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Studies with arylhydrazonopyridinones: Synthesis of new arylhydrazono thieno[3,4-*c*]pyridinones as novel D2T2 dye class; classical verse green methodologies

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ABSTRACT

A variety of arylhydrazonopyridinones were prepared *via* heating cyanoacetamides with ethyl acetoacetate in absence of solvent under reflux conventionally or ultrasound irradiation or in a microwave oven. The formed products **5** and **6** could be readily converted to thienopyridones. Attempted addition of the latter to electron poor olefins afforded only arylhydrazonopyridinones.

1. Introduction

Arylhydrazonopyridinones are now rapidly replacing arylazopyrazolones in classical dye industry. Moreover, reasonable solubility of these derivatives in lipophilic solvents gives these dyes high potential for utility in D2T2 (dye diffusion thermal transfer) printing. Although almost all commercial arylhydrazonopyridinones have an alkyl function utility of these pyridinones, synthesis of arylhydrazone condensed pyridinones have not received interest. Moreover, to our knowledge, modern green synthetic methodologies have not yet been adopted for synthesis of these pyridinones. Hence, there remains a demand for more efficious and safer green technologies [1–5] for synthesis of alkyl azinylcarbonitriles **3** as precursors to condensed azines.

Motivated by the afore-mentioned findings, we report here on an adaptation of green methodologies such as microwave and ultrasound [6–11] for the synthesis of aryl and heteroaromatic hydrazonopyridinones **5, 6** and on the potential of **5, 6** as precursors to condensed pyridinones. The structure of the products was established on different analytical and spectroscopic data.

2. Results and discussion

The standard route to arylhydrazonopyridinones is coupling of **3**, prepared from **1** and alkylamine, with aromatic and heteroaromatic diazonium salts. In our laboratory several cyanoacetamides **2** have been prepared *via* treatment of **1** with primary amines either at room temperature for long time or *via* irradiation with microwave (μω) for 1–4 min at 100 W or with ultrasound (US) for 2–10 min at 40 °C.

Compounds **2** were reacted with a β-ketoester also either *via* long reflux of neat reagents or by short time microwave or by US for 5–7 h at 40 °C to afford in each case the same product **3a–d** which may be exist in another tautmeric form **4** (Scheme 1).

Coupling of **3a–d** with aromatic and heteroaromatic diazonium salts afforded the corresponding aryl and heteroaromatic hydrazones **5a–l** and **6a–f**. The structure attributed to compounds **5** could be unequivocally established by single crystal X-ray diffraction of compound **5k** [12] (Fig. 1). Single crystal X-ray diffraction of compound **5k** add a sharp evidence for the proposed structure (Scheme 2).

From X-ray data of compound **5K**, we observed that the arylhydrazone bond lengths N5–C9 and N5–N6 are little shorter than N–N bond lengths (Table 1). This may be a result of the presence of an intramolecular hydrogen bond N6–H–O2.

As anticipated the aryl and heteroaromatic hydrazones **5a–l, 6a–f** reacted with elemental sulphur either by heating with

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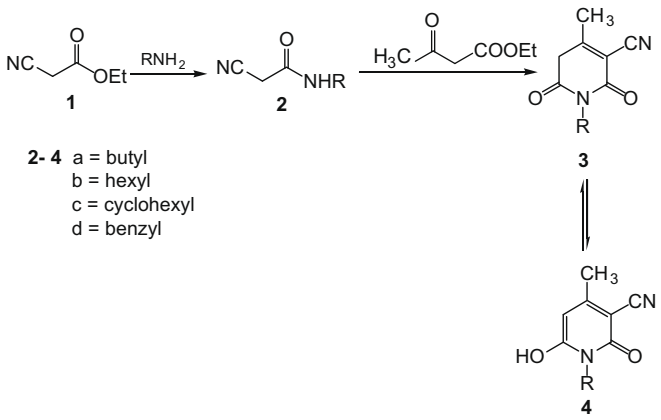


Scheme 1.

microwave or by US and by conventional heating to yield the corresponding aminothienopyridinones **7a–k** and **8a, b**.

Table 2 shows yields as well as reaction times by the three methodologies are compared.

Although aminothienopyridine **7e** were reported to react readily and smoothly with electronpoor dienophiles to yield phthalazines under similar conditions **7a–k** failed to react with dienophiles; long reflux with the reagent resulted in regeneration of arylazopyridinones. Conversion of thienoazines into alkylazinylcarbonnitriles has been observed earlier by Elnagdi et al. [13–18].

In few cases products of apparent addition and hydrogen sulphide elimination were produced. In fact these have resulted from a Michael addition at **5e**. In support of this view compound **5e** reacted with acrylonitrile to yield compound **9** (Scheme 3).

3. Conclusion

We have synthesized a class of novel substituted arylhydrazono thieno[3,4-*c*]pyridinones **7**, **8** under microwave, sonication and classical conditions. In general, improvements in rates and yield of reactions are observed when reactions were carried out under microwave and sonication compared with classical condition.

It should be noted, however, that activation occurs at different temperatures with these techniques and, therefore strict comparisons will require a balance between effectiveness and energy costs.

4. Experimental

4.1. Materials and methods

All melting points were measured on a Gallenkamp electrothermal melting point apparatus and are uncorrected. The IR absorption spectra were measured on a Nicolet Magna 520FT IR spectrophotometer. ^{1}H NMR, ^{13}C NMR spectra were recorded in deuterated dimethylsulfoxide [DMSO] or deutrated chloroform ($CDCl_3$) at 200 MHz on a Varian Gemini NMR spectrometer and a Bruker DPX 400 MHz spectrometer using tetramethylsilane (TMS) as an internal reference. Mass spectra were performed on a Shimadzu GCMS-QP 1000 EX mass spectrometer at 70 eV. X-ray crystallography was carried out on a Kappa CCD Enraf Nonius FR 590 diffractometer, National Research Center, Dokki, Cairo, Egypt. Microwave irradiation was carried out using the commercial microwave oven (SGO 1000 W), a thermocouple used to monitor the temperature inside the vessel, it was found that ≈105–110 °C.

Ultrasound, microprocessor controlled-2004, high intensity ultrasonic processor with temperature controller (750 W), the ultrasonic frequency of the cleaning bath used equal 25 kHz. The reaction temperature stabilized at 35–40 °C even after more than 1 h by addition or removal of water in ultrasonic bath to keep the required temperature. Elemental analyses, Perkin–Elmer 2400 CHN Elemental analyzer flowchart.

4.2. Typical procedure for reactions

4.2.1. General procedure for the preparation of N-substituted-2-cyanoacetamide ***2a–d***

4.2.1.1. Method I (thermal). Equimolar amounts (0.1 mol) of ethyl cyanoacetate and the appropriate amount of amine compounds (0.1 mol) were stirred at room temperature for 1–4 h. The resulting solid product was recrystallized from ethanol.

4.2.1.2. Method II (microwaves). A mixture of ethyl cyanoacetate (0.1 mol) and the appropriate amount of amine compounds

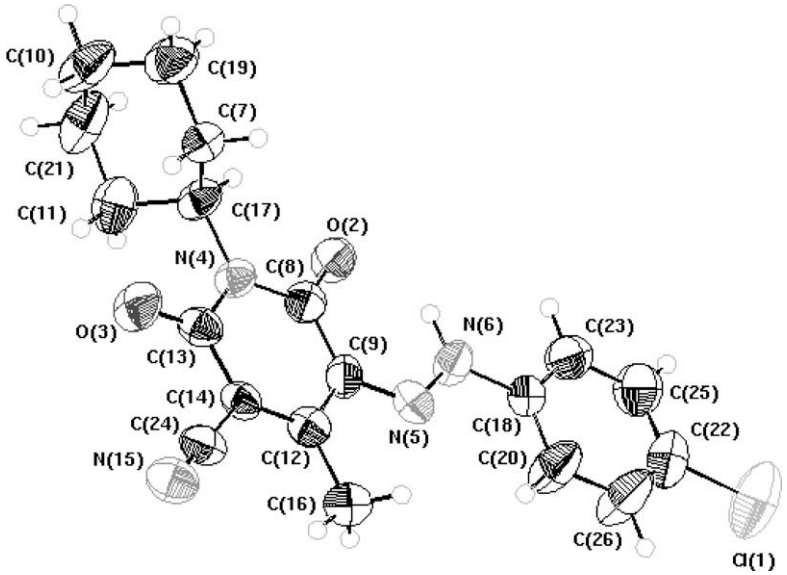
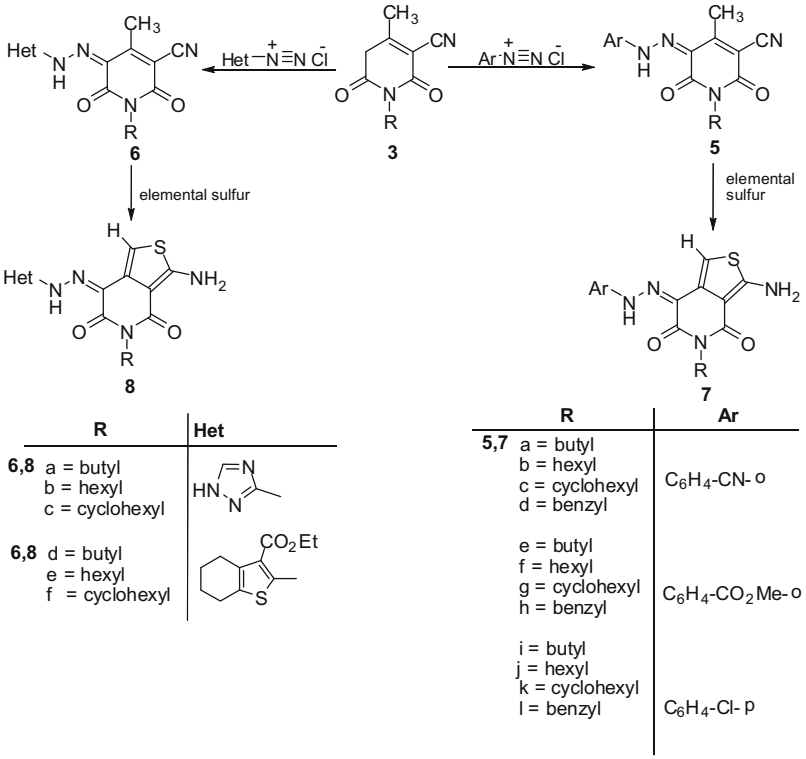


Fig. 1. X-ray crystal structure of **5k**.



Scheme 2.

Table 1
Selected bond lengths and bond angles of **5K**.

Bond	Bond length (Å)	Bond	Bond angle (°)
O2–C8	1.25	N5–N6–C18	117.5
N4–C8	1.39	N6–N5–C9	122.3
N4–C17	1.48	N5–C9–C8	124.6
N4–C13	1.41	N5–C9–C12	115.0
N5–C9	1.32	C8–C9–C12	120.4
C5–C11	1.49	N4–C8–C9	120.1
N5–N6	1.31	O2–C8–C9	120.4
N6–C18	1.41	O2–C8–N4	119.5
C8–C9	1.45		
C9–C12	1.43		

(0.1 mol) were placed in the microwave oven and irradiated at 460 W for 1–4 min and then left to cool to room temperature. The solid product so formed was filtered and recrystallized from ethanol.

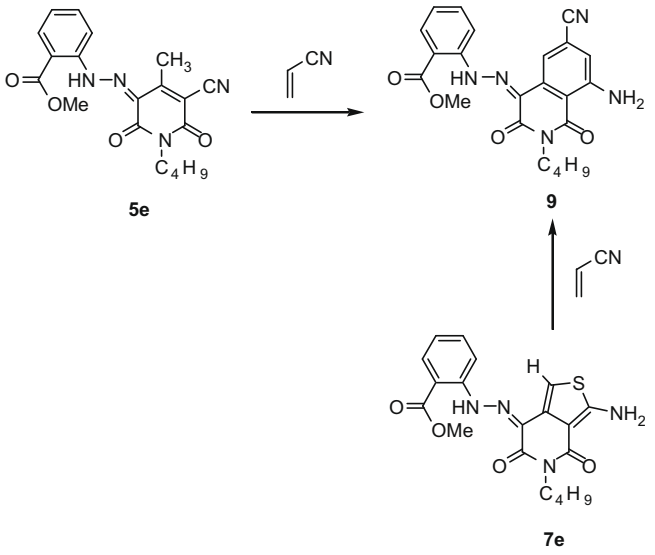
4.2.1.3. Method III (ultrasound). Equimolar amounts (0.1 mol) of ethyl cyanoacetate and the amine compounds (0.1 mol) were mixed and the reaction mixture was heated under ultrasound irradiation at 40 °C for 2–10 min, and then left to cool to room temperature. The solid product so formed was filtered and recrystallized from ethanol.

*N-Butyl-2-cyanoacetamide (**2a**)*: Dark yellow crystals from ethanol; m.p. 72 °C. IR (KBr): ν = 3299 (NH), 2954 (CH aliphatic), 2258 (CN) and 1653 (C=O) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.85 (t, J = 7 Hz, 3H, CH_3CH_2), 1.27 (sextet, J = 7 Hz, 2H, CH_3CH_2), 1.38 (quintet, J = 7 Hz, 2H, CH_2CH_2–NH), 3.06 (q, J = 7 Hz, 2H, CH_2CH_2NH), 3.56 (s, 2H, CH_2CN) and 8.18 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 14.02, 20.00, 25.76, 31.40 (butyl carbons), 39.27 (CH_2CN), 116.71 (CN) and 162.39 (C=O) ppm; m/z (%) = 141. Anal. for $C_7H_{12}N_2O$ (140.19) Calcd. C 59.98, H 8.63, N 19.98. Found C 59.90, H 8.70, N19.92.

Table 2
Formation of compounds **2–9** by (Δ, thermal; μω, microwave irradiation; US, ultrasound).

No.	Time (min)			Yield %			Temperature (°C)		
	Δ	μω	US	Δ	μω	US	Δ	μω	US
2a	180	4	7	68	89	74	R.T.	100–105	35–40
2b	240	3	10	90	91	88			
2c	120	2	5	84	90	80			
2d	60	1	2	89	93	90			
3a	1560	20	420	46	90	63	170–180		
3b	1560	20	420	51	92	79			
3c	1560	20	420	49	95	82			
3d	1560	20	420	72	93	88			
7a	180	5	90	77	95	80	80 (ethanol)		
7b	180	5	90	68	92	83			
7c	180	5	90	73	90	86			
7d	180	5	90	55	92	75			
7e	180	5	90	67	92	80			
7f	180	5	90	74	93	90	Or		
7g	180	10	90	83	94	88	130–140 (DMF)		
7h	180	5	90	73	90	84			
7i	180	5	90	78	96	88			
7j	180	5	90	80	92	89			
7k	180	5	90	70	93	87			
8a	180	5	90	80	97	78			
8b	180	5	90	83	98	85			
9	180	20	–	56	70	–	130		

*2-Cyano-N-hexyl-acetamide (**2b**)*: Yellow crystals from ethanol; m.p. 67 °C. IR (KBr): ν = 3299 (NH), 2932 (CH aliphatic), 2260 (CN) and 1645 (C=O) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 0.81 (t, J = 6 Hz, 3H, CH_3CH_2), 1.24 (m, 6H, $3CH_2$), 1.45 (quintet, J = 7 Hz, 2H, CH_2CH_2NH), 3.17 (q, J = 7 Hz, 2H, CH_2CH_2NH), 3.42 (s, 2H, CH_2CN) and 7.17 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.99, 22.54, 26.04, 26.55, 29.11, 31.43 (hexyl carbons), 40.45 (CH_2CN), 115.22 (CN) and 162.03 (C=O) ppm; m/z (%) = 169. Anal. for $C_9H_{16}N_2O$ (168.24) Calcd. C 64.25, H 9.59, N 16.65. Found C 64.20, H 9.61, N 16.69.



Scheme 3.

*2-Cyano-N-cyclohexyl-acetamide (**2c**)*: White crystals from ethanol; m.p. 136 °C. IR (KBr): ν = 3272 (NH), 2933 (CH aliphatic), 2261 (CN) and 1628 (C=O) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 1.12–1.63 (m, 6H, cyclohexyl H-3, H-4, H-5), 1.70–2.03 (m, 4H, cyclohexyl H-2, H-6), 3.46–3.54 (m, 1H, cyclohexyl H-1), 3.22 (s, 2H, CH_2CN) and 8.14 (d, 1H, NH, J = 7 Hz) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 24.35, 24.87, 25.62, 25.84, 30.91, 32.60 (cyclohexyl carbons), 48.73 (CH_2CN), 116.73 (CN) and 161.51 (C=O) ppm; m/z (%) = 166. Anal. for $C_9H_{14}N_2O$ (166.22) Calcd. C 65.05, H 8.49, N 16.85. Found C 65.10, H 8.36, N 16.89.

*N-Benzyl-2-cyano-acetamide (**2d**)*: Brown crystals from ethanol; m.p. 124 °C. IR (KBr): ν = 3295 (NH), 3091 (CH aromatic), 2923 (CH aliphatic), 2220 (CN) and 1640 (C=O) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 3.71 (s, 2H, CH_2CN), 4.30 (d, J = 5 Hz, 2H, $PhCH_2NH$), 7.29–7.34 (m, 5H, Ph-H) and 8.74 (d, J = 5 Hz, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 24.35, 117.29, 119.23, 119.29, 126.35, 126.52, 126.99 and 165.63 (C=O) ppm; m/z = 174. Anal. for $C_{10}H_{10}N_2O$ (174.20) Calcd. C 68.95, H 5.79, N 16.08. Found C 68.90, H 5.67, N 16.20.

*4.2.2. Preparation of pyridinone compounds **3a–d***

4.2.2.1. Method I (thermal). Ethyl acetoacetate (0.1 mol) was added to amide derivative **2a–d** (0.1 mol) and the reaction mixture was refluxed at 170–180 °C, for 8–13 h. The reaction mixture was poured into ice-cold water and acidified with dilute HCl and then left to cool to room temperature. The solid product so formed was filtered and recrystallized from ethanol.

4.2.2.2. Method II (microwaves). A mixture of ethyl acetoacetate (0.1 mol) and amide derivative **2a–d** (0.1 mol), was placed in the microwave oven and irradiated at 460 W for 10–20 min. The reaction mixture was poured into ice-cold water and acidified with dilute HCl and then left to cool to room temperature. The solid product so formed was filtered and recrystallized from ethanol.

4.2.2.3. Method III (ultrasound). Ethyl acetoacetate (0.1 mol) was added to a mixture of amine derivative (0.1 mol) and ethyl cyanoacetate (0.1 mol) and the reaction mixture was catalyzed by 0.1 mol of ceric ammonium nitrate under ultrasound irradiation at 70 °C for 5–7 h. The reaction mixture was poured into ice-cold water and acidified with dilute HCl and then left to cool to room temperature. The solid product so formed was filtered and recrystallized from ethanol.

*1-Butyl-4-methyl-2,6-dioxo-1,2,5,6-tetrahydropyridine-3-carbonitrile (**3a**)*: Brown crystals from ethanol; m.p. 254 °C. IR (KBr): ν = 3019 (CH aromatic), 2920 (CH aliphatic), 2222 (CN) and 1645 (2C=O) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 0.91 (t, J = 7 Hz, 3H, CH_3CH_2), 1.23 (sextet, J = 7 Hz, 2H, CH_3CH_2), 1.35 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.42 (s, 3H, CH_3), 2.61 (s, 2H,CH_2 ring) and 3.97 (t, J = 7 Hz, 2H, CH_2N) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 13.38, 14.01, 20.29, 25.29, 32.51, 33.70 (C-5), 93.12 (C-3), 116.79 (CN), 158.58 (C-4) and 160.96, 162.36 (2C=O) ppm; m/z (%) = 206. Anal. for $C_{11}H_{14}N_2O_2$ (206.25) Calcd. C 64.06, H 6.84, N 13.58. Found C 64.15, H 6.80, N 13.65.

*1-Hexyl-4-methyl-2,6-dioxo-1,2,5,6-tetrahydropyridine-3-carbonitrile (**3b**)*: Light tan crystals from ethanol; m.p. 126 °C. IR (KBr): ν = 3074 (CH aromatic), 2932 (CH aliphatic), 2218 (CN) and 1656 (2C=O) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.84 (t, J = 6 Hz, 3H, CH_3CH_2), 1.24 (m, 6H, $3CH_2$), 1.51 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.07 (s, 3H, CH_3), 2.20 (s, 2H, CH_2 ring) and 3.87 (t, 2H, CH_2N, J = 7 Hz) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 14.39, 22.50, 22.58, 26.50, 27.84, 31.46 (hexyl carbons), 21.06 (CH_3), 31.40 (C-5), 92.54 (C-3), 116.79 (CN), 158.58 (C-4) and 160.96, 162.36 (2C=O) ppm; m/z (%) = 233. Anal. for $C_{13}H_{18}N_2O_2$ (234.30) Calcd. C 66.64, H 7.74, N 11.96. Found C 66.55, H 7.47, N 11.83.

*1-Cyclohexyl-4-methyl-2,6-dioxo-1,2,5,6-tetrahydropyridine-3-carbonitrile (**3c**)*: Yellow crystals from ethanol; m.p. 130 °C. IR (KBr): ν = 3066 (CH aromatic), 2988 (CH aliphatic), 2220 (CN) and 1642 (2C=O) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 1.44–2.41 (m, 10H, cyclohexyl-H), 1.71 (s, 3H, CH_3), 2.85 (s, 2H, CH_2 ring) and 3.54–3.88 (m, 1H, CHN cyclohexyl-H) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 14.39 (CH_3), 27.11, 22.02, 30.50, 40.34 (cyclohexyl carbons), 36.70 (C-5), 98.90 (C-3), 117.29 (CN), 159.18 (C-4) and 162.80, 164.06 (2C=O) ppm; m/z (%) = 232. Anal. for $C_{13}H_{16}N_2O_2$ (232.28) Calcd. C 76.22, H 6.94, N 12.06. Found C 76.35, H 6.82, N 12.15.

1-Benzyl-4-methyl-2,6-dioxo-1,2,5,6-tetrahydropyridine-3-carbonitrile (3d): Light brown crystals from ethanol; m.p. 187 °C. IR (KBr): ν = 3109 (CH aromatic), 2910 (CH aliphatic), 2224 (CN) and 1650 (2C=O) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 2.20 (s, 3H, CH_3), 2.85 (s, 2H, CH_2 ring), 4.74 (d, J = 5 Hz, 2H, $PhCH_2$) and 7.24–7.43 (m, 5H, Ph-H) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 14.52 (CH_3), 36.25, 40.22, 98.90 (C-3), 115.11 (CN), 125.32, 125.92, 128.21, 129.63, 129.99, 138.11, 159.14 (C-4) and 161.80, 164.55 (2C=O) ppm; m/z (%) = 240. Anal. for $C_{14}H_{12}N_2O_2$ (240.26) Calcd. C 69.99, H 5.03, N 11.66. Found C 69.90, H 5.15, N 11.69.

*4.2.3. Preparation of arylhydrazone and heterohydrazone compounds (**5a–l**, **6a–f**)*

A cold solution of arenediazonium salt (10 mmol), [prepared by adding a solution of sodium nitrite (1 g in 10 mL H_2O) to a cold solution of aryl amine hydrochloride or aryl amine nitrate (10 mmol) with stirring as described earlier]. The resulting solution of the arenediazonium was then added to a cold solution of **3a–d** (0.1 mol) in ethanol (50 mL) containing sodium acetate (1 g in 10 mL H_2O). The mixture was stirred at room temperature for 1 h and the solid product so formed was collected by filtration and recrystallized from ethanol [19,20].

*1-Butyl-5-[(4-cyanophenyl)hydrazono]-4-methyl-2,6-dioxo-1,2,5,6-tetrahydropyridine-3-carbonitrile (**5a**)*: Brown crystals from ethanol; m.p. 206 °C. Yield 89%. IR (KBr): ν = 3333 (NH, broadened due to H-bond between O and NH), 3120 (CH aromatic), 2949 (CH aliphatic), 2223 (2CN) and 1633 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.90 (t, J = 7 Hz, 3H, CH_3CH_2), 1.32 (sextet, J = 7 Hz, 2H, CH_3CH_2), 1.53 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.54 (s, 3H, CH_3), 3.83 (t, J = 7 Hz, 2H, CH_2CH_2N), 7.41 (t, J = 7 Hz, 1H, Ar H-5), 7.81 (t, J = 7 Hz, 1H, Ar H-4), 7.93

(d, J = 8 Hz, 2H, Ar H-3, H-6) and 14.87 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 10.25 (CH_3), 14.22, 19.85, 29.53, 36.22 (butyl carbons), 71.25 (C-3), 100.01, 111.12, 115.44, 125.98, 133.16, 135.01 (C_6H_4–CN-*o*), 115.53, 117.53 (2CN), 150.29 (C-4), 159.15 (C-5) and 160.11, 163.28 (2C=O) ppm; *m/z* (%) = 335. Anal. for $C_{18}H_{17}N_5O_2$ (335.37) Calcd. C 64.47, H 5.11, N 20.88. Found C 64.58, H 5.15, N 20.80.

*5-[(4-Cyanophenyl)hydrazono]-1-hexyl-4-methyl-2,6-dioxo-1,2,5,6-tetrahydropyridine-3-carbonitrile (**5b**)*: Yellow crystals from ethanol; m.p. 156 °C. Yield 90%. IR (KBr): ν = 3307 (NH, broadened due to H-bond between O and NH), 3109 (CH aromatic), 2933 (CH aliphatic), 2223 (2CN) and 1636 (2C=O ring) cm^{-1}. ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.86 (t, J = 6 Hz, 3H, CH_3CH_2), 1.28–1.32 (m, 6H, $3CH_2$), 1.54 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.54 (s, 3H, CH_3), 3.82 (t, J = 7 Hz, 2H, CH_2N), 7.42 (t, J = 7 Hz, 1H, Ar H-5), 7.81 (t, J = 7 Hz, 1H, Ar H-4), 7.94 (d, J = 8 Hz, 2H, Ar H-3, H-6) and 14.87 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 11.12 (CH_3), 14.19, 20.58, 25.98, 30.59, 31.99, 39.01 (hexyl carbons), 66.28 (C-3), 101.11, 112.14, 115.48, 123.08, 133.58, 136.56 (C_6H_4–CN-*o*), 115.50, 117.99 (2CN), 150.29 (C-4), 156.99 (C-5) and 163.85, 167.21 (2C=O) ppm; *m/z* (%) = 363. Anal. for $C_{20}H_{21}N_5O_2$ (363.42) Calcd. C 66.10, H 5.82, N 19.27. Found C 66.22, H 5.77, N 19.30.

*5-[(4-Cyanophenyl)hydrazono]-1-cyclohexyl-4-methyl-2,6-dioxo-1,2,5,6-tetrahydropyridine-3-carbonitrile (**5c**)*: Orange crystals from ethanol/dioxane (2:1); m.p. 292 °C. Yield 93%. IR (KBr): ν = 3301 (NH, broadened due to H-bond between O and NH), 3064 (CH aromatic), 2926 (CH aliphatic), 2228 (2CN) and 1640 (2C=O ring) cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 1.22–1.67 (m, 6H, cyclohexyl H-3′, H-4′, H-5′), 1.81–2.43 (m, 4H, cyclohexyl H-2′, H-6′), 4.77–4.83 (m, 1H, cyclohexyl H-1′), 2.59 (s, 3H, CH_3), 7.31 (t, J = 7 Hz, 1H, Ar H-4), 7.68 (t, J = 7 Hz, 1H, Ar H-5), 7.78 (d, J = 8 Hz, 2H, Ar H-3, H-6) and 15.26 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 16.68 (CH_3), 25.15, 26.31, 28.76, 54.17 (cyclohexyl carbons), 67.16 (C-3), 101.11, 113.98, 125.44, 126.16, 133.46, 134.58 (C_6H_4–CN-*o*), 115.53, 116.53 (2CN), 143.65 (C-4), 157.88 (C-5) and 159.97,162.04 (2C=O) ppm; *m/z* (%) = 361. Anal. for $C_{20}H_{19}N_5O_2$ (361.41) Calcd. C 66.47, H 5.30, N 19.38. Found C 66.54, H 5.21, N 19.49.

*1-Benzyl-5-[(4-cyanophenyl)hydrazono]-4-methyl-2,6-dioxo-1,2,5,6-tetrahydro-pyridine-3-carbonitrile (**5d**)*: Dark orange crystals from ethanol; m.p. 229 °C. Yield 92%. IR (KBr): ν = 3320 (NH), 3106 (CH aromatic), 2920 (CH aliphatic), 2222 (2CN) and 1672, 1654 (2C=O) cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 2.69 (s, 3H, CH_3), 5.04 (s, 2H, CH_2Ph), 7.25–7.83 (m, 9H, Ar-H) and 15.14 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 11.12 (CH_3), 42.25 (CH_2), 66.28 (C-3), 101.11, 112.14, 115.48, 123.08, 126.55, 126.98, 127.58, 128.12, 128.33, 133.58, 135.21, 136.56 (C_6H_5, C_6H_4–CN-*o*), 115.50, 117.99 (2CN), 150.29 (C-4), 156.99 (C-5) and 163.85, 167.21 (2C=O) ppm; *m/z* (%) = 369. Anal. for $C_{21}H_{15}N_5O_2$ (369.39) Calcd. C 68.28, H 4.09, N 18.96. Found C 68.35, H 4.23, N 18.90.

*2-[N′-(1-Butyl-5-cyano-4-methyl-2,6-dioxo-1,6-dihydro-2H-pyridin-3-ylidene)-hydrazino]benzoic acid methyl ester (**5e**)*: Yellow crystals from ethanol/dioxane (3:1); m.p. 248 °C. Yield 90%. IR (KBr): ν = 3303 (NH, broadened due to H-bond between O and NH), 3060 (CH aromatic), 2963 (CH aliphatic), 2223 (CN), 1698 (C=O ester) and 1677, 1632 (2C=O ring) cm^{-1}. ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.91 (t, J = 7 Hz, 3H, CH_3CH_2), 1.31 (sextet, J = 7 Hz, 2H, CH_3CH_2), 1.51 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.49 (s, 3H, CH_3), 3.83 (t, J = 7 Hz, 2H, CH_2CH_2N), 3.96 (s, 3H, $COOCH_3$), 7.39 (t, J = 7 Hz, 1H, Ar H-5), 7.79 (t, J = 7 Hz, 1H, Ar H-4), 8.08 (d, J = 8 Hz, 2H, Ar H-6, H-3) and 15.61 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 11.22 (CH_3), 13.91, 19.88, 25.02, 38.29 (butyl carbons), 52.18 ($COOCH_3$), 105.78 (C-3), 112.05, 117.11, 125.00, 125.70,133.79, 134.15 (C_6H_4–$COOCH_3$-*o*), 116.51 (CN), 142.95 (C-4), 158.02 (C-5), 163.98, 164.64 (2C=O) and 166.99 ($COOCH_3$) ppm; *m/z* (%) = 368. Anal. for $C_{19}H_{20}N_4O_4$ (368.40) Calcd. C 61.95, H 5.47, N 15.21. Found C 61.90, H 5.54, N 15.25.

*2-[N′-(5-cyano-1-hexyl-4-methyl-2,6-dioxo-1,6-dihydro-2H-pyridin-3-ylidene)-hydrazino]benzoic acid methyl ester (**5f**)*: Dark yellow crystals from ethanol; m.p. 207 °C. Yield 94%. IR (KBr): ν = 3419 (NH, broadened due to H-bond between O and NH), 3064 (CH aromatic), 2932 (CH aliphatic), 2226 (CN) and 1662 (3C=O) cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 0.86 (t, J = 6 Hz, 3H, CH_3CH_2), 1.28–1.31 (m, 6H, $3CH_2$), 1.61 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.62 (s, 3H, CH_3), 3.99 (t, J = 7 Hz, 2H, CH_2N), 4.04 (s, 3H, $COOCH_3$), 7.31 (t, J = 7 Hz, 1H, Ar H-5), 7.63 (t, J = 7 Hz, 1H, Ar H-4), 7.98 (d, J = 8 Hz, 1H, Ar H-6), 8.12 (d, J = 8 Hz, 2H, Ar H-3) and 15.82 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.11 (CH_3), 16.91, 22.60, 26.66, 27.78, 31.54, 40.16 (hexyl carbons), 53.04 ($COOCH_3$), 103.40 (C-3), 134.75, 114.38, 116.87 124.70, 125.77,131.71 (C_6H_4–$COOCH_3$-*o*), 116.51 (CN), 143.12 (C-4), 158.74 (C-5), 160.10, 160.25 (2C=O) and 166.91 ($COOCH_3$) ppm; *m/z* (%) = 396. Anal. for $C_{21}H_{24}N_4O_4$ (396.45) Calcd. C 63.62, H 6.10, N 14.13. Found C 63.60, H 6.20, N 14.19.

*2-[N′-(5-cyano-1-cyclohexyl-4-methyl-2,6-dioxo-1,6-dihydro-2H-pyridin-3-ylidene)-hydrazino]benzoic acid methyl ester (**5g**)*: Yellow crystals from ethanol; m.p. 299 °C. Yield 87%. IR (KBr): ν = 3475 (NH, broadened due to H-bond between O and NH), 3010 (CH aromatic), 2932 (CH aliphatic), 2223 (CN) and 1662 (3C=O) cm^{-1}. ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 1.24–1.68 (m, 6H, cyclohexyl H-3′, H-4′, H-5′), 1.81–2.45 (m, 4H, cyclohexyl H-2′, H-6′), 2.61 (s, 3H, CH_3), 4.06 (s, 3H, $COOCH_3$), 4.88–4.90 (m, 1H, cyclohexyl H-1′), 7.29 (t, J = 7 Hz, 1H, Ar H-4), 7.65 (t, J = 7 Hz, 1H, Ar H-5), 7.98 (d, J = 8 Hz, 1H, Ar H-6), 8.11 (d, J = 8 Hz, 1H, Ar H-3) and 15.81 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 11.50 (CH_3), 24.25, 26.22, 28.76, 54.17 (cyclohexyl carbons), 52.95 ($COOCH_3$), 104.74 (C-3), 111.26, 117.17, 125.98, 125.85,131.54, 133.99 (C_6H_4–$COOCH_3$-*o*), 117.00 (CN), 142.56 (C-4), 159.00 (C-5), 162.98, 164.52 (2C=O) and 166.99 ($COOCH_3$) ppm; *m/z* (%) = 394. Anal. for $C_{21}H_{22}N_4O_4$ (394.43) Calcd. C 63.95, H 5.62, N 14.20. Found C 63.80, H 5.71, N 14.34.

*2-[N′-(1-Benzyl-5-cyano-4-methyl-2,6-dioxo-1,6-dihydro-2H-pyridin-3-ylidene)-hydrazino]benzoic acid methyl ester (**5h**)*: Light orange crystals from ethanol; m.p. 272 °C. Yield 91%. IR (KBr): ν = 3334 (NH, broadened due to H-bond between O and NH), 3039 (CH aromatic), 2223 (CN) and 1671 (3C=O) cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 2.63 (s, 3H, CH_3), 4.06 (s, 3H, $COOCH_3$), 5.21 (s, 2H, CH_2Ph), 7.26–8.13 (m, 9H, Ar-H) and 15.83 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 11.86 (CH_3), 42.25 (CH_2), 51.03 ($COOCH_3$), 103.84 (C-3), 111.55, 117.85, 125.98, 125.85, 126.52, 126.87, 127.63, 128.25, 128.36, 131.54, 133.99 (C_6H_4, C_6H_4–$COOCH_3$-*o*), 116.99 (CN), 142.99 (C-4), 159.54 (C-5), 161.99, 163.25 (2C=O) and 167.03 ($COOCH_3$) ppm; *m/z* (%) = 402. Anal. for $C_{22}H_{18}N_4O_4$ (402.41) Calcd. C 65.67, H 4.51, N 15.90. Found C 65.70, H 4.48, N 15.95.

*1-Butyl-4-methyl-2,6-dioxo-5-(4-chlorophenyl-hydrazono)-1,2,5,6-tetrahydropyridine-3-carbonitrile (**5i**)*: Orange crystals from ethanol; m.p. 179 °C. Yield 76%. IR (KBr): ν = 3421 (NH, broadened due to H-bond between O and NH), 3094 (CH aromatic), 2955 (CH aliphatic), 2220 (CN) and 1637 (2C=O ring) cm^{-1}. ^{1}H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.89 (t, J = 7 Hz, 3H, CH_3CH_2), 1.29 (sextet, J = 7 Hz, 2H, CH_3CH_2), 1.52 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.54 (s, 3H, CH_3), 3.82 (t, J = 7 Hz, 2H, CH_2CH_2N), 7.51 (d, J = 8 Hz, 2H, Ar H-2, H-6), 7.75 (d, J = 8 Hz, 2H, Ar H-3, H-5) and 14.45 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 10.66 (CH_3), 14.21, 19.55, 29.91, 37.03 (butyl carbons), 72.56 (C-3), 101.21, 111.34, 115.58, 126.45, 136.26, 137.52 (C_6H_4–Cl-*p*), 117.53 (CN), 151.12 (C-4), 158.65 (C-5) and 160.27, 162.79 (2C=O) ppm; *m/z* (%) = 343. Anal. for $C_{17}H_{17}N_4O_2Cl$ (344.80) Calcd. C 59.22, H 4.97, N 16.25. Found C 59.36, H 4.90, N 16.44.

*5-[(4-Chlorophenyl)hydrazono]-1-hexyl-4-methyl-2,6-dioxo-1,2,5,6-tetrahydropyridine-3-carbonitrile (**5j**)*: Yellow crystals from ethanol; m.p. 187 °C; Yield 89%. IR (KBr): ν = 3302 (NH, broadened due to H-bond between O and NH), 3069 (CH aromatic), 2958 (CH aliphatic), 2222 (CN) and 1671, 1630 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 0.86 (t, J = 6 Hz, 3H, CH_3CH_2), 1.30–1.32 (m, 6H, 3 CH_2), 1.59 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.59 (s, 3H, CH_3), 3.93 (t, J = 7 Hz, 2H, CH_2CH_2N), 7.37–7.45 (m, 4H, Ar-H), and 15.00 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 14.10 (CH_3) 16.65, 22.57, 26.69, 27.74, 31.59, 40.21 (hexyl carbons), 102.43 (C-3), 108.37, 114.37, 118.21, 123.32, 130.19, 133.11 (C_6H_4–Cl-*p*), 117.91 (CN), 139.45 (C-4), 158.39 (C-5) and 159.92, 161.75 (2C=O) ppm; *m/z* (%) = 372. Anal. for $C_{19}H_{21}N_4O_2Cl$ (372.86) Calcd. C 61.21, H 5.68, N 15.03. Found C 61.25, H 5.75, N 15.15.

*5-[(4-Chlorophenyl)hydrazono]-1-cyclohexyl-4-methyl-2,6-dioxo-1,2,5,6-tetrahydro-pyridine-3-carbonitrile (**5k**)*: Orange crystals from ethanol; m.p. 248 °C. Yield 80%. IR (KBr): ν = 3275 (NH, broadened due to H-bond between O and NH), 3101 (CH aromatic), 2931 (CH aliphatic), 2219 (CN) and 1622 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 1.12–1.65 (m, 6H, cyclohexyl H-3′, H-4′, H-5′), 1.79–2.31 (m, 4H, cyclohexyl H-2′, H-6′), 2.63 (s, 3H, CH_3), 4.63–4.69 (m, 1H, cyclohexyl H-1′), 7.52 (d, J = 8 Hz, 2H, Ar H-2, H-6), 7.76 (d, J = 8 Hz, 2H, Ar H-3, H-5), and 14.44 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 11.68 (CH_3), 24.45, 26.36, 28.58, 54.89 (cyclohexyl carbons), 66.45 (C-3), 102.15, 122.56, 125.26, 126.75, 131.58, 136.23 (C_6H_4–Cl-*p*), 116.53 (CN), 141.89 (C-4), 155.00 (C-5) and 158.91, 164.52 (2C=O) ppm; *m/z* (%) = 370. Anal. for $C_{19}H_{19}N_4O_2Cl$ (370.84) Calcd. C 61.54, H 5.16, N 15.11. Found C 61.49, H 5.25, N 15.20.

*1-Benzyl-5-[(4-chlorophenyl)hydrazono]-4-methyl-2,6-dioxo-1,2,5,6-tetrahydro-pyridine-3-carbonitrile (**5l**)*: Brown crystals from ethanol; m.p. 271 °C. Yield 86%. IR (KBr): ν = 3434 (NH, broadened due to H-bond between O and NH), 3092 (CH aromatic), 2961 (CH aliphatic), 2225 (CN) and1672, 1625 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 3.49 (s, 3H, CH_3), 5.05 (s, 2H, CH_2Ph), 7.25–7.78 (m, 9H, Ar-H), and 15.02 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$, TMS): δ = 13.22 (CH_3), 40.02 (CH_2), 63.55 (C-3), 100.32, 114.48, 114.99, 125.08, 126.02, 126.25, 127.99, 128.01, 128.94, 133.00, 135.15, 137.85 (C_6H_5, C_6H_4–Cl-*p*), 116.52 (CN), 148.20 (C-4), 159.99 (C-5) and 161.00, 165.85 (2C=O) ppm; *m/z* (%) = 378. Anal. for $C_{20}H_{15}N_4O_2Cl$ (378.82) Calcd. C 63.41, H 3.99, N 14.79. Found C 63.52, H 3.95, N 14.83.

*1-Butyl-4-methyl-2,6-dioxo-5[(2H)-[1,2,4]triazol-3-yl)hydrazono]-1,2,5,6-tetrahydro-pyridine-3-carbonitrile (**6a**)*: Yellow crystals from ethanol; m.p. 264 °C. Yield 93%. IR (KBr): ν = 3310, 3261 (2 NH), 3122 (CH aromatic), 2947 (CH aliphatic), 2230 (CN) and 1630 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 0.94 (t, J = 7 Hz, 3H, CH_3CH_2), 1.35 (sextet, J = 7 Hz, 2H, CH_3CH_2), 1.59 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.62 (s, 3H, CH_3), 3.96 (t, J = 7 Hz, 2H, CH_2CH_2N), 8.19 (s, 1H, CH triazole ring), 14.24 (s, 1H, NH triazole ring) and 14.95 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 13.99, 14.02, 18.41, 27.91, 36.25 (butyl carbons), 105.60 (C-3), 117.22, 138.00 (C-4), 147.87 (triazole ring carbons), 157.78 (C-5) and 163.96, 167.88 (2C=O) ppm; *m/z* (%) = 301. Anal. for $C_{13}H_{15}N_7O_2$ (301.31) Calcd. C 51.82, H 5.05, N 32.54. Found C 51.75, H 5.15, N 32.49.

*1-Hexyl-4-methyl-2,6-dioxo-5[(2H)-[1,2,4]triazol-3-yl)hydrazono]-1,2,5,6-tetrahydro-pyridine-3-carbonitrile (**6b**)*: Yellow crystals from ethanol; m.p. 257 °C. Yield 96%. IR (KBr): ν = 3300, 3261 (2 NH), 3121 (CH aromatic), 2932 (CH aliphatic), 2231 (CN) and 1629 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 0.88 (t, J = 6 Hz, 3H, CH_3CH_2), 1.31 (m, 6H, 3CH_2), 1.56 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.62 (s, 3H, CH_3), 3.95 (t, J = 7 Hz, 2H, CH_2CH_2N), 8.20 (s, H, CH triazole ring), 14.32 (s, 1H, NH, triazole ring) and 14.81 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 14.12, 16.52, 21.00, 25.89, 27.52, 36.42, 40.16 (hexyl carbons), 104.77 (C-3), 116.89, 138.85 (C-4), 145.48 (triazole ring carbons), 159.49 (C-5) and 161.58, 164.41 (2C=O) ppm; *m/z* (%) = 329. Anal. for $C_{15}H_{19}N_7O_2$ (329.36) Calcd. C 54.70, H 5.81, N 29.77. Found C 54.66, H 5.89, N 29.90.

*1-Cyclohexyl-4-methyl-2,6-dioxo-5[(2H)-[1,2,4]triazol-3-yl)hydrazono]-1,2,5,6-tetra- hydropyridine-3-carbonitrile (**6c**)*: Yellow crystals from ethanol; m.p. 299 °C. Yield 90%. IR (KBr): ν = 3319, 3210 (2 NH), 3150 (CH aromatic), 2928 (CH aliphatic), 2234 (CN) and 1620 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 1.12–1.62 (m, 6H, cyclohexyl H-3′, H-4′, H-5′), 1.78–2.29 (m, 4H, cyclohexyl H-2′, H-6′), 2.43 (s, 3H, CH_3), 4.60–4.66 (m, 1H, cyclohexyl H-1′), 8.60 (s, 1H, CH triazole ring), 14.24 (s, 1H, NH triazole ring) and 14.58 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 14.00, 25.58, 26.44, 26.89, 28.73, 31.25, 53.46 (cyclohexyl carbons), 103.50 (C-3), 117.25, 138.50 (C-4), 145.20 (triazole ring carbons), 159.49 (C-5) and 160.66, 162.51 (2C=O) ppm; *m/z* (%) = 327. Anal. for $C_{15}H_{17}N_7O_2$ (327.35) Calcd. C 55.04, H 5.23, N 29.95. Found C 54.15, H 5.30, N 29.90.

2[N′-(1-Butyl-5-cyano-4-methyl-2,6-dioxo-1,6-dihydro-2H-pyridine-3-ylidene)-hydrazino]-4,5,6,7-tetrahydro-benzo[b]thiophene-3-carboxylic acid ethyl ester (**6d**): Red crystals from ethanol; m.p. 210 °C. Yield 63%. IR (KBr): ν = 3368 (NH), 3102 (CH aromatic), 2871 (CH aliphatic), 2226 (CN), 1681 (C=O ester) and 1638 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.92 (t, J = 7 Hz, 3H, CH_3CH_2), 1.30 (t, J = 7 Hz, 3H, $COOCH_2CH_3$), 1.33 (sextet, J = 7 Hz, 2H, CH_3CH_2), 1.56 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.62 (s, 3H, CH_3), 3.94 (t, J = 7 Hz, 2H, CH_2CH_2N), 4.20 (q, J = 7 Hz, 2H, $COOCH_2CH_3$), 1.63-2.60 (m, 8H, cyclohexane-H) and 15.15 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 13.89, 14.99, 18.22, 23.45, 23.99, 24.56, 25.25, 36.25, 62.9, 105.60, 117.51, 132.58, 133.55, 135.99, 138.00, 142.56, 145.68, 147.87, 157.78, 160.25 and 163.96, 167.88 (2C=O) ppm; *m/z* (%) = 442. Anal. for $C_{22}H_{26}N_4O_4S$ (442.54) Calcd. C 59.71, H 5.92, N 12.66. Found C 59.79, H 5.85, N 12.77.

*2[N-(5-Cyano-1-hexyl-4-methyl-2,6-dioxo-1,6-dihydro-2H-pyridine-3-ylidene)-hydrazino]-4,5,6,7-tetrahydro-benzo[b]thiophene-3-carboxylic acid ethyl ester (**6e**):* Red crystals from ethanol; m.p. 197 °C. Yield 70%. IR (KBr): ν = 3434 (NH, broadend due to H-bond between O and NH), 2933 (CH aliphatic), 2226 (CN), 1683 (C=O ester) and 1631 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$, 25 °C, TMS): δ = 0.88 (t, J = 6 Hz, 3H, CH_3CH_2), 1.31 (m, 6H, 3CH_2), 1.56 (quintet, J = 7 Hz, 2H, CH_2CH_2N), 2.62 (s, 3H, CH_3), 3.95 (t, J = 7 Hz, 2H, CH_2CH_2N), 4.25 (q, J = 7 Hz, 2H, $COOCH_2CH_3$), 1.75–2.78 (m, 8H, cyclohexane-H) and 14.59 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 13.99, 14.48, 18.22, 19.25, 23.45, 23.25, 24.56, 25.25, 26.85, 30.45, 32.59, 36.25, 59.25, 107.60, 116.87, 130.18, 135.25, 135.99, 139.74, 142.46, 147.25, 158.20 and 161.85, 163.25 (2C=O) ppm; *m/z* (%) = 470. Anal. for $C_{24}H_{30}N_4O_4S$ (470.60) Calcd. C 61.26, H 6.43, N 11.91. Found C 61.13, H 6.50, N 11.95.

*2[N-(5-Cyano-1-cyclohexyl-4-methyl-2,6-dioxo-1,6-dihydro-2H-pyridine-3-ylidene)-hydrazino]-4,5,6,7-tetrahydro-benzo[b]thiophene-3-carboxylic acid ethyl ester (**6f**):* Red crystals from ethanol; m.p. 242 °C. Yield 85%. IR (KBr): ν = 3300 (NH, broadend due to H-bond between O and NH), 2934 (CH aliphatic), 2226 (CN), 1678 (C=O ester) and 1634 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 1.21 (t, J = 7 Hz, 3H, $COOCH_2CH_3$), 1.30–3.54 (m, 19H, cyclohexyl, cyclohexen thiophen), 2.62 (s, 3H, CH_3), 4.32 (q, J = 7 Hz, 2H, $COOCH_2CH_3$) and 15.45 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 14.12, 23.52, 23.66, 24.45, 25.25, 25.23, 26.89, 31.55, 36.25, 50.25 59.25, 102.52, 116.54, 133.18, 134.42, 134.99, 138.75, 141.15, 143.72, 145.74, 160.28 and 163.24, 167.85 (2C=O) ppm;

m/*z* (%) = 469. Anal. for $C_{24}H_{28}N_4O_4S$ (468.58) Calcd. C 61.52, H 6.02, N 11.96. Found C 61.64, H 6.15, N 11.90.

*4.2.4. General procedure for the reaction of aryl and heteroaromatic hydrazones **5a–l**, **6a–f** with elemental sulphur*

4.2.4.1. Method I (thermal)

A. To a solution of **5a–l, 6a–f** (0.1 mol) in ethanol (30 mL), elemental sulphur (0.1 mol) and a catalytic amount of triethylamine were added. The reaction mixture was heated under reflux at 80 °C for 3 h. The solid product so formed was collected by filtration and crystallized from ethanol [13].

B. To a solution of **5a–l, 6a–f** (0.1 mol) in DMF (30 mL), elemental sulphur (0.1 mol) and a catalytic amount of piperidine were added. The reaction mixture was heated under reflux at 130 °C for 3 h. The solid product so formed was collected by filtration and recrystallized from ethanol [21].

4.2.4.2. Method II (microwaves). A mixture of arylazopyridones derivatives **5a–l, 6a–f** (0.1 mol), elemental sulphur (0.1 mol) and some drops of triethylamine was placed in the microwave oven and irradiated at full power for 5–10 min, and then left to cool to room temperature. The solid product so formed was filtered off and recrystallized from ethanol.

4.2.4.3. Method III (ultrasound). To a solution of **5a–l, 6a–f** (0.1 mol) in ethanol (30 ml), elemental sulphur (0.1 mol) and a catalytic amount of triethylamine were added. The reaction mixture was heated under ultrasound irradiation at 40 °C for 90 min, and then left to cool to room temperature. The solid product so formed was filtered off and recrystallized from ethanol.

*2-(2-(3-Amino-5-butyl-4,6-dioxo-5,6-dihydrothieno[3,4-c]pyridin-7(4H)-ylidene) hydrazinyl)benzonitrile (**7a**)*: Brown crystals from ethanol; m.p. 263 °C. IR (KBr): *ν* = 3506 (NH, broadened due to H-bond between O and NH), 3423, 3307 (NH_2), 3171 (CH aromatic), 2955 (CH aliphatic), 2220 (CN) and 1655 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): *δ* = 0.89 (t, *J* = 7 Hz, 3H, CH_3CH_2), 1.29 (sextet, *J* = 7 Hz, 2H, CH_3CH_2), 1.49 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N), 3.83 (t, *J* = 7 Hz, 2H, CH_2CH_2N), 7.03–7.89 (m, 4H, Ar-H), 8.46 (s, 1H, CH thienyl ring), 9.77 (s, 2H, NH_2) and 14.17 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): *δ* = 14.21, 19.37, 30.42, 39.21 (butyl carbons), 101.68 (C-3), 116.13, 117.52, 123.41, 124.80, 127.27, 129.31, 133.58 (C_6H_4–CN-*o*), 108.51 (C-S), 130.43 (C-4), 141.00 (C-NH_2), 162.47 (C-5) and 163.62, 167.28 (2C=O) ppm; *m*/*z* (%) = 367. Anal. for $C_{18}H_{17}N_5O_2S$ (367.43) Calcd. C 58.84, H 4.66, N 19.06. Found C 58.80, H 4.72, N 19.15.

*2-(2-(3-Amino-5-hexyl-4,6-dioxo-5,6-dihydrothieno[3,4-c]pyridin-7(4H)-ylidene) hydrazinyl)benzonitrile (**7b**)*: Brown crystals from ethanol; m.p. 208 °C. IR (KBr): *ν* = 3178 (NH, broadened due to H-bond between O and NH), 3414, 3311 (NH_2), 3171 (CH aromatic), 2931 (CH aliphatic), 2222 (CN) and 1650 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): *δ* = 0.85 (t, *J* = 6 Hz, 3H, CH_3CH_2), 1.28 (m, 6H, $3CH_2$), 1.53 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N), 3.37 (s, 2H, NH_2), 3.84 (t, *J* = 6 Hz, 2H, CH_2CH_2N), 7.06 (t, *J* = 7 Hz, 1H, Ar H-5), 7.35 (t, *J* = 7 Hz, 1H, Ar H-4), 7.68 (d, *J* = 7 Hz, 1H, Ar H-6), 7.73 (d, *J* = 7 Hz, 1H, ArH-3), 8.00 (s, 1H, CH thienyl ring) and 14.19 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): *δ* = 17.52, 22.57, 25.69, 26.87, 31.59, 42.21 (hexyl carbons), 100.68 (C-3), 117.13, 117.88, 123.41, 124.80, 127.27, 130.71, 134.68 (C_6H_4–CN-*o*), 105.59 (C-S), 131.52 (C-4), 143.02 (C-NH_2), 158.58 (C-5) and 161.00, 163.18 (2C=O) ppm; *m*/*z* (%) = 395. Anal. for $C_{20}H_{21}N_5O_2S$ (395.49) Calcd. C 60.74, H 5.35, N 17.71. Found C 60.80, H 5.25, N 17.67.

*2-(2-(3-Amino-5-benzyl-4,6-dioxo-5,6-dihydrothieno[3,4-c]pyridin-7(4H)-ylidene) hydrazinyl)benzonitrile (**7c**)*: Dark brown crystals from ethanol; m.p. 232 °C. IR (KBr): *ν* = 3520 (NH, broadened due to H-bond between O and NH), 3420, 3311 (NH_2), 3075 (CH aromatic), 2219 (CN) and 1654 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): *δ* = 5.06 (s, 2H, CH_2Ph), 6.86 (s, 2H, NH_2), 7.24–7.81 (m, 9H, Ar-H), 8.01 (s, 1H, CH thienyl ring) and 14.12 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): *δ* = 40.78 (CH_2), 101.01 (C-3), 113.59, 117.58, 123.01, 125.12, 125.40, 125.99, 126.97, 126.99, 127.58, 128.39, 130.48, 134.66, 135.05 (C_6H_5, C_6H_4–CN-*o*), 108.54 (C-S), 132.88 (C-4), 143.85 (C-NH_2), 161.58 (C-5) and 163.99, 168.54 (2C=O) ppm; *m*/*z* (%) = 401. Anal. for $C_{21}H_{15}N_5O_2S$ (401.45) Calcd. C 62.83, H 3.77, N 17.45. Found C 62.91, H 3.70, N 17.52.

*Methyl-2-(2-(3-amino-5-butyl-4,6-dioxo-5,6-dihydrothieno[3,4-c]pyridin-7(4H)-ylidene)hydrazinyl)benzoate (**7d**)*: Dark brown crystals from ethanol; m.p. 255 °C. IR (KBr): *ν* = 3450 (NH, broadened due to H-bond between O and NH), 3398, 3306 (NH_2), 3117 (CH aromatic), 2955 (CH aliphatic), 1701 (C=O ester) and 1666, 1627 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): *δ* = 0.91 (t, *J* = 7 Hz, 3H, CH_3CH_2), 1.19 (sextet, *J* = 7 Hz, 2H, CH_3CH_2), 1.32 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N), 3.93 (t, *J* = 7 Hz, 2H, CH_2CH_2N), 3.94 (s, 3H, $COOCH_3$), 6.72 (s, 2H, NH_2), 7.00–7.95 (m, 4H, Ar-H), 8.06 (s, 1H, CH thienyl ring) and 14.59 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): *δ* = 13.99, 19.52, 31.40, 38.78 (butyl carbons), 51.48 ($COOCH_3$), 100.78 (C-3), 111.26, 125.25, 125.99,133.19, 134.22 (C_6H_4–$COOCH_3$-*o*), 108.58 (C-S), 131.89 (C-4), 142.99 (C-NH_2), 160.76 (C-5) and 166.79, 168.00 (2C=O) ppm; *m*/*z* (%) = 400. Anal. for $C_{19}H_{20}N_4O_4S$ (400.46) Calcd. C 56.99, H 5.03, N 13.99. Found C 56.89, H 5.15, N 13.78.

*Methyl-2-(2-(3-amino-5-hexyl-4,6-dioxo-5,6-dihydrothieno[3,4-c]pyridin-7(4H)-ylidene)hydrazinyl)benzoate (**7e**)*: Dark brown crystals from ethanol; m.p. 250 °C. IR (KBr): *ν* = 3402, 3309 (NH_2), 3289 (NH), 3089 (CH aromatic), 2951 (CH aliphatic), 1701 (C=O ester) and 1666, 1627 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): *δ* = 0.81 (t, *J* = 6 Hz, 3H, CH_3CH_2), 1.08–1.10 (m, 6H, $3CH_2$), 1.47 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N), 3.03 (t, *J* = 7 Hz, 2H, CH_2CH_2N), 3.87 (s, 3H, $COOCH_3$), 6.89 (s, 2H, NH_2), 7.17–7.88 (m, 4H, Ar-H), 7.94 (s, 1H, CH thienyl ring) and 14.91 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): *δ* = 18.42, 21.63, 24.54, 26.78, 31.15, 41.01 (hexyl carbons), 52.01 ($COOCH_3$), 101.62 (C-3), 112.20, 125.14, 126.99,134.11, 134.78 (C_6H_4–$COOCH_3$-*o*), 105.99 (C-S), 131.00 (C-4), 141.99 (C-NH_2), 159.98 (C-5) and 164.52, 167.12 (2C=O) ppm; *m*/*z* (%) = 428. Anal. for $C_{21}H_{24}N_4O_4S$ (428.51) Calcd. C 58.86, H 5.65, N 13.07. Found C 58.92, H 5.60, N 13.15.

*Methyl-2-(2-(3-amino-5-cyclohexyl-4,6-dioxo-5,6-dihydrothieno[3,4-c]pyridin-7(4H)-ylidene)hydrazinyl)benzoate (**7f**)*: Brown crystals from ethanol; m.p. 251 °C. IR (KBr): *ν* = 3511 (NH, broadened due to H-bond between O and NH), 3406, 3306 (NH_2), 3028 (CH aromatic), 2924 (CH aliphatic), 1697 (C=O ester) and 1666, 1627 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): *δ* 1.22–1.75 (m, 6H, cyclohexyl H-3′, H-4′, H-5′), 1.85–2.23 (m, 4H, cyclohexyl H-2′, H-6′), 4.13-4.51 (m, 1H, cyclohexyl H-1′), 3.25 (s, 3H, $COOCH_3$), 6.89 (s, 2H, NH_2), 7.02–7.56 (m, 4H, Ar-H), 7.85 (s, 1H, CH thienyl ring) and 14.91 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): *δ* = 25.58, 26.44, 26.89, 28.73, 31.25, 53.46 (cyclohexyl carbons), 51.12 ($COOCH_3$), 103.54 (C-3), 112.11, 125.78, 127.03,133.81, 133.98 (C_6H_4–$COOCH_3$-*o*), 106.23 (C-S), 131.00 (C-4), 141.12 (C-NH_2), 159.55 (C-5) and 163.16, 166.11 (2C=O) ppm; *m*/*z* (%) = 426. Anal. for $C_{21}H_{22}N_4O_4S$ (426.50) Calcd. C 59.14, H 5.20, N 13.14. Found C 59.20, H 5.15, N 13.27.

*Methyl-2-(2-(3-amino-5-benzyl-4,6-dioxo-5,6-dihydrothieno[3,4-c]pyridin-7(4H)-ylidene)hydrazinyl)benzoate (**7g**)*: Dark brown crystals from ethanol; m.p. 253 °C. IR (KBr): *ν* = 3649 (NH, broadened due to H-bond between O and NH), 3405, 3305 (NH_2), 3002 (CH

aromatic), 2923 (CH aliphatic), 1700 (C=O ester) and 1670, 1632 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 3.94 (s, 3H, $COOCH_3$), 5.02 (s, 2H, CH_2Ph), 4.90 (s, 2H, NH_2), 7.26–7.98 (m, 9H, Ar-H), 8.11 (s, 1H, CH thienyl ring) and 14.56 (s, 1H, NH) ppm; ^{13}C NMR (100 MHz, DMSO-d_6, TMS): δ = 40.78 (CH_2), 51.12 ($COOCH_3$), 101.23 (C-3), 111.91, 125.23, 125.78, 126.03, 126.45, 127.03, 128.09, 128.55, 133.81, 133.98, 134.89 (C_6H_5, C_6H_4–$COOCH_3$-*o*), 105.78 (C-S), 136.00 (C-4), 142.00 (C-NH_2), 158.55 (C-5) and 161.89, 166.15 (2C=O) ppm; *m/z* (%) = 434. Anal. for $C_{22}H_{18}N_4O_4S$ (434.48) Calcd. C 60.82, H 4.18, N 12.90. Found C 60.77, H 4.20, N 12.85.

*3-Amino-5-butyl-7-[2-(4-chlorophenyl)hydrazono]-7H-thieno[3,4-c]pyridine-4,6-dione (**7h**)*: Brown crystals from ethanol; m.p. 113 °C. IR (KBr): *v* = 3649 (NH, broadened due to H-bond between O and NH), 3399, 3297 (NH_2), 3102 (CH aromatic), 2958 (CH aliphatic) and 1656, 1621 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.88 (t, *J* = 7 Hz, 3H, CH_3CH_2), 1.26 (sextet, *J* = 7 Hz, 2H, CH_3CH_2), 1.48 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N), 3.82 (t, *J* = 7 Hz, 2H, CH_2CH_2N), 4.52 (s, 2H, NH_2), 7.12 (d, *J* = 8 Hz, 2H, Ar H-2, H-6), 7.43 (d, *J* = 8 Hz, 2H, Ar H-3, H-5), 7.88 (s, 1H, CH thienyl ring) and 13.61 (s, 1H, NH) ppm; ^{13}C NMR (400 MHz, DMSO-d_6, TMS): δ = 14.28, 20.37, 26.58, 30.42 (butyl carbons), 102.68 (C-3), 117.13, 122.41, 127.27, 129.31 (C_6H_4–Cl-*p*), 106.51 (C-S), 129.43 (C-4), 142.07 (C-NH_2), 160.47 (C-5) and 162.62, 164.28 (2C=O) ppm; *m/z* (%) = 376. Anal. for $C_{17}H_{17}N_4O_2SCl$ (376.87) Calcd. C 54.18, H 4.55, N 14.87. Found C 54.25, H 4.50, N 14.85.

*3-Amino-7-[2-(4-chlorophenyl)hydrazono]-5-hexyl-7H-thieno[3,4-c]pyridine-4,6-dione (**7i**)*: Dark brown crystals from ethanol; m.p. 138 °C. IR (KBr): *v* = 3430, 3393 (NH_2), 3349 (NH, broadened due to H-bond between O and NH), 3110 (CH aromatic), 2954 (CH aliphatic) and 1666, 1629 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.85 (t, *J* = 6 Hz, 3H, CH_3CH_2), 1.15–1.28 (m, 6H, $3CH_2$), 1.48 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N), 3.07 (t, *J* = 7 Hz, 2H, CH_2CH_2N), 7.09–7.89 (m, 4H, Ar-H), 8.03 (s, 1H, CH thienyl ring), 9.01 (s, 2H, NH_2) and 13.33 (s, 1H, NH) ppm; ^{13}C NMR (400 MHz, DMSO-d_6, TMS): δ = 18.78, 22.54, 26.29, 26.98, 32.52, 41.51 (hexyl carbons), 100.99 (C-3), 116.45, 126.57, 127.78, 129.56 (C_6H_4–Cl-*p*), 105.79 (C-S), 130.89 (C-4), 143.89 (C-NH_2), 159.78 (C-5) and 163.92, 166.55 (2C=O), *m/z* (%) = 404. Anal. for $C_{19}H_{21}N_4O_4SCl$ (404.92) Calcd. C 56.36, H 5.23, N 13.84. Found C 56.41, H 5.47, N 13.79.

*3-Amino-7-[2-(4-chlorophenyl)hydrazono]-5-cyclohexyl-7H-thieno[3,4-c]pyridine-4,6-dione (**7j**)*: Dark brown crystals from ethanol; m.p. 222 °C. IR (KBr): *v* = 3471, 3410 (NH_2), 3313 (NH), 3120 (CH aromatic), 2928 (CH aliphatic) and 1662, 1627 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 1.15–4.70 (m, 11H, cyclohexyl-H), 3.08 (s, 2H, NH_2), 7.18 (d, *J* = 8 Hz, 2H, Ar H-2, H-6), 7.46 (d, *J* = 8 Hz, 2H, Ar H-3, H-5), 7.91 (s, 1H, CH thienyl ring) and 13.59 (s, 1H, NH) ppm; ^{13}C NMR (400 MHz, DMSO-d_6, TMS): δ = 25.98, 26.58, 26.74, 28.56, 31.55, 53.99 (cyclohexyl carbons), 101.25 (C-3), 114.47, 126.35, 127.96, 129.75 (C_6H_4–Cl-*p*), 106.80 (C-S), 131.97 (C-4), 144.58 (C-NH_2), 160.78 (C-5) and 164.99, 167.00 (2C=O), *m/z* (%) = 402. Anal. for $C_{19}H_{19}N_4O_2SCl$ (402.91) Calcd. C 56.64, H 4.75, N 13.91. Found C 56.49, H 4.79 N 13.95.

*3-Amino-5-benzyl-7[2-(4-chlorophenyl)-hydrazono]-7H-thieno[3,4-c]pyridine-4,6-dione (**7k**)*: Dark brown crystals from ethanol; m.p. 221 °C. IR (KBr): *v* = 3425, 3317 (NH_2), 3303 (NH, broadened due to H-bond between O and NH), 3051 (CH aromatic), 2952 (CH aliphatic) and 1662, 1624 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 4.95 (s, 2H, CH_2Ph), 7.14–7.55 (m, 9H, Ar-H), 8.02 (s, 1H, CH thienyl ring), 8.12 (s, 2H, NH_2) and 13.45 (s, 1H, NH) ppm; ^{13}C NMR (400 MHz, DMSO-d_6, TMS): δ = 40.52 (CH_2), 101.46 (C-3), 117.58, 123.85, 125.35, 125.88, 126.15, 126.87, 127.39, 127.96, 129.75, 133.52 (C_6H_5, C_6H_4–Cl-*p*), 106.80 (C-S), 131.97 (C-4), 144.58 (C-NH_2), 160.98 (C-5) and 165.89, 168.99 (2C=O), *m/z* (%) = 410. Anal. for $C_{20}H_{15}N_4O_2SCl$ (410.8) Calcd. C 58.46, H 3.68, N 13.64. Found C 58.50, H 3.62, N 13.70.

*2-[N-(3-Amino-5-butyl-4,6-dioxo-5,6-dihydro-4H-thieno[3,4-c]pyridin-7-ylidene)-hydrazino]-4,5,6,7-tetrahydro-benzo[b]thiophene-3-carboxylic acid ethyl ester (**8a**)*: Dark brown crystals from ethanol; m.p. 229 °C. IR (KBr): *v* = 3533 (NH, broadened due to H-bond between O and NH), 3420, 3304 (NH_2), 3102 (CH aromatic), 2932 (CH aliphatic), 1681 (C=O ester) and 1659, 1624 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.89 (t, *J* = 7 Hz, 3H, CH_3CH_2 butyl-H), 1.14 (t, *J* = 7 Hz, 3H, CH_3CH_2), 1.27 (sextet, J = 7 Hz, 2H, CH_3CH_2 butyl-H), 1.37 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N), 1.67, 2.54 (m, 8H, cyclohexene), 3.37 (t, *J* = 7 Hz, 2H, CH_2CH_2N), 4.28 (q, *J* = 7 Hz, 2H, CH_3CH_2), 7.80 (s, 2H, NH_2), 8.10 (s, 1H, CH thienyl ring) and 14.61 (s, 1H, NH) ppm; ^{13}C NMR (400 MHz, DMSO-d_6, TMS): δ = 14.52, 20.85, 27.75, 31.36 (butyl carbons), 100.68 (C-3), 145.28, 147.87 (triazole ring carbons), 105.98 (C-S), 129.43 (C-4), 142.07 (C-NH_2), 160.47 (C-5) and 162.62, 164.28 (2C=O) ppm; *m/z* (%) = 474. Anal. for $C_{22}H_{26}N_4O_4S_2$ (474.60) Calcd. C 55.68, H 5.52, N 11.80. Found C 55.57, H 5.68, N 11.77.

*2-[N-(3-Amino-5-hexyl-4,6-dioxo-5,6-dihydro-4H-thieno[3,4-c]pyridin-7-ylidene)-hydrazino]-4,5,6,7-tetrahydro-benzo[b]thiophene-3-carboxylic acid ethyl ester (**8b**)*: Dark brown crystals from ethanol m.p. > 300 °C. IR (KBr): *v* = 3425, 3331 (NH_2), 3328 (NH), 3132 (CH aromatic), 2939 (CH aliphatic), 1685 (C=O ester) and 1665, 1636 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.86 (t, *J* = 6 Hz, 3H, CH_3CH_2 hexyl-H), 1.15 (t, *J* = 7 Hz, 3H, CH_3CH_2), 1.26–1.31 (m, 6H, $3CH_2$, hexyl-H), 1.51 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N hexyl-H), 1.60, 2.32 (m, 8H, cyclohexen), 3.77 (t, *J* = 7 Hz, 2H, CH_2CH_2N hexyl-H), 4.29 (q, *J* = 7 Hz, 2H, CH_3CH_2), 7.82 (s, 2H, NH_2), 8.13 (s, 1H, CH thienyl ring) and 13.61 (s, 1H, NH) ppm; ^{13}C NMR (400 MHz, DMSO-d_6, TMS): δ = 14.1 (CH_3), 18.75, 22.69, 23.25, 23.58, 23.99, 24.59, 25.35, 26.47, 32.45, 41.52 (hexyl and cyclohexyl carbons), 40.28 (CH_2), 100.52 (C-3), 105.98 (C-S), 112.58, 128.25, 129.43 (C-4), 137.65, 143.07 (C-NH_2), 160.75 (C-5) and 163.55, 168.55 (2C=O) ppm; *m/z* (%) = 503. Anal. for $C_{24}H_{30}N_4O_4S_2$ (502.66) Calcd. C 57.35, H 6.02, N 11.15. Found C 57.49, H 6.16, N 11.27.

*4.2.5. Procedure for the reaction of **5e** and **7e** with acrylonitrile*

4.2.5.1. Method I (thermal). A solution of compound **7e** (0.1 mol) in DMF (20 mL) was treated with acrylonitrile (0.1 mol). The reaction mixture was heated under reflux at 130 °C for 3 h. The solvent was removed and the residue cooled to deposit a solid, which was recrystallized from dioxane/ethanol (1:1).

4.2.5.2. Method II (microwaves). A mixture of compound **5e** (0.1 mol) and acrylonitrile (0.1 mol) was placed in the microwave oven and irradiated at 450 W for 20 min, then left to cool to room temperature. The solid product so formed was filtered off and recrystallized from ethanol.

*2[N′-(7-Amino-2-butyl-6-cyano-1,3-dioxo-2,3-dihydro-1H-isoquinolin-4-ylidene)-hydrazino]-benzoic acid methyl ester (**9**)*: Dark brown m.p. > 300 °C. IR (KBr): *v* = 3430, 3329 (NH_2), 3315 (NH), 3142 (CH aromatic), 2919 (CH aliphatic), 2222 (CN), 1742 (C=O ester) and 1662, 1626 (2C=O ring) cm^{-1}. ^1H NMR (400 MHz, DMSO-d_6, 25 °C, TMS): δ = 0.90 (t, *J* = 7 Hz, 3H, CH_3CH_2), 1.32 (sextet, *J* = 7 Hz, 2H, CH_3CH_2), 1.53 (quintet, *J* = 7 Hz, 2H, CH_2CH_2N), 3.78 (s, 3H, $COOCH_3$), 3.94 (t, *J* = 7 Hz, 2H, CH_2CH_2N), 7.25–8.21 (m, 6H Ar-H, NH_2), 8.48, 8.80 (d, 2H, H-5, H-6, isoquinoline H) and 15.21 (s, 1H, NH) ppm; ^{13}C NMR (400 MHz, DMSO-d_6, TMS): δ = 14.31, 17.90, 20.33, 30.20 (butyl carbons), 53.11 ($COOCH_3$), 116.50 (CN), 101.51, 119.80, 121.33, 135.10, 136.30, 149.15 (isoquinoline carbons), 115.01, 117.12, 118.45, 130.51, 133.62, 147.03 (C_6H_4–$COOCH_3$-*o*), 160.41 (C=N–NH), 162.63, 165.90

Table 3
Crystal data of compound **5k**.

Chemical formula	$C_{19}H_{19}ClN_4O_2$
M	370.840
System	Monoclinic
Space group	$P2_1/c$
a	5.25480 (10)Å
b	28.3791 (10)Å
c	13.1887 (5)Å
α	90.00°
β	111.7582 (2)°
V	1826.66 (10)Å^3
Z	4
Dc	1.348 Mg m^{-3}
θ	2.910–22.465°
μ(Mo Kα)	0.23 mm^{-1}
T	298 K
Measured reflections	3850
Independent reflections	2575
Observed reflections	731
R_{int}	0.039
R(all)	0.192
wR(ref)	0.067
wR(all)	0.110
S(ref)	1.685
S(all)	2.198
D/s_{max}	0.007
Dr_{max}	0.54eÅ^3
Dr_{min}	−0.58eÅ^3

(2C=O) and 167.05 ($COOCH_3$) ppm; m/z (%) = 419. Anal. for $C_{22}H_{21}N_5O_4$ (419.44) Calcd. C 63.00, H 5.05, N 16.70. Found C 63.41, H 5.45, N 16.31.

5. X-ray crystallography

A single crystal of compound **5k** was obtained by slow evaporation from a mixture of ethanol:DMF (2:1). The crystal structure was solved and refined using maxus (nonius, Deflt and MacScience, Japan) [22] Mo Kα radiation (λ = 0.71073 Å) and a graphite monochromator were used for data collection. The chemical formula and ring labeling system is shown in Fig. 1.

Crystallographic data (Table 3) (excluding structure factors) for the structure in this paper have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication number CCDC 686225. Copies of the data can be obtained, free of charge, on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK [fax: 144-(0)1223-336033 or e-mail: deposit@ccdc.cam.ac.uk].

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[12] Crystallographic data for the structures reported in this paper have been deposited with the Cambridge Crystallographic Data Centre as Supplementary Publications Nos. CCDC 686225. These data can be obtained free of charge via http://www.ccdc.cam.ac.uk/conts/retrieving.html (or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; Fax: +44 1223 336033; E-mail: deposit@ccdc.cam.ac.uk).
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