A Convenient Preparation of 2-Aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes and Their Application in the Synthesis of 5-Aroyl-2-oxo-1,2-dihydro-2-pyridinecarbonitriles

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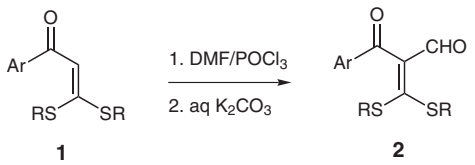
Abstract: The reaction of aroylketene dithioacetals **1** with Vilsmeier–Haack reagent, prepared from $POCl_3$ and DMF, under mild conditions gave 2-aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes **2** in excellent yields. Cyclization of 2-[2-aroyl-3,3-bis(methylsulfanyl)-2-propylidene]malononitriles **3**, derived from **2** and malononitrile, in the presence of concentrated hydrochloric acid in tertiary butanol afforded 2-pyridone derivatives **4**.

Key words: ketene dithioacetals, Knoevenagel condensations, cyclizations, Vilsmeier–Haack reactions, 2-pyridones

The Vilsmeier–Haack reaction is a widely used method for the formylation of electron-rich aromatic compounds and alkenes.[1] The versatile reactivity of carbonyl compounds with chloromethylene iminium salts and a variety of cyclization reactions leading to heterocyclic compounds induced by this reagent have been investigated.[2] In our earlier reports, we demonstrated the utility of this reagent in the synthesis of functionalized heterocycles,[3] enaldehydes and polyenaldehydes.[4] As part of our continuing interest in the synthetic transformations of α-oxoketene dithioacetals,[5] we examined their reactivity towards the Vilsmeier–Haack reagent. We observed that acylketene dithioacetals lead to a facile formylation at the α-position. While these studies were in progress, Dong et al. reported their findings on the reactions of the acylketene dithioacetals with the Vilsmeier reagent.[6] Here we report a convenient preparation of 2-aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes **2** via the formylation of aroylketene dithioacetals **1** and their application in the synthesis of 2-pyridone derivatives **4**.

Dimethyl aroylketene dithioacetals **1a–h** were treated with 1.5 equivalents of the Vilsmeier–Haack reagent prepared from $POCl_3$ and DMF for 12–16 hours at room temperature followed by treatment with a saturated aqueous solution of K_2CO_3 to afford 2-aroyl-3,3-bis(methylsulfanyl)acrylaldehydes **2a–h** in 62–98% yield. The reactions of 1-aryl-2-(1,3-dithiolan-2-yliden)-1-ethanone **1i–m** and dibenzylketene dithioacetal **1n** with the Vilsmeier–Haack reagent also resulted in the formation of the corresponding substituted aldehydes **2i–m** and **2n**, respectively, in good yields under similar conditions (Scheme 1, Table 1). Generally, α-formyl derivatives of ketene dithioacetals are obtained indirectly from the corresponding bis(methylsulfanyl)ethylene carboxylates via a reduction–oxidation process.[7] Rudorf et al. reported the synthesis of **2** from aroylacetaldehydes by treating them with carbon disulfide in the presence of base, followed by alkylation.[8] Most of the 2-aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes **2** have already been reported and were characterized by comparison of their spectral and physical properties with the reported data.



Scheme 1

Table 1 2-Aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes **2**

2	Ar	R	Yield (%)
a	C_6H_5	CH_3	98
b	4-$CH_3OC_6H_4$	CH_3	96
c	4-$CH_3C_6H_4$	CH_3	83
d	4-$NO_2C_6H_4$	CH_3	92
e	4-ClC_6H_4	CH_3	90
f	4-BrC_6H_4	CH_3	98
g	2-naphthyl	CH_3	98
h	2-thienyl	CH_3	62
i	C_6H_5	$(CH_2)_2$	95
j	4-$CH_3C_6H_4$	$(CH_2)_2$	89
k	4-ClC_6H_4	$(CH_2)_2$	95
l	4-BrC_6H_4	$(CH_2)_2$	92
m	4-$CH_3OC_6H_4$	$(CH_2)_2$	92
n	C_6H_5	CH_2Ph	62

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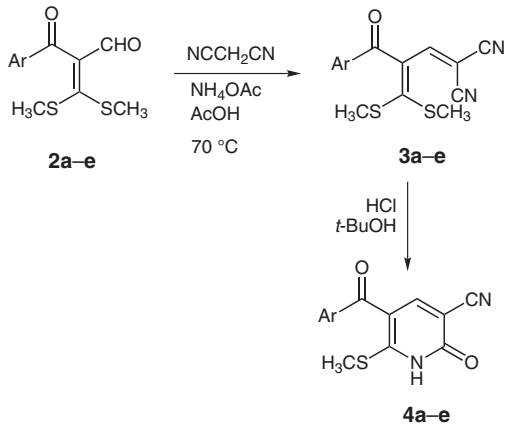
The 2-aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes **2** are stable at room temperature but easily undergo a deformylation reaction in the presence of bases. We noticed that the 2-benzoyl-3,3-bis(methylsulfanyl)acrylaldehyde **2a** is completely converted to benzoylketene dithioacetal **1a** on treatment with one equivalent of sodium tertiary butoxide for four hours at room temperature. The preparation of 2-aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes from aroylacetaldehydes could lead to lower yields as a result of the possible deformylation of the product under the basic reaction conditions.

Having developed a simple procedure for the preparation of 2-aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes **2**, we became interested in exploring their synthetic potential further. Rudorf and co-workers reported applications of functionalized ketene dithioacetals analogous to **2** in the synthesis of substituted thiophenes and thienothiophenes.[9] They have also reported the condensation of ketene dithioacetals **2** with thiocyanoacetamide leading to the formation of substituted thiopyridones.[10] We have treated 2-aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes **2** with malononitrile in the presence of ammonium acetate in acetic acid and the corresponding Knoevenagel adducts **3** were formed in 82–91% yields (Table 2).[11] The reaction did not proceed to form the 2-amino pyridines under these conditions, even after heating for longer periods.[12] Ketene dithioacetals having a push–pull butadiene moiety similar to **3** are known to undergo cyclization reactions under a variety of conditions.[13] The conversion of **3** to 2-pyridone derivatives was of interest due to the presence of this moiety in a number of biologically active molecules.[14] Mosti and co-workers reported that substituted 1,2-dihydro-2-oxo-3-pyridinecarbonitriles show better cardiac activity compared to the common amrinone- and milrinone-based drugs used in therapy for congestive heart failure.[15]

The treatment of 2-[2-aroyl-3,3-bis(methylsulfanyl)-2-propylidene]malononitrile **3** with concentrated hydrochloric acid in refluxing methanol gave 5-aroyl-6-(methylsulfanyl)-2-oxo-1,2-dihydro-3-pyridinecarbonitrile **4** along with the 6-methoxy substituted pyridones. The pyridone derivatives **4** could be obtained exclusively when the reaction was carried out in the presence of concentrated hydrochloric acid in tertiary butanol (Scheme 2, Table 2).



Scheme 2

In conclusion, we have developed a high-yielding protocol for the synthesis of pharmaceutically important 2-pyridone derivatives from readily available starting materials. The 3-cyano-2-pyridone derivatives **4** are appropriately functionalized for further aromatic annulations[16] and are potential precursors for the synthesis of a variety of fused heterocycles.

Table 2 Yields of 2-[2-Aroyl-3,3-bis(methylsulfanyl)-2-propylidene]malononitrile **3** and 5-Aroyl-6-(methylsulfanyl)-2-oxo-1,2-dihydro-3-pyridinecarbonitrile **4**

Product	Ar	Yield (%)	
3, **4**		**3**	**4**
a	C_6H_5	82	96
b	4-$CH_3OC_6H_4$	83	94
c	4-$CH_3C_6H_4$	88	95
d	4-$NO_2C_6H_4$	84	70
e	4-ClC_6H_4	91	94

Melting points were determined on a Büchi 530 melting point apparatus and were not corrected. The IR spectra were recorded from KBr pellets on a Shimadzu IR-470 spectrometer, and the frequencies are reported in cm^{-1}. ^1H NMR spectra were recorded on a Bruker WM 300 (300 MHz) using TMS as internal standard and $CDCl_3$ as solvent. ^{13}C NMR spectra were recorded on a Bruker WM 300 (75.47 MHz) spectrometer using $CDCl_3$ as solvent. Electron impact mass spectra were obtained on a Finnigan-Mat 312 instrument or a Shimadzu model GCMS 5050 instrument. CHN analyses were done on an Elementar Vario EL III Carlo Erba 1108 instrument.

All reagents were commercially available and were purified before use. The previously reported aroylketene dithioacetals were prepared via a known procedure.[5] Anhydrous Na_2SO_4 was used as drying agent.

2-Aroyl-3,3-bis(alkylsulfanyl)acrylaldehydes 2; General Procedure

The Vilsmeier–Haack reagent was prepared by adding $POCl_3$ (0.67 mL, 7 mmol) to DMF (6 mL, 70 mmol) at 0 °C and stirring the mixture for 20 min at r.t. The appropriate α-oxoketene dithioacetal (4.7 mmol) was added to this mixture, and the solution was stirred well for 10–16 h (monitored by TLC). The reaction mixture was poured into cold sat. K_2CO_3 soln (70 mL) and was extracted with Et_2O (3 × 25 mL). The combined organic layers were washed with H_2O then dried, and the solvent was evaporated. The crude product obtained was filtered through a column with silica gel (EtOAc–hexane, 1:50).

2-Benzoyl-3,3-bis(methylsulfanyl)acrylaldehyde (2a)

Pale yellow oil; yield: 1.16 g (98%). The analytical data are in accord with literature values.[8]

2-(4-Methoxybenzoyl)-3,3-bis(methylsulfanyl)acrylaldehyde (2b)
Yellow crystalline solid; yield: 1.27 g (96%); mp 91–92 °C (lit.[8] 91–93 °C).

2-(4-Methylbenzoyl)-3,3-bis(methylsulfanyl)acrylaldehyde (2c)
Pale yellow oil; yield: 1.04 g (83%). The analytical data are in accord with literature values.[8]

3,3-Bis(methylsulfanyl)-2-(4-nitrobenzoyl)acrylaldehyde (2d)
Pale yellow oil; yield: 1.29 g (92%). The analytical data are in accord with literature values.[8]

2-(4-Chlorobenzoyl)-3,3-bis(methylsulfanyl)acrylaldehyde (2e)
Pale yellow oil; yield: 1.20 g (90%). The analytical data are in accord with literature values.[8]

2-(4-Bromobenzoyl)-3,3-bis(methylsulfanyl)acrylaldehyde (2f)
Pale yellow oil; yield: 1.52 g (98%). The analytical data are in accord with literature values.[8]

3,3-Bis(methylsulfanyl)-2-(2-naphthoyl)acrylaldehyde (2g)
Yellow crystalline solid; yield: 1.39 g (98%); mp 78–79 °C.

IR (KBr): 3055, 2925, 1670, 1624, 1513, 1287, 1169, 1119, 923, 750 cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 2.37 (s, 6 H, SCH_3), 7.42–7.55 (m, 2 H, ArH), 7.78–7.90 (m, 4 H, ArH), 8.27 (s, 1 H, ArH), 10.15 (s, 1 H, CHO).

MS (EI, 70 eV): *m*/*z* (%) = 302 (12) [M^+], 255 (24), 227 (32), 207 (18), 155 (100), 127 (98), 99 (82), 77 (43).

Anal. Calcd for $C_{16}H_{14}O_2S_2$: C, 63.55; H, 4.67. Found: C, 63.30; H, 4.69.

3,3-Bis(methylsulfanyl)-2-(2-thienylcarbonyl)acrylaldehyde (2h)
Yellow crystalline solid; yield:750 mg (62%); mp 60–61 °C (lit.[8] 61.5–63.5 °C).

2-(1,3-Dithiolane-2-ylidene)-3-oxo-3-phenylpropanal (2i)
Yellow crystalline solid; yield: 1.16 g (95%); mp 103–104 °C (lit.[8] 100–102 °C).

2-(1,3-Dithiolane-2-ylidene)-3-(4-methylphenyl)-3-oxopropanal (2j)
Yellow crystalline solid; yield: 1.10 g (89%); mp 152–153 °C (lit.[8] 152–153 °C).

3-(4-Chlorophenyl)-2-(1,3-dithiolane-2-ylidene)-3-oxopropanal (2k)
Yellow crystalline solid; yield: 1.27 g (95%); mp 146–147 °C (lit.[8] 144–146 °C).

3-(4-Bromophenyl)-2-(1,3-dithiolane-2-ylidene)-3-oxopropanal (2l)
Yellow crystalline solid; yield: 1.41 g (92%); mp 144–145 °C (lit.[8] 144 °C).

(1,3-Dithiolane-2-ylidene)-3-(4-methoxyphenyl)-3-oxopropanal (2m)
Yellow crystalline solid; yield: 1.17 g (92%); mp 131–132 °C (lit.[8] 132–133 °C).

2-Benzoyl-3,3-bis(benzylsulfanyl)acrylaldehyde (2n)
Yellow crystalline solid; yield 1.17 g (62%); mp 108–109 °C (lit.[8] 106–108 °C).

2-[2-Aroyl-3,3-bis(methylsulfanyl)-2-propylidene]malononitriles 3; General Procedure
To a mixture of malononitrile (500 mg, 7.5 mmol), NH_4OAc (1.5 g, 20 mmol), and AcOH (5 mL) at 70 °C, 2-aroyl-3,3-bis(methylsulfanyl)acrylaldehyde **2** (5 mmol) was added, stirred for 5 min at the same temperature and then cooled to attain r.t. The reaction mixture was poured into ice-cold water, extracted with $CHCl_3$ (3 × 25 mL) then dried, and the solvent was evaporated. The crude product obtained was recrystallized from hexane–EtOAc, 95:5.

2-[2-Benzoyl-3,3-bis(methylsulfanyl)-2-propenylidene]malononitrile (3a)
Deep yellow crystals; yield: 1.23 g (82%); mp 112–114 °C.

IR (KBr): 2223, 1667, 1548, 1456, 1306, 1091 cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 2.39 (s, 6 H, SCH_3), 7.46–7.52 (m, 2 H, ArH), 7.58–7.65 (m, 1 H, ArH), 7.75–7.82 (m, 2 H, ArH), 8.03 (s, 1 H, vinylic).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 18.7, 81.6, 111.2, 114.4, 128.6, 129.2, 134.2, 136.4, 144.8, 151.2, 166.4, 192.1.

MS (EI, 70 eV): *m*/*z* (%) = 300 (15) [M^+], 286 (6), 256 (5), 183 (12), 149 (25), 137 (23), 123 (32), 105 (100).

Anal. Calcd for $C_{15}H_{12}N_2OS_2$: C, 59.97; H, 4.03; N, 9.33. Found: C, 60.17; H, 4.05; N, 9.38.

2-[2-(4-Methoxybenzoyl)-3,3-bis(methylsulfanyl)-2-propenylidene]malononitrile (3b)
Deep yellow crystals; yield: 1.37 g (83%); mp 114–116 °C.

IR (KBr): 2227, 1661, 1601, 1508, 1460, 1299, 1259, 1166, 1024 cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 2.47 (s, 6 H, SCH_3), 3.89 (s, 3 H, OCH_3), 6.97 (d, 2 H, *J* = 8.3 Hz, ArH), 7.83 (d, 2 H, *J* = 8.3 Hz, ArH), 8.11 (s, 1 H, vinylic).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 18.8, 55.6, 81.3, 111.2, 114.4, 114.6, 129.4, 131.8, 136.5, 151.1, 164.6, 165.7, 190.7.

MS (EI, 70 eV): *m*/*z* (%) = 330 (29) [M^+], 205 (5) 135 (100), 107 (9), 77 (19).

Anal. Calcd for $C_{16}H_{14}N_2O_2S_2$: C, 58.16; H, 4.27; N, 8.48. Found: C, 58.32; H, 4.29; N, 8.51.

2-[2-(4-Methylbenzoyl)-3,3-bis(methylsulfanyl)-2-propenylidene]malononitrile (3c)
Deep yellow crystals; yield: 1.38 g (88%); mp 120–122 °C.

IR (KBr): 2214, 1663, 1594, 1532, 1463, 1287, 1200 cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 2.43 (s, 3 H, CH_3), 2.46 (s, 6 H, SCH_3), 7.29 (d, 2 H, *J* = 8.7 Hz, ArH), 7.75 (d, 2 H, *J* = 8.7 Hz, ArH), 8.10 (s, 1 H, vinylic).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 18.8, 21.9, 81.3, 111.3, 114.6, 129.4, 129.8, 133.9, 136.3, 145.5, 151.3, 166.3, 191.8.

MS (EI, 70 eV): *m*/*z* (%) = 314 (32) [M^+], 297 (6), 133 (9), 119 (100), 91 (48), 65 (27).

Anal. Calcd for $C_{16}H_{14}N_2OS_2$: C, 61.12; H, 4.49; N, 8.91. Found: C, 60.92; H, 4.51; N, 8.96.

2-[3,3-Bis(methylsulfanyl)-2-(4-nitrobenzoyl)-2-propenylidene]malononitrile (3d)
Deep yellow crystals; yield: 1.4 g (84%); mp 128–130 °C.

IR (KBr): 2219, 1667, 1548, 1524, 1463, 1342, 1290, 1195 cm^{-1}.

^1H NMR (300 MHz, $CDCl_3$): δ = 2.48 (s, 6 H, SCH_3), 8.03 (d, 2 H, *J* = 8.3 Hz, ArH), 8.10 (d, 2 H, *J* = 8.3 Hz, ArH), 8.34 (s, 1 H, vinylic).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 18.9, 82.3, 111.6, 114.0, 124.2, 130.0, 134.6, 141.3, 150.6, 151.8, 168.1, 190.3.

MS (EI, 70 eV): *m/z* (%) = 345 (17) [M$^+$], 150 (69), 139 (27), 120 (100), 104 (42), 76 (63).

Anal. Calcd for $C_{15}H_{11}N_3O_3S_2$: C, 52.16; H, 3.21; N, 12.17. Found: C, 52.31; H, 3.24; N, 12.21.

2-[2-(4-Chlorobenzoyl)-3,3-bis(methylsulfanyl)-2-propenylidene]malononitrile (3e)

Deep yellow crystals; yield: 1.52 g (91%); mp 132–134 °C.

IR (KBr): 2220, 1657, 1581, 1544, 1450, 1294, 1206, 1093 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.46 (s, 6 H, SCH_3), 7.47 (d, 2 H, *J* = 8.3 Hz, ArH), 7.79 (d, 2 H, *J* = 8.3 Hz, ArH), 8.09 (s, 1 H, vinylic).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 18.8, 81.5, 111.4, 114.4, 129.4, 130.5, 134.9, 135.3, 140.7, 151.4, 167.2, 190.9.

MS (EI, 70 eV): *m/z* (%) = 336 (7) [M$^+$ + 2], 334 (17) [M$^+$], 319 (4), 142 (28), 139 (100), 110 (30), 75 (18).

Anal. Calcd for $C_{15}H_{11}ClN_2OS_2$: C, 53.80; H, 3.31; N, 8.37. Found: C, 54.07; H, 3.34; N, 8.41.

5-Aroyl-6-(methylsulfanyl)-2-oxo-1,2-dihydro-3-pyridinecarbonitriles 4; General Procedure

2-Aroyl-2-[3,3-bis(methylsulfanyl)-2-propylidene]malononitrile **3** (1.7 mmol) was dissolved in *t*-BuOH (10 mL) and concd HCl (1 mL) was added. The reaction mixture was refluxed for 30 min and cooled to r.t. Then it was poured into ice-cold water, extracted with $CHCl_3$, dried, and the solvent was evaporated off. The crude product obtained was recrystallized from hexane–EtOAc, 4:1.

5-Benzoyl-6-(methylsulfanyl)-2-oxo-1,2-dihydro-3-pyridinecarbonitrile (4a)

Colorless crystals; yield: 440 mg (96%); mp 224–226 °C.

IR (KBr): 3178, 2364, 2227, 1680, 1643, 1546, 1191 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.35 (s, 3 H, SCH_3), 7.25–7.58 (m, 5 H, ArH), 8.45 (s, 1 H, H-4), 13.15 (s, 1 H, NH).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 12.2, 102.6, 115.0, 127.9, 128.2, 130.7, 131.3, 148.6, 150.3, 154.3, 166.7, 188.6.

MS (EI, 70 eV): *m/z* (%) = 270 (6) [M$^+$], 229 (15), 223 (100), 198 (8), 180 (22), 140 (38), 104 (52), 95 (51), 83 (76).

Anal. Calcd for $C_{14}H_{10}N_2O_2S$: C, 62.21; H, 3.73; N, 10.36. Found: C, 62.40; H, 3.75; N, 10.41.

5-(4-Methoxybenzoyl)-6-(methylsulfanyl)-2-oxo-1,2-dihydro-3-pyridinecarbonitrile (4b)

Yellow crystals; yield: 480 mg (94%); mp 194–196 °C.

IR (KBr): 2965, 2365, 2225, 1646, 1610, 1310, 1263, 1186, 1025 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.39 (s, 3 H, SCH_3), 3.87 (s, 3 H, OCH_3), 7.15 (d, 2 H, *J* = 8.8 Hz, ArH), 7.47 (d, 2 H, *J* = 8.8 Hz, ArH), 8.26 (s, 1 H, H-4), 12.18 (br s, 1 H, NH).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 12.7, 55.5, 102.0, 114.5, 117.7, 122.8, 130.5, 130.8, 147.8, 153.8, 161.3, 162.7, 189.7.

MS (EI, 70 eV): *m/z* (%) = 301 (11) [M$^+$], 284 (19), 269 (18), 253 (100), 238 (10), 210 (18), 182 (12), 170 (13), 127 (23), 119 (15), 91 (13), 77 (13).

Anal. Calcd for $C_{15}H_{12}N_2O_3S$: C, 59.99; H, 4.03; N, 9.33. Found: C, 59.69; H, 4.05; N, 9.28.

5-(4-Methylbenzoyl)-6-(methylsulfanyl)-2-oxo-1,2-dihydro-3-pyridinecarbonitrile (4c)

Colorless crystals; yield: 460 mg (95%); mp 208–210 °C.

IR (KBr): 2365, 2236, 1662, 1568, 1196, 1118 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.35 (s, 3 H, SCH_3), 2.45 (s, 3 H, CH_3), 7.34–7.41 (br m, 4 H, ArH), 8.28 (s, 1 H, H-4), 12.10 (s, 1 H, NH).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 12.7, 21.6, 102.0, 114.3, 117.8, 128.7, 129.3, 129.8, 142.8, 147.8, 154.1, 161.1, 189.4.

MS (EI, 70 eV): *m/z* (%) = 284 (3) [M$^+$], 268 (17), 253 (18), 237 (100), 219 (4), 209 (6), 194 (19), 179 (12), 153 (14), 127 (14), 118 (33), 91 (30), 77 (9).

Anal. Calcd for $C_{15}H_{12}N_2O_2S$: C, 63.36; H, 4.25; N, 9.85. Found: C, 63.60; H, 4.27; N, 9.89.

6-(Methylsulfanyl)-5-(4-nitrobenzoyl)-2-oxo-1,2-dihydro-3-pyridinecarbonitrile (4d)

Yellow crystals; yield: 440 mg (70%); mp 222–224 °C.

IR (KBr): 3425, 2952, 2364, 2227, 1654, 1569, 1521, 1350, 1284 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.61 (s, 3 H, SCH_3), 7.78 (s, 1 H, H-4), 7.86 (d, 2 H, *J* = 8.8 Hz, ArH), 8.37 (d, 2 H, *J* = 8.8 Hz, ArH).

MS (EI, 70 eV): *m/z* (%) = 316 (4) [M$^+$], 230 (4), 193 (6), 165 (11), 149 (12), 129 (18), 120 (24), 95 (32), 81 (63), 69 (100).

Anal. Calcd for $C_{14}H_9N_3O_4S$: C, 53.33; H, 2.88; N, 13.33. Found: C, 53.64; H, 2.91; N, 13.39.

5-(4-Chlorobenzoyl)-6-(methylsulfanyl)-2-oxo-1,2-dihydro-3-pyridinecarbonitrile (4e)

Colorless crystals; yield: 490 mg (94%); mp 210–212 °C.

IR (KBr): 3405, 3054, 2896, 2226, 1727, 1656, 1485, 1187, 1092 cm^{-1}.

^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.73 (s, 3 H, SCH_3), 7.40 (d, 2 H, *J* = 8 Hz, ArH), 7.46 (d, 2 H, *J* = 8 Hz, ArH), 8.32 (s, 1 H, H-4).

^{13}C NMR (75.47 MHz, $CDCl_3$): δ = 12.1, 102.6, 114.7, 116.4, 127.8, 128.2, 130.1, 136.5, 146.6, 153.2, 159.8, 188.3.

MS (EI, 70 eV): *m/z* (%) = 304 (9) [M$^+$], 288 (18), 273 (24), 257 (100), 232 (13), 222 (33), 194 (19), 174 (29), 138 (43), 111 (29), 75 (35).

Anal. Calcd for $C_{14}H_9ClN_2O_2S$: C, 55.18; H, 2.98; N, 9.19. Found: C, 55.39; H, 3.01; N, 9.26.

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