HETEROCYCLES, Vol. 89, No. 8, 2014, pp. 1933 - 1939. © 2014 The Japan Institute of Heterocyclic Chemistry
Received, 4th June, 2014, Accepted, 20th June, 2014, Published online, 30th June, 2014
DOI: 10.3987/COM-14-13038

A SIMPLE METHOD FOR THE PREPARATION OF PYRIMIDO[4,5-*d*]PYRIMIDINE-2,4(1*H*,3*H*)-DITHIONE DERIVATIVES

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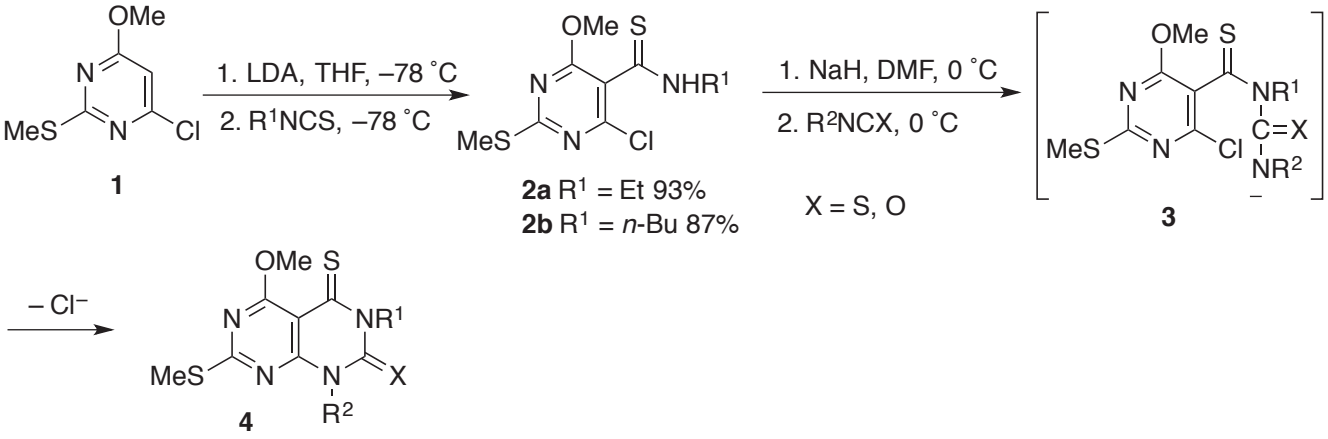
Abstract – A facile and efficient two-step sequence for the preparation of 1,3-disubstituted pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithiones starting with 4-chloro-6-methoxy-2-(methylsulfanyl)pyrimidine has been developed. Thus, the reaction of 4-chloro-5-lithio-6-methoxy-2-(methylsulfanyl)pyrimidine, generated by the treatment of the starting material with lithium diisopropylamide (LDA), with some aliphatic isothiocyanates gives *N*-alkyl-4-chloro-6-methoxy-2-(methylsulfanyl)pyrimidine-5-carbothioamides, which are then allowed to react with various isothiocyanates in the presence of sodium hydride to give the desired products. This method is applicable to the synthesis of 1,3-disubstituted 4-thioxo-3,4-dihydropyrimido[4,5-*d*]pyrimidin-2(1*H*)-ones using phenyl isocyanate in place of isothiocyanates.

Nagarajan and co-workers have reported the synthesis of some derivatives with the pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dione structure and their potential uses for chemotherapeutic agents.[1] So, pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithiones may also be of biological interest. However, literature survey revealed that there is only one report on the synthesis of this class of heterocycles. In this report, Evers and Fischer have demonstrated the preparation of derivatives carrying no substituents at both the 1- and 3-positions by the reaction of 4-aminopyrimidine-5-carbonitriles with *O*-ethyl

S-potassium dithiocarbonate ($EtOCS_2K$).[2] In the course of our study on exploring the versatility of 4,6-dichloro-2-(methylsulfanyl)pyrimidine (DCSMP) as a starting material for the preparation of useful heterocycle-fused pyrimidine derivatives,[3,4] we became interested in developing a general method for the preparation of pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione derivatives from DCSMP. In this paper, we wish to report a facile procedure for the preparation of 1,3-disubstituted pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithiones (**4**, X = S). The method involves successive treatment of *N*-alkyl-4-chloro-6-methoxy-2-(methylsulfanyl)pyrimidine-5-carbothioamides (**2**) with sodium hydride and isothiocyanates. Compounds (**2**) can be prepared by the lithiation of the 5-position of 4-chloro-6-methoxy-2-(methylsulfanyl)pyrimidine, easily derived from DCSMP, with LDA,[3] followed by the reaction with some alkyl isothiocyanates. In addition, we also present the applicability of the present method to the synthesis 1,3-disubstituted 4-thioxo-3,4-dihydropyrimido[4,5-*d*]pyrimidin-2(1*H*)-one derivatives (**4**, X = O) using phenyl isocyanate in place of isothiocyanates.

Our synthetic route to 1,3-disubstituted pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithiones (**4**, X = S) is illustrated in Scheme 1. It started with 4-chloro-6-methoxy-2-(methylsulfanyl)pyrimidine (**1**), which is readily obtained by displacing one of the two chloro substituents of 4,6-dichloro-2-(methylsulfanyl)pyrimidine (DCSMP) with sodium methoxide.[3] Compound (**1**) was lithiated with lithium diisopropylamide (LDA) at –78 ˚C in THF as described previously,[3,4] and then the resulting lithium product was allowed to react with ethyl isothiocyanate and *n*-butyl isothiocyanate at the same temperature to give, after aqueous workup and subsequent purification by column chromatography on silica gel, the corresponding *N*-ethyl and *N*-*n*-butyl thioamides (**2a**) and (**2b**) in 93 and 87% yields, respectively. However, the uses of cyclohexyl isothiocyanate, benzyl isothiocyanate, and phenyl isothiocyanate did not give the expected thioamides under the reaction conditions probably due to low reactivity of these isothiocyanates mainly arising from the steric bulkiness. It is worth noting that the reaction of 4-chloro-5-lithio-6-methoxypyrimidine,[1] generated from 4-chloro-6-methoxypyrimidine, with ethyl isothiocyanate resulted in the formation of an intractable mixture of products.



Scheme 1

The desired products (**4**, X = S) were produced by successive treatment of **2** with sodium hydride and various isothiocyanates in DMF at 0 ˚C, followed by stirring for 15 min at the same temperature. After usual aqueous workup, the resulting precipitates were collected by filtration and recrystallized from appropriate solvents to provide **4** in a pure form in each case. As indicated in Table 1, Entries 1-8, both of aliphatic and aromatic isothiocyanates were usable and the yields of the products (**4a**-**4h**) were generally good. These products were characterized by spectral (IR, ^{1}H NMR, ^{13}C NMR, MS) data and elemental analyses. For example, the IR spectrum of compound (**4a**) exhibits two absorption bands at 1287 and 1247 cm^{-1} due to the two C=S bonds. Two signals at δ 181.68 and 175.59, assignable to two C=S carbons are observed in the ^{13}C NMR spectrum. The other data are in good agreement with the structure of **4a** (see Experimental section).

Table 1. Preparation of pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithiones and 4-thioxo-3,4-dihydropyrimido[4,5-*d*]pyrimidin-2(1*H*)-ones (**4**)

Entry	**2**	R^2NCX	**4**	Yield/%[a]
1	**2a** (R^1 = Et)	PhNCS	**4a**	84
2	**2a**	2-MeC_6H_4NCS	**4b**	65
3	**2a**	3-ClC_6H_4NCS	**4c**	87
4	**2a**	3-$MeOC_6H_4NCS$	**4d**	66
5	**2a**	EtNCS	**4e**	74
6	**2b** (R^1 = *n*-Bu)	PhNCS	**4f**	85
7	**2b**	3,5-$Me_2C_6H_3NCS$	**4g**	72
8	**2b**	*c*-HexNCS	**4h**	62
9	**2a**	PhNCO	**4i**	49
10	**2b**	PhNCO	**4j**	33

[a] Yields of isolated products.

Subsequently, to further prove the utility of this procedure, we examined the use of isocyanates in place of isothiocyanates expecting formation of 1,3-disubstituted 4-thioxo-3,4-dihydropyrimido[4,5-*d*]pyrimidin-2(1*H*)-ones (**4**, X = O). It was found that when compounds (**2a**) and (**2b**) were similarly treated with sodium hydride and then with phenyl isocyanate, the corresponding desired products (**4i**) and (**4j**), respectively, were obtained but in rather lower yields than those of **4a**-**4h** as indicated in Table 1, Entries 9 and 10. Unfortunately, however, *n*-butyl isocyanate could not be successfully employed in the reaction with **2a**; a considerably complex mixture of products was obtained, from which no more than a trace amount of the desired product could be isolated.

In conclusion, we have presented an efficient sequence for the preparation of a range of 1,3-disubstituted pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione derivatives of biological interest starting from 4-chloro-6-methoxy-2-(methylsulfanyl)pyrimidine. We have also demonstrated that the sequence can be

applied to the synthesis of 1,3-disubstituted 4-thioxo-3,4-dihydropyrimido[4,5-*d*]pyrimidin-2(1*H*)-ones, though the yields were not so high. The present method may find some value in that the starting materials are readily available and that synthetic operations are very simple.

EXPERIMENTAL

All melting points were obtained on a Laboratory Devices MEL-TEMP II melting apparatus and are uncorrected. IR spectra were recorded with a Perkin–Elmer Spectrum65 FTIR spectrophotometer. ^{1}H NMR spectra were recorded in $CDCl_3$ using TMS as an internal reference with a JEOL ECP500 FT NMR spectrometer operating at 500 MHz or a JEOL LA400FT NMR spectrometer operating at 400 MHz. ^{13}C NMR spectra were recorded in $CDCl_3$ using TMS as an internal reference with a JEOL ECP500 FT NMR spectrometer operating at 125 MHz or a JEOL LA400FT NMR spectrometer operating at 100 MHz. Low-resolution MS spectra (EI, 70 eV) were measured by a JEOL JMS AX505 HA spectrometer. High-resolution MS spectra (DART, positive) were measured by a Thermo Scientific Exactive spectrometer. TLC was carried out on Merck Kieselgel 60 PF_{254}. Column chromatography was performed using WAKO GEL C-200E. All of the organic solvents used in this study were dried over appropriate drying agents and distilled prior to use.

Starting Materials. *n*-BuLi was supplied by Asia Lithium Corporation. All other chemicals used in this study were commercially available.

4-Chloro-5-methoxy-2-(methylsulfanyl)pyrimidine (1).[3] To a stirred solution of 4,6-dichloro-2-(methylsulfanyl)pyrimidine (1.9 g, 10 mmol) in MeOH (6 mL) at 0 ˚C was added NaH (60% in mineral oil; 0.48 g, 12 mmol) in several portions. After evolution of H_2 had ceased, the temperature was raised to rt and stirring was continued for 10 min. The precipitate was filtered off, and the filtrate was concentrated by evaporation. The residue was purified by column chromatography on silica gel (AcOEt/hexane 1:30) to give **1** (0.17g, 91%); a white solid; mp 36–38 ˚C (hexane); IR (KBr) 1560, 1541 cm^{-1}; ^{1}H NMR (400 MHz) δ 2.56 (s, 3H), 3.98 (s, 3H), 6.42 (s, 1H).

Typical Procedure for the Preparation of Pyrimidine-5-carbothioamides (2). 4-Chloro-*N*-ethyl-6-methoxy-2-(methylsulfanyl)pyrimidine-5-carbothioamide (2a). To a stirred solution of LDA (4.5 mmol), generated by the standard method from *n*-BuLi and *i*-Pr_2NH, in THF (4 mL) at –78 ˚C was added a solution of **1** (0.86 g, 4.5 mmol) in THF (4 mL) dropwise. After 1 h, EtNCS (0.39 g, 4.5 mmol) was added and stirring was continued for 5 min at the same temperature before addition of aqueous NH_4Cl (20 mL). The mixture was warmed to room temperature and extracted with AcOEt (3 × 15 mL). The combined extracts were washed with brine (10 mL), dried (Na_2SO_4), and concentrated by evaporation. The residue was purified by column chromatography on silica gel ($CHCl_3$) to give **2a** (1.2 g, 93%); a white solid; mp 112–113 ˚C (hexane/CH_2Cl_2); IR (KBr) 3208, 1566, 1039 cm^{-1}; ^{1}H NMR (400 MHz) δ

1.36 (t, *J* = 7.3 Hz, 3H), 2.55 (s, 3H), 3.80–3.86 (m, 2H), 4.01 (s, 3H), 7.36 (br s, 1H). Anal. Calcd for $C_9H_{12}ClN_3OS_2$: C, 38.91; H, 4.35; N, 15.13. Found: C, 38.82; H, 4.38; N, 15.04.

***N*-Butyl-4-chloro-6-methoxy-2-(methylsulfanyl)pyrimidine-5-carbothioamide (2b):** a pale-yellow solid; mp 95–96 ˚C (hexane/CH_2Cl_2); IR (KBr) 3244, 1567, 1370 cm^{-1}; ^1H NMR (500 MHz) δ 0.98 (t, *J* = 7.6 Hz, 3H), 1.46 (sext, *J* = 7.6 Hz, 2H), 1.73 (quint, *J* = 7.6 Hz, 2H), 2.55 (s, 3H), 3.80 (q, *J* = 7.6 Hz, 2H), 4.01 (s, 3H), 7.33 (br s, 1H). Anal. Calcd for $C_{11}H_{16}ClN_3OS_2$: C, 43.20; H, 5.27; N, 13.74. Found: C, 42.90; H, 5.38; N, 13.66.

Typical Procedure for the Preparation of Pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithiones (4a-h). 3-Ethyl-5-methoxy-7-methylsulfanyl-1-phenylpyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione (4a). To a stirred suspension of NaH (60% in mineral oil; 25 mg, 0.6 mmol) in DMF (3 mL) at 0 ˚C was added a solution of **2a** (0.17 g, 0.6 mmol) in THF (2 mL) dropwise. After evolution of H_2 gas had ceased, PhNCS (81 mg, 0.6 mmol) was added and stirring was continued for 15 min at the same temperature before addition of aqueous NH_4Cl (20 mL). The precipitate was collected by filtration and recrystallized from hexane/CH_2Cl_2 to give **4a** (0.16 g, 84%); yellow needles; mp 145–147 ˚C; IR (KBr) 1572, 1287, 1247 cm^{-1}; ^1H NMR (500 MHz) δ 1.42 (t, *J* = 6.9 Hz, 3H), 2.00 (s, 3H), 4.11 (s, 3H), 5.27 (br s, 2H), 7.17 (d, *J* = 7.4 Hz, 2H), 7.45 (t, *J* = 7.4 Hz, 1H), 7.51 (t, *J* = 7.4 Hz, 2H); ^{13}C NMR (100 MHz) δ 10.64, 13.78, 50.06, 55.44, 104.22, 128.46, 128.51, 129.35, 141.02, 152.66, 168.53, 174.57, 175.59, 181,68; MS *m/z* 376 (M^+, 100). Anal. Calcd for $C_{16}H_{16}N_4OS_3$: C, 51.04; H, 4.28; N, 14.88. Found: C, 50.96; H, 4.26; N, 14.80.

3-Ethyl-5-methoxy-1-(2-methylphenyl)-7-(methylsulfanyl)pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione (4b): an orange solid; mp 183–184 ˚C (hexane/CH_2Cl_2); IR (KBr) 1562, 1291, 1243 cm^{-1}; ^1H NMR (500 MHz) δ 1.43 (t, *J* = 6.9 Hz, 3H), 1.98 (s, 3H), 2.07 (s, 3H), 4.11 (s, 3H), 5.28 (br s, 2H), 7.06 (d, *J* = 6.9 Hz, 1H), 7.31–7.38 (m, 3H); ^{13}C NMR (125 MHz) δ 10.65, 13.80, 17.60, 49.96, 55.47, 103.75, 127.11, 127.98, 128.80, 130.83, 135.32, 140.02, 152.12, 168.57, 174.59, 174.88, 181.66; MS *m/z* 390 (M^+, 100). Anal. Calcd for $C_{17}H_{18}N_4OS_3$: C, 52.28; H, 4.65; N, 14.35. Found: C, 52.20; H, 4.65; N, 14.41.

1-(3-Chlorophenyl)-3-ethyl-5-methoxy-7-(methylsulfanyl)pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione (4c): an orange solid; mp 170–172 ˚C (hexane/CH_2Cl_2); IR (KBr) 1574, 1290, 1246 cm^{-1}; ^1H NMR (500 MHz) δ 1.42 (t, *J* = 6.9 Hz, 3H), 2.06 (s, 3H), 4.11 (s, 3H), 5.24 (br s, 2H), 7.10 (dd, *J* = 8.4, 2.3 Hz, 1H), 7.21 (br s, 1H), 7.43–7.47 (m, 2H); ^{13}C NMR (125 MHz) δ 10.66, 13.91, 50.02, 55.48, 103.78, 127.07, 128.73, 129.14, 130.22, 134.80, 141.71, 152.42, 168.47, 174.73, 175.19, 181.47; MS *m/z* 410 (M^+, 100). Anal. Calcd for $C_{16}H_{15}ClN_4OS_3$: C, 46.76; H, 3.68; N, 13.63. Found: C, 46.60; H, 3.60; N, 13.67.

3-Ethyl-5-methoxy-1-(3-methoxyphenyl)-7-(methylsulfanyl)pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione (4d): an orange solid; mp 177–179 ˚C (hexane/CH_2Cl_2); IR (KBr) 1605, 1572, 1287, 1251 cm^{-1};

^{1}H NMR (500 MHz) δ 1.42 (t, *J* = 6.9 Hz, 3H), 2.05 (s, 3H), 3.82 (s, 3H), 4.10 (s, 3H), 5.26 (br s, 2H), 6.73 (t, *J* = 2.3 Hz, 1H), 6.77 (d, *J* = 7.6 Hz, 1H), 6.99 (dd, *J* = 8.4, 2.3 Hz, 1H), 7.41 (dd, *J* = 8.4, 7.6 Hz, 1H); ^{13}C NMR (125 MHz) δ 10.64, 13.87, 50.04, 55.47 (2C), 103.82, 114.21, 114.29, 120.75, 129.91, 141.83, 152.54, 160.53, 168.50, 174.57, 175.35, 181.65. HR MS. Calcd for $C_{17}H_{19}N_4O_2S_3$ (M+H): 407.0670. Found: *m/z* 407.0659. Anal. Calcd for $C_{17}H_{18}N_4O_2S_3$: C, 50.22; H, 4.46; N, 13.78. Found: C, 50.18; H, 4.50; N, 13.80.

1,3-Diethyl-5-methoxy-7-(methylsulfanyl)pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione (4e): an orange solid; mp 118–119 °C (hexane/CH_2Cl_2); IR (KBr) 1567, 1277, 1240 cm^{-1}; ^{1}H NMR (500 MHz) δ 1.388 and 1.394 (2t, *J* = 6.9 Hz each, combined 6H), 2.59 (s, 3H), 4.11 (s, 3H), 4.88 (q, *J* = 6.8 Hz, 2H), 5.25 (br, 2H); ^{13}C NMR (125 MHz) δ 10.64, 11.83, 14.35, 46.24, 50.25, 55.34, 104.05, 151.53, 168.77, 174.46, 174.80, 181.27. HR MS. Calcd for $C_{12}H_{17}N_4OS_3$ (M+H): 329.0564. Found: *m/z* 329.0558. Anal. Calcd for $C_{12}H_{16}N_4OS_3$: C, 43.88; H, 4.91; N, 17.06. Found: C, 43.84; H, 4.94; N, 17.01.

3-Butyl-5-methoxy-7-methylsulfanyl-1-phenylpyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione (4f): an orange solid; mp 166–168 °C (hexane/CH_2Cl_2); IR (KBr) 1567, 1287, 1263 cm^{-1}; ^{1}H NMR (500 MHz) δ 0.96 (t, *J* = 7.6 Hz, 3H), 1.41 (sext, *J* = 7.6 Hz, 2H), 1.86 (quint, *J* = 7.6 Hz, 2H), 1.99 (s, 3H), 4.10 (s, 3H), 5.0–5.3 (br, 2H), 7.17 (d, *J* = 7.6 Hz, 2H), 7.45 (t, *J* = 7.6 Hz, 1H), 7.51 (t, *J* = 7.6 Hz, 2H); ^{13}C NMR (125 MHz) δ 13.73, 13.79, 19.91, 26.70, 54.38, 55.45, 103.89, 128.44, 128.50, 129.34, 141.05, 152.63, 168.49, 174.51, 175.78, 181.81; MS *m/z* 404 (M^+, 100). Anal. Calcd for $C_{18}H_{20}N_4OS_3$: C, 53.44; H, 4.98; N, 13.85. Found: C, 53.37; H, 4.98; N, 13.93.

3-Butyl-1-(3,5-dimethylphenyl)-5-methoxy-7-(methylsulfanyl)pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione (4g): an orange solid; mp 220–223 °C (hexane/CH_2Cl_2); IR (KBr) 1566, 1292, 1261 cm^{-1}; ^{1}H NMR (500 MHz) δ 0.96 (t, *J* = 7.6 Hz, 3H), 1.41 (sext, *J* = 7.6 Hz, 2H), 1.87 (quint, *J* = 7.6 Hz, 2H), 2.02 (s, 3H), 2.36 (s, 6H), 4.10 (s, 3H), 5.07–5.23 (br, 2H), 6.78 (s, 2H), 7.06 (s, 1H); ^{13}C NMR (125 MHz) δ 13.74, 13.85, 19.92, 21.24, 16.73, 54.42, 55.43, 103.89, 125.89, 130.05, 138.99, 140.75, 152.59, 168.52, 174.41, 175.79, 181.84. HR MS. Calcd for $C_{20}H_{25}N_4OS_3$ (M+H): 433.1190. Found: *m/z* 433.1171. Anal. Calcd for $C_{20}H_{24}N_4OS_3$: C, 55.52; H, 5.59; N, 12.95. Found: C, 55.34; H, 5.72; N, 13.08.

3-Butyl-1-cyclohexyl-5-methoxy-7-(methylsulfanyl)pyrimido[4,5-*d*]pyrimidine-2,4(1*H*,3*H*)-dithione (4h): an orange solid; mp 143–145 °C (hexane/CH_2Cl_2); IR (KBr) 1565, 1293, 1268 cm^{-1}; ^{1}H NMR (500 MHz) δ 0.99 (t, *J* = 7.6 Hz, 3H), 1.18–1.27 (m, 1H), 1.37–1.47 (m, 4H), 1.71–1.74 (m, 1H), 1.79–1.89 (m, 6H), 2.64 (s, 3H), 2.69–2.77 (m, 2H), 4.09 (s, 3H), 5.09 (br, 2H), 5.77–5.83 (m, 1H); ^{13}C NMR (125 MHz) δ 13.73, 14.66, 19.93, 25.56, 26.47, 26.93, 29.01, 45.12, 55.16, 66.97, 104.05, 152.31, 168.30, 173.59, 176.43, 181.83; MS *m/z* 410 (M^+, 100). Anal. Calcd for $C_{18}H_{26}N_4OS_3$: C, 52.65; H, 6.38; N, 13.64. Found: C, 52.35; H, 6.19; N, 13.58.

Typical Procedure for the Preparation of 4-Thioxo-3,4-dihydropyrimido[4,5-*d*]pyrimidin-2(1*H*)-ones (4i) and (4j). 3-Ethyl-5-methoxy-7-methylsulfanyl-1-phenyl-4-thioxo-3,4-dihydropyrimido[4,5-*d*]pyrimidin-2(1*H*)-one (4i). To a stirred suspension of NaH (60% in mineral oil; 25 mg, 0.6 mmol) in DMF (3 mL) at 0 ˚C was added a solution of **2a** (0.17 g, 0.6 mmol) in THF (2 mL) dropwise. After evolution of H_2 gas had ceased, PhNCO (73 mg, 0.6 mmol) was added and stirring was continued for 15 min at the same temperature before addition of aqueous NH_4Cl (10 mL). The mixture was warmed to room temperature and extracted with AcOEt (3 × 10 mL). The combined extracts were washed with water (3 × 10 mL) and brine (10 mL), dried (Na_2SO_4), and concentrated by evaporation. The residual solid was recrystallized from hexane/$CHCl_3$ to give **4i** (0.11 g, 49%); a yellow solid; mp 193–195 ˚C; IR (KBr) 1702, 1571, 1284 cm^{-1}; ^1H NMR (500 MHz) δ 1.33 (t, *J* = 6.9 Hz, 3H), 2.11 (s, 3H), 4.11 (s, 3H), 4.68 (q, *J* = 6.9 Hz, 2H), 7.25 (d, *J* = 8.4 Hz, 2H), 7.45 (t, *J* = 7.6 Hz, 1H), 7.51 (dd, *J* = 8.4, 7.6 Hz, 2H); ^{13}C NMR (125 MHz) δ 11.49, 13.88, 42.89, 55.30, 101.19, 128.52, 128.80, 129.19, 135.72, 148.38, 154.30, 168.40, 174.31, 184.52. HR MS. Calcd for $C_{16}H_{17}N_4O_2S_2$ (M+H): 361.0793. Found: *m/z* 361.0783. Anal. Calcd for $C_{16}H_{16}N_4O_2S_2$: C, 53.31; H, 4.47; N, 15.54. Found: C, 53.24; H, 4.64; N, 15.44.

3-Butyl-5-methoxy-7-methylsulfanyl-1-phenyl-4-thioxo-3,4-dihydropyrimido[4,5-*d*]pyrimidin-2(1*H*)-one (4j): a yellow solid; mp 153–155 ˚C (hexane/CH_2Cl_2); IR (KBr) 1705, 1563, 1286 cm^{-1}; ^1H NMR (500 MHz) δ 0.95 (t, *J* = 7.6 Hz, 3H), 1.40 (sext, *J* = 7.6 Hz, 2H), 1.74 (quint, *J* = 7.6 Hz, 2H), 2.11 (s, 3H), 4.12 (s, 3H), 4.60 (t, *J* = 7.6 Hz, 2H), 7.25 (d, *J* = 7.6 Hz, 2H), 7.46 (tt, *J* = 7.6, 1.5 Hz, 1H), 7.51 (t, *J* = 7.6 Hz, 2H); ^{13}C NMR (125 MHz) δ 13.72, 13.89, 20.13, 28.02, 47.36, 55.31, 101.21, 128.48, 128.79, 129.20, 135.74, 148.60, 154.24, 168.37, 174.28, 184.65. HR MS. Calcd for $C_{18}H_{21}N_4O_2S_2$ (M+H): 389.1106. Found: *m/z* 389.1088. Anal. Calcd for $C_{18}H_{20}N_4O_2S_2$: C, 55.65; H, 5.19; N, 14.42. Found: C, 55.60; H, 5.30; N, 14.39.

ACKNOWLEDGEMENTS

We are grateful to Mrs. Miyuki Tanmatsu of our university for recording mass spectra and performing combustion analyses.

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