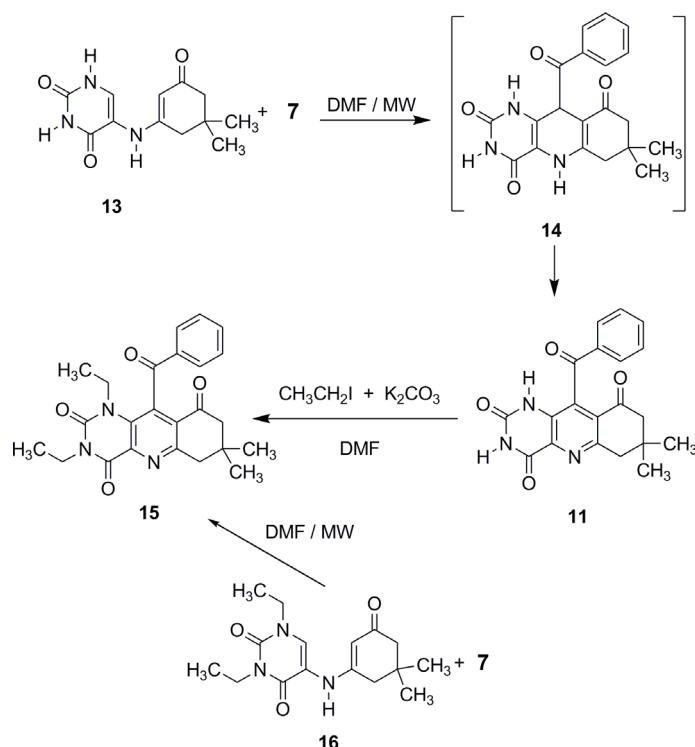
Results and Discussion

Thus, 5-aminouracil (**1**), dimedone (**2**) and phenylglyoxal hydrate (**7**) in DMF gave under controlled microwave heating for 20 min at 160 °C a solid product of molecular formula $C_{20}H_{19}N_3O_4$ ($m/z = 365$ (30 %) $[M]^+$) which may be formulated as the pyrrolo[2,3-d]pyrimidine-2,4-dione **10** or pyrimido[5,4-*b*]quinoline-2,4,9(1*H*,3*H*,5*H*)-trione **11** (Scheme 2).

The product was assigned structure **10** on the basis of spectral data and the chemical transformations outlined below. Thus, its 1H NMR spectrum revealed the presence of D_2O -exchangeable protons at $\delta = 10.36$, 10.53 and 11.95 ppm which are attributable to the three NH protons, 1-NH, 3-NH and 7-NH, respectively. Also, the structure assigned for compound **10** was fully supported by its ^{13}C NMR spectrum. Further confirmation of structure **10** was achieved *via* the

synthesis of its ethylated derivative **12** *via* the reaction of **10** with ethyl iodide in DMF and in the presence of anhydrous potassium carbonate (Scheme 3).

A distinction between compounds **10** and **12** is clearly manifested in the spectroscopic data. For example, the 1H NMR spectrum of compound **12** revealed no NH protons, and the presence of four ethyl groups indicated that the alkylation occurs at the N-1, N-3, N-7 and OH atoms. Furthermore, the structure assigned to **12** was fully supported by its mass spectrum, which showed a molecular formula $C_{28}H_{35}N_3O_4$ ($m/z = 477$ (35 %) $[M]^+$). With these spectroscopic data the proposed structure of **10** is identified. The formation of **10** was rationalized in terms of the initial formation of the intermediate **8** [29]. A subsequent reaction at the nucleophilic carbon atom C-6 in 5-aminouracil (**1**) leads to the formation of intermediate **9**,



Scheme 4. Synthesis of pyrimido[5,4-*b*]quinolines **11** and **15**.

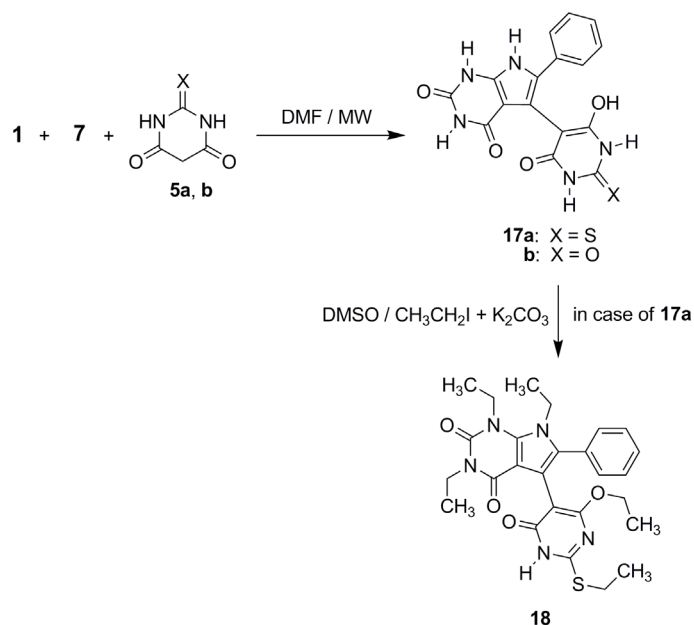
which was cyclized *via* loss of water to finally form pyrrolopyrimidine **10** (Scheme 2). The same product was obtained by refluxing 5-aminouracil (**1**), dimedone (**2**) and phenylglyoxal hydrate (**7**) in DMF for 10 h.

In addition, the structure of **10** was confirmed further by an alternative synthesis of its isomer **11** (Scheme 4). The reaction of phenylglyoxal hydrate (**7**) with enaminoketone **13** [16] in DMF under microwave irradiation at 160 °C for 20 min afforded 10-benzoyl-7,7-dimethyl-7,8-dihydropyrimido[5,4-*b*]quinoline-2,4,9(1*H*,3*H*,6*H*)-trione (**11**) (Scheme 4). The structure of the product **11** was confirmed by elemental analysis and spectral data. The disappearance of signals for 10-H and 5-NH in the ^1H NMR spectrum indicated the formation of compound **11**.

We also studied the alkylation of **11** with ethyl iodide. The reaction was carried out at r. t. in DMF and in the presence of anhydrous potassium carbonate to afford the ethylated derivative **15** (Scheme 4). The structure of the product **15** was established by elemental analysis and spectral data. Its IR spectrum revealed absorption bands around 1654–1690 cm^{-1} , characteristic of a carbonyl function. The ^1H NMR spectrum revealed that the alkylation occurs at the N-1 and N-3 atoms. Thus, the ^1H NMR spectrum of com-

pound **15** contained signals from the N^1CH_2 ($\delta = 3.80$) and N^3CH_2 protons ($\delta = 4.00$ ppm). Furthermore, the structure assigned to **15** was fully supported by its mass spectrum, which indicated the molecular formula $\text{C}_{24}\text{H}_{25}\text{N}_3\text{O}_4$ ($m/z = 419$ (35 %) $[\text{M}]^+$). Further confirmation of structure **15** was obtained *via* the reaction of ethylated enaminoketone **16** [17] with **7** in DMF under controlled microwave heating (Scheme 4).

As an extension of our synthetic methodology, 5-aminouracil (**1**), phenylglyoxal hydrate (**7**) and barbituric acids **5a, b** were also exposed to MW irradiation. The reaction proceeded similarly to give **17a, b** (Scheme 5). The proposed molecular structures of **17a, b** are supported by elemental and spectral analyses. The fragmentation patterns of the mass spectra of **17a** and **17b** showed the molecular ion peaks $[\text{M}]^+$ at $m/z = 369$ (70 %) and 353 (25 %), respectively, in good agreement with the assigned structure. The IR, ^1H NMR as well as the ^{13}C NMR spectra agreed with the proposed structures **17a, b**. For example, the ^1H NMR spectrum of **17a** revealed five relatively sharp singlets at $\delta = 10.55, 10.69, 12.11, 12.13$ and 12.26 ppm assigned to the five NH groups, in addition to the signals for the dimedone and phenyl protons. Moreover, the ethylated derivative **18** was

Scheme 5. Synthesis of **17** and **18**.

obtained by reacting **17a** with ethyl iodide in DMF and in the presence of anhydrous potassium carbonate (Scheme 5). The structure of **18** was confirmed by its elemental and spectral analyses, which showed the molecular ion peak $[M]^+$ at $m/z = 509$ (100%). Also, the ^1H NMR spectrum of **18** displayed signals of five ethyl groups indicating that the alkylation occurred at the N-1, N-3, N-7, OH and SH atoms. The imide hydrogen atoms in thiobarbituric acid take part in tautomerism so that the alkylation of this compound leads to a mixture of *N*- and *S*-alkyl derivatives [30, 31]

Experimental Section

General procedures

Melting points were measured with a Gallenkamp apparatus and are uncorrected. The reactions and purity were monitored by thin layer chromatography (TLC) on aluminum plates coated with silica gel with fluorescence indicator (Merck, 60 F₂₅₄) using CHCl_3 - CH_3OH (10:5) as eluent. Microwave irradiation was carried out using the Milestone Start Labstation for microwave-enhanced chemistry. Infrared spectra were recorded in potassium bromide disks on a Jasco FT/IR-450 Plus infrared spectrophotometer. ^1H NMR and ^{13}C NMR spectra were recorded on a Bruker DPX spectrometer operating at 400 MHz for ^1H NMR and 100 MHz for ^{13}C NMR, with deuterated chloroform (CDCl_3) or dimethylsulfoxide ($[\text{D}_6]\text{DMSO}$) as solvent. Chemical shifts are reported in δ (ppm) and with TMS or the solvent signal as internal standard. Mass spectra were recorded on a Trace

GC 2000/Finnigan Mat SSQ 7000 and a Shimadzu GCMS-QP-1000EX mass spectrometer at 70 eV. Elemental analyses were measured with a Vario EL III CHNOS Elemental Analyzer in the Microanalytical Center of Cairo University. Compounds **13** [16] and **16** [17] were synthesized using the published procedures.

Preparation of 5-(2-hydroxy-4,4-dimethyl-6-oxocyclohex-1-en-1-yl)-6-phenyl-1*H*-pyrrolo[2,3-*d*]pyrimidine-2,4(3*H*,7*H*)-dione (**10**)

Method A: A mixture of 5-aminouracil (**1**) (0.127 g, 1 mmol), dimedone (**2**) (0.140 g, 1 mmol) and phenylglyoxal hydrate (**7**) (0.134 g, 1 mmol) in DMF (5 mL) was heated under reflux in a Milestone Microwave Labstation at 160 °C for 20 min. The solvent was evaporated under reduced pressure. The solid product was collected by filtration and recrystallized from ethanol; yield 76%.

Method B: A solution of equimolar amounts of **1** (0.127 g, 1 mmol), **2** (0.140 g, 1 mmol) and **7** (0.134 g, 1 mmol) in DMF (10 mL) was refluxed for 10 h. Product **10** was isolated as described above; yield 70%.

Pale-yellow powder, m. p. 335–337 °C. – IR (film): $\nu = 3186, 3059, 2953, 1692 \text{ cm}^{-1}$. – ^1H NMR (400 MHz, $[\text{D}_6]\text{DMSO}$): $\delta = 1.03$ (s, 3H, CH_3), 1.07 (s, 3H, CH_3), 2.12 (brs, 2H, CH_2), 2.47 (brs, 2H, CH_2), 7.28 (t, 1H, $J = 6.8 \text{ Hz}$, Ar-H), 7.31 (t, 2H, $J = 7.2 \text{ Hz}$, Ar-H), 7.50 (d, 2H, $J = 7.2 \text{ Hz}$, Ar-H), 10.36 (s, 1H, NH, D_2O -exchangeable), 10.53 (s, 1H, NH, D_2O -exchangeable), 11.95 (s, 1H, NH, D_2O -exchangeable). – ^{13}C NMR (100 MHz, $[\text{D}_6]\text{DMSO}$): $\delta = 26.45, 30.40, 31.22, 38.89, 40.28, 100.30, 105.93, 109.97,$

126.93, 127.59, 128.02, 131.98, 135.74, 137.80, 151.64, 155.66, 162.05, 195.94. – MS (EI, 70 eV): m/z (%) = 366 (23) $[M+1]^+$, 365 (100) $[M]^+$. – $C_{20}H_{19}N_3O_4$ (365.38): calcd. C 65.74, H 5.24, N 11.50; found C 65.49, H 5.17, N 11.66

Preparation of 5-(2-ethoxy-4,4-dimethyl-6-oxocyclohex-1-en-1-yl)-1,3,7-triethyl-6-phenyl-1H-pyrrolo[2,3-d]pyrimidine-2,4(3H,7H)-dione (12)

Ethyl iodide (2.496 g, 16 mmol) was added to a mixture of **10** (0.73 g, 2 mmol) and anhydrous potassium carbonate (1.104 g, 8 mmol) in DMF (20 mL). The reaction mixture was stirred for 80 h at r.t. and then poured into cold water and extracted with carbon tetrachloride (3×20 mL). The combined organic extracts were washed with water and dried (anhydrous magnesium sulfate). After evaporation of some of the solvent (~ 5 mL), petroleum ether (30 mL) was added, and the resulting precipitate was collected, dried and recrystallized from diphenylether-*n*-hexane to afford **12** (yield 50 %). Colorless solid, m.p. 220–222 °C. – IR (film): $\nu = 3064, 2968, 1683, 1642\text{ cm}^{-1}$. – ^1H NMR (400 MHz, $[D_6]DMSO$): $\delta = 0.92$ (s, 6H, $2CH_3$), 1.11–1.14 (m, 12H, $4CH_3$), 1.95 (d, 1H, $J = 15.6$ Hz, CH_2), 2.25 (d, 1H, $J = 15.6$ Hz, CH_2), 2.32 (d, 1H, $J = 18$ Hz, CH_2), 2.58 (d, 1H, $J = 18$ Hz, CH_2), 3.87 (q, 2H, $J = 8$ Hz, CH_2), 3.96 (q, 2H, $J = 11$ Hz, CH_2), 4.06 (q, 2H, $J = 7$ Hz, CH_2), 4.17 (q, 2H, $J = 7$ Hz, CH_2), 7.17–7.41 (m, 5H, ArH). – ^{13}C NMR (100 MHz, $[D_6]DMSO$): $\delta = 13.23, 13.30, 15.29, 16.70, 25.81, 25.98, 27.17, 31.16, 31.31, 35.22, 38.66, 49.93, 63.73, 99.97, 100.61, 107.56, 109.23, 110.18, 120.64, 128.03, 128.68, 129.59, 130.03, 133.03, 141.96, 150.15, 154.21, 174.05, 196.99$. – MS (EI, 70 eV): m/z (%) = 478 (40) $[M+1]^+$, 477 (35) $[M]^+$. – $C_{28}H_{35}N_3O_4$ (477.60): calcd. C 70.42, H 7.39, N 8.80; found C 70.59, H 7.37, N 8.66.

*Preparation of 10-benzoyl-7,7-dimethyl-7,8-dihydropyrimido[5,4-*b*]quinoline-2,4,9(1H,3H,6H)trione (11)*

A mixture of 5-((5,5-dimethyl-3-oxocyclohex-1-en-1-yl)-amino)pyrimidine-2,4(1H,3H)-dione (**13**) (0.249 g, 1 mmol) and **7** (0.134 g, 1 mmol) in DMF (5 mL) was heated under reflux in a Microwave Labstation at 160 °C for 30 min. The solvent was evaporated under vacuum. The solid product was collected by filtration and crystallized from benzene, yield 60 %. Pale-brown powder, m.p. 282–285 °C. – IR (film): $\nu = 3157, 3028, 2931, 1675, 1632\text{ cm}^{-1}$. – ^1H NMR (400 MHz, $[D_6]DMSO$): $\delta = 1.02$ (s, 6H, $2CH_3$), 2.49 (s, 2H, CH_2), 3.22 (s, 2H, CH_2), 7.40–7.55 (m, 5H, Ar-H), 10.32 (s, 1H, NH, D_2O -exchangeable), 10.48 (s, 1H, NH, D_2O -exchangeable). – MS (EI, 70 eV): m/z (%) = 364 (40) $[M+1]^+$, 363 (60) $[M]^+$. – $C_{20}H_{17}N_3O_4$ (363.37): calcd. C 66.11, H 4.72, N 11.56; found C 65.89, H 4.75, N 11.61.

*Preparation of 10-benzoyl-1,3-diethyl-7,7-dimethyl-7,8-dihydropyrimido[5,4-*b*]quinoline-2,4,9(1H,3H,6H)-trione (15)*

Method A: Ethyl iodide (0.624 g, 4 mmol) was added to a mixture of **11** (0.363 g, 1 mmol) and anhydrous potassium carbonate (0.276 g, 2 mmol) in DMF (10 mL). The reaction mixture was stirred for 70 h at r.t. and then poured into cold water and extracted with chloroform (3×20 mL). The combined organic extracts were washed with water and dried (anhydrous magnesium sulfate). After evaporation of some of the solvent (~ 10 mL), petroleum ether (40 mL) was added, and the resulting precipitate was collected, dried and recrystallized from petroleum ether-chloroform to give **14**; yield 43 %.

Method B: A mixture of 5-((5,5-dimethyl-3-oxocyclohex-1-en-1-yl)amino)-1,3-diethyl pyrimidine-2,4(1H,3H)-dione (**16**) (0.710 g, 1 mmol) and **7** (0.134 g, 1 mmol) in DMF (5 mL) was heated under reflux in a Milestone Microwave Labstation at 160 °C for 50 min. The solvent was evaporated under vacuum. Product **14** was isolated by filtration and recrystallized as described above; yield 5 %.

Brown powder, m.p. 183–185 °C. – IR (film): $\nu = 3060, 2954, 2877, 1690, 1654\text{ cm}^{-1}$. – ^1H NMR (400 MHz, $CDCl_3$): $\delta = 1.05$ (s, 6H, $2CH_3$), 1.20 (t, 3H, $J = 6$ Hz, CH_3), 1.27 (t, 3H, $J = 6$ Hz, CH_3), 2.53 (s, 2H, CH_2), 3.35 (s, 2H, CH_2), 3.80 (q, 2H, $J = 9$ Hz, CH_2), 4.00 (q, 2H, $J = 6$ Hz, CH_2), 7.25–7.33 (m, 3H, Ar-H), 7.50 (d, 2H, Ar-H, $J = 7.2$ Hz). – MS (EI, 70 eV): m/z (%) = 419 (35) $[M]^+$. – $C_{24}H_{25}N_3O_4$ (419.47): calcd. C 68.72, H 6.01, N 10.02; found C 68.90, H 5.96, N 10.11.

*Preparation of 6-phenyl-1H-pyrrolo[2,3-*d*]pyrimidine-2,4(3H,7H)-diones (17a, b)*

A solution of equimolar amounts of **1** (0.127 g, 1 mmol), **7** (0.134 g, 1 mmol) and thiobarbituric acid **5a** (0.144 g, 1 mmol) and/or barbituric acid **5b** (0.128 g, 1 mmol) in DMF (5 mL) was heated under reflux in a Milestone Microwave Labstation at 160 °C for 20 min. The solvent was evaporated under reduced pressure. The solid product was collected by filtration and crystallized from the appropriate solvent.

*5-(6-Hydroxy-4-oxo-2-thioxo-1,2,3,4-tetrahydropyrimidin-5-yl)-6-phenyl-1H-pyrrolo[2,3-*d*]pyrimidine-2,4(3H,7H)-dione (17a)*

Pale-brown crystals, yield 80 % (EtOH); m.p. > 360 °C. – IR (film): $\nu = 3147, 3018, 2954, 1667\text{ cm}^{-1}$. – ^1H NMR (400 MHz, $[D_6]DMSO$): $\delta = 7.27$ (t, 1H, Ar-H, $J = 6.2$ Hz), 7.40 (t, 2H, Ar-H, $J = 6.9$ Hz), 7.49 (d, 2H, Ar-H, $J = 7.2$ Hz), 10.55 (s, 1H, NH, D_2O -exchangeable), 10.69 (s, 1H, NH,

D₂O-exchangeable), 12.11 (s, 1H, NH, D₂O-exchangeable), 12.13 (s, 1H, NH, D₂O-exchangeable), 12.26 (s, 1H, HN, D₂O-exchangeable). – ¹³C NMR (100 MHz, [D₆]DMSO): δ = 86.57, 97.98, 109.25, 109.98, 126.75, 127.72, 128.25, 131.69, 136.54, 138.70, 151.58, 155.71, 161.33, 173.59, 200.11. – MS (EI, 70 eV): m/z (%) = 369.11 (70) [M]⁺, 370.12 (25.6), 371.22 (20). – C₁₆H₁₁N₅O₄S (369.35): calcd. C 52.03, H 3.00, N 18.96; found C 52.19, H 2.96, N 18.91.

5-(6-Hydroxy-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-5-yl)-6-phenyl-1H-pyrrolo[2,3-d]pyrimidine-2,4(3H,7H)-dione (17b)

Colorless powder, yield 76 % (DMF); m. p. > 350 °C. – IR (film): ν = 3173, 3030, 2822, 1702, 1670 cm⁻¹. – ¹H NMR (400 MHz, [D₆]DMSO): δ = 7.21 (t, 1H, Ar-H, J = 7.0), 7.30 (t, 2H, Ar-H, J = 8), 7.68 (d, 2H, Ar-H, J = 7), 9.53 (s, 2H, NH, D₂O-exchangeable), 10.08 (s, 1H, NH, D₂O-exchangeable), 10.44 (s, 1H, NH, D₂O-exchangeable), 11.71 (s, 1H, NH, D₂O-exchangeable). – ¹³C NMR (100 MHz, [D₆]DMSO): δ = 100.01, 109.72, 126.77, 127.35, 128.04, 132.16, 138.53, 151.15, 151.57, 155.74, 163.09. – MS (EI, 70 eV): m/z (%) = 355.2 (10) [M+2]⁺, 353.2 (25) [M]⁺. – C₁₆H₁₁N₅O₅ (353.29): calcd. C 54.39, H 3.14, N 19.82; found C 54.22, H 3.28, N 19.90.

Synthesis of 5-(4-ethoxy-2-(ethylthio)-6-oxo-1,6-dihydropyrimidin-5-yl)-1,3,7-triethyl-6-phenyl-1H-pyrrolo[2,3-d]pyrimidine-2,4(3H,7H)-dione (18)

Ethyl iodide (3.79 g, 24 mmol) was added to a mixture of **17** (0.739 g, 2 mmol) and anhydrous potassium carbonate (1.65 g, 12 mmol) in DMSO (10 mL). The reaction mixture was stirred for 86 h at r. t. and then poured into cold water, the precipitate was collected by filtration and recrystallized from diethyl ether-petroleum ether to give **18** (yield 40 %). Colorless solid, m. p. 230–233 °C. – IR (film): ν = 3205, 3064, 2968, 1703, 1682 cm⁻¹. – ¹H NMR (400 MHz, [D₆]DMSO): δ = 1.01 (t, 3H, J = 9 Hz, CH₃), 1.15 (t, 3H, J = 7 Hz, CH₃), 1.25 (t, 3H, J = 7 Hz, CH₃), 1.31 (t, 3H, J = 7 Hz, CH₃), 1.36 (t, 3H, J = 11 Hz, CH₃), 3.16 (q, 2H, J = 8 Hz, CH₂), 3.76 (q, 2H, J = 8 Hz, CH₂), 3.94 (q, 2H, J = 10 Hz, CH₂), 4.14 (q, 2H, J = 7 Hz, CH₂), 4.21 (q, 4H, J = 7 Hz, CH₂), 7.21–7.50 (m, 5H, ArH), 12.11 (s, 1H, NH). – MS (EI, 70 eV): m/z (%) = 508.25 (6.87), 509.20 (100) [M]⁺, 510.20 (33), 511.15 (11). – C₂₆H₃₁N₅O₄S (509.62): calcd. C 61.28, H 6.13, N 13.74; found C 61.21, H 6.22, N 13.79.

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