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Four-Component, One-Pot Synthesis of 2-Aryl-4-Thionylquinoline Derivatives and Their Aromatization

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Four-Component, One-Pot Synthesis of 2-Aryl-4-Thionylquinoline Derivatives and Their Aromatization

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Abstract: Four-component, one-pot condensation of dimedon, thiophene-2-carbaldehyde, ammonium acetate, and numerous acetophenones yielded novel 2-aryl-4-thionylquinoline derivatives. The structures were characterized by ^{1}H NMR, ^{13}C NMR, IR, and elemental analysis.

Keywords: Ammonium acetate, 2-aryl-4-thionylquinoline, dimedon, four-component coupling reactions

The synthesis of oxygen-, nitrogen-, or sulfur-containing heterocycles is of importance in organic and medicinal chemistry.[1] Among these structures, quinolines,[2] tetrahydroquinolines,[3] and their derivatives are excellent precursors of potential drugs.[4]

Quinolines and their derivatives, which usually possess diverse biological activities, play important roles as versatile building blocks for the synthesis of natural products and as therapeutic agents.[5] In particular, 2-arylquinolines are biologically active and occur in structures of a number of antimalarial compounds and antitumor agents.[6] The biological activity of quinoline compounds has been found to possess anti-asthmatic, antibacterial, anti-inflammatory, and antihypertensive properties.[7] Therefore, the synthesis of quinolines has attracted much attention in organic synthesis. The classic methods for the synthesis of quinolines include Skraup,[8] Doebner–von Miller,[9] Conrad–Limbach,[10]

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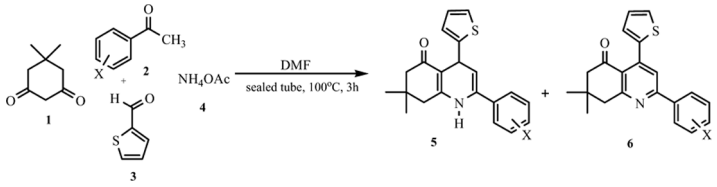


Scheme 1.

Combes,[11] and Pfitzinger[12] quinoline syntheses. A number of general synthetic methods have also been reported.[13] However, some of these methods suffer from several disadvantages such as harsh reaction conditions, multiple steps, a large amount of promoters, and/or long reaction time.[14]

In this study, we reported synthesis of 2-aryl-4-thionylquinoline derivatives (**5a–j**) by a one-pot, four-component condensation of dimedon (**1**), thiophene-2-carbaldehyde (**3**), ammonium acetate (**4**), and numerous acetophenone derivatives (**2a–j**).

The quinoline derivatives (**5a–j** and **6a–j**) were synthesized by one-pot, four-component condensation of dimedon (**1**), thiophene-2-carbaldehyde (**3**), ammonium acetate (**4**), and numerous acetophenone derivatives **2a–j** (Scheme 1, Table 1). Also, compound **5** converted to compound **6** with effect of air oxygen action.

Table 1. Four-component, one-pot synthesis of 2-aryl-4-thionylquinoline derivatives

			Products			
Entry	ArX	Time (h)	**5**	Yield (%)[a]	**6**	Yield (%)[a]
1	4-OHPh	3	**5a**	51	**6a**	9
2	3-BrPh	3	**5b**	62	**6b**	17
3	3-NH_2Ph	3	**5c**	72	**6c**	22
4	3-CH_3OPh	3	**5d**	71	**6d**	15
5	3-ClPh	3	**5e**	64	**6e**	13
6	3-NO_2Ph	3	**5f**	60	**6f**	37
7	3-pyridyl	3	**5g**	57	**6g**	38
8	3-furyl	3	**5h**	73	**6h**	12
9	4-CH_3Ph	3	**5i**	65	**6i**	18
10	4-ClPh	3	**5j**	67	**6j**	18

[a]Yield of isolated products.

Table 2. Effective of solvent on the reaction

Entry	Solvent	Time (h)	Isolated yield (%)
1	H_2O	9	–
2	CH_3COOH	7	–
3	DMSO	4	85
4	CH_3CH_2OH	2.5	15
5	$CHCl_3$	5	23
6	CH_3CN	4	75
7	DMF	3	93

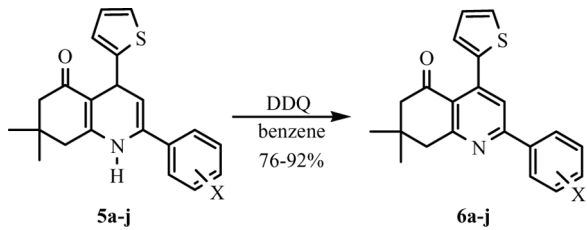
Structures of the synthesized compounds **5a–j** were assigned by elemental analyses and ^{1}H NMR and IR spectral data. ^{1}H NMR spectra of all the derivatives **5** show the signals as AB system of the protons H3 and H4 at $\delta = 5.92$–4.87 ppm, the AB system signals of $-CH_2$ protons in moiety of dimedon at $\delta = 2.48$–2.04 ppm, and the signal of amine NH proton at $\delta = 8.14$–6.30 ppm.

The formation mechanism of compounds (**5a–j**) can be explained by a Hantzsch-type reaction.

We examined the effect of solvent for the reaction of 4-chloroacetophenone, thiophene-2-carbaldehyde, dimedon, and ammonium acetate (Table 2). Among the solvents tested, dimethylformamide (DMF) gave the best result. Although the yield was moderate in the cases of dimethylsulphoxide (DMSO) and CH_3CN, the yield was very low in the cases of CH_3CH_2OH and $CHCl_3$ and the reaction did not occur in H_2O and CH_3COOH.

In addition, the oxidation of **5a–j** with DDQ (dichloro dicyano quinone) in benzene at room temperature for 2 h gave the aromatic **6a–j** (Scheme 2).

This reaction formed only desired heterocyclic compounds (**5, 6**) in one step, and no other by-products were isolated. Accordingly, we suggest that the present reaction is a convenient synthetic method of preparing the 2-aryl-4-thionylquinoline derivatives.



5a-j **6a-j**

Scheme 2.

EXPERIMENTAL

^{1}H and ^{13}C NMR spectra were recorded with Bruker AC 400 instruments. As internal standards, we used TMS (δ 0.00) for ^{1}H NMR and $CDCl_3$ (δ 77.0) for ^{13}C NMR spectroscopy. *J* values are given in hertz. The multiplicities of the signals in the ^{1}H NMR spectra are abbreviated to s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), br (broad), and combinations thereof. IR spectra were recorded on a Jasco FT/IR-430 spectrometer. Elemental analyses were performed using a LECO CHNS 932 Elemental Analyzer. Melting points were measured on an Electrothermal 9100 apparatus.

All column chromatographies were performed on silica gel (60–230 mesh, Merck).

General Procedure for Synthesis of 2-Aryl-4-thionylquinolines (5a–j)

A mixture of dimedon (0.3 g, 2.2 mmol), thiophene-2-carbaldehyde (0.25 g, 2.2 mmol), acetophenone derivative (0.34 g, 2.2 mmol), and ammonium acetate (0.19 g, 2.2 mmol) in DMF (5 ml) was heated in the sealed tube at 100 °C (oil bath temperature) for 3 h. Water was added to the mixture and extracted with CH_2Cl_2 (3×20 mL), dried over anhydrous Na_2SO_4, and evaporated. Crude products were purified by column chromatography on silica gel or preparative thin-layer chromatography (TLC, 20- × 20-cm plates, 2 mm thick) using *n*-hexane/EtOAc (9:1) as eluent. While the first fraction was 6, the second fraction was 5. The solid products were crystallized in *n*-hexane/EtOAc (9:1).

Data

2-(4-Hydroxyphenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5(1H,4H-,6H)-one (5a): Yellowish liquid; 51%; ^{1}H NMR (400 MHz, DMSO-d_6) δ = 8.14 (s, 1H, NH), 7.23 (brd, *J* = 8.8 Hz, 2H, ArH, AA′ part of AA′XX′ system), 6.97 (t, *J* = 3.6 Hz, 1H, thionyl), 6.77 (m, 2H, thionyl), 6.74 (brd, *J* = 8.8 Hz, 2H, ArH, XX′ part of AA′XX′ ′ system), 5.06 (dd, $J_{3,4}$ = 5.6, $J_{3,\text{thionyl3}}$ = 1.6 Hz, 1H, olefinic), 4.88 (d, *J* = 5.6 Hz, 1H, allylic), 3.32 (s, 1 H, OH), 2.34 (d, *J* = 16.4 Hz, A part of AB system, 1H, $-CH_2$), 2.31 (d, *J* = 16.4 Hz, B part of AB system, 1H, $-CH_2$), 2.15 (d, *J* = 16.4 Hz, A part of AB system, 1H, $-CH_2$), 2.06 (d, *J* = 16.4 Hz, B part of AB system, 1H, $-CH_2$), 1.00 (s, 3H), 0.92 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 195.23, 157.93, 153.72, 152.67, 135.38, 127.37 (2C), 126.71, 126.52, 123.13, 122.51, 115.47 (2C), 106.94, 103.19, 50.83, 40.91, 32.21, 32.03, 29.66, 27.09; IR (KBr

disc) cm^{-1}: 3899, 2960, 1652, 1610, 1494, 1275, 1243, 1050, 1025, 1003, 763, 632. Anal. calcd. for $C_{21}H_{21}NO_2S$: C, 71.76; H, 6.02; N, 3.99; S, 9.12. Found: C, 72.37; H, 5.82; N, 3.65; S, 9.18.

2-(3-Bromophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(1H,4H,-6H)-one (5b): Yellowish liquid; 62%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.61$ (t, $J = 1.6$ Hz, 1H, ArH), 7.46 (bd, $J = 8.0$ Hz, 1H, ArH), 7.38 (bt, $J = 8.0$, 1.2 Hz, 1H, ArH), 7.25 (t, $J = 7.8$ Hz, 1H, ArH), 7.09 (dd, $J = 4.5$, 1.8 Hz, 1H, thionyl), 6.99 (bs, 1H, −NH), 6.88 (m, 2H, thionyl), 5.34 (dd, $J_{3,4} = 5.6$, $J_{3,\text{thionyl3}} = 1.8$ Hz, 1H, olefinic), 5.01 (d, $J = 5.6$ Hz, 1H, allylic), 2.35 (d, $J = 16.8$ Hz, A part of AB system, 1H, $-CH_2$), 2.26 (d, $J = 16.8$ Hz, B part of AB system, 1H, $-CH_2$), 2.19 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.13 (d, $J = 16.4$ Hz, B part of AB system, 1H, $-CH_2$), 1.07 (s, 3H), 1.01 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 195.75$, 152.31, 151.59, 137.71, 133.80, 131.59, 130.29, 128.68, 126.70, 124.37, 123.59, 123.07, 122.84, 107.83, 106.86, 50.64, 41.49, 32.36, 32.14, 29.58, 27.16 ; IR (KBr disc) cm^{-1}: 3244, 3069, 2957, 2869, 1684, 1593, 1474, 1387, 1240, 785, 761, 612. Anal. calcd. for $C_{21}H_{20}BrNOS$: C, 60.87; H, 4.87; N, 3.38; S, 7.74. Found:C, 60.47; H, 4.50; N, 3.19; S, 7.85.

2-(3-Aminophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(1H,4H,-6H)-one (5c): Yellowish liquid; 72%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.13$ (t, $J = 8.0$ Hz, 1H, ArH), 7.08 (dd, $J = 4.8$, 1.4 Hz, 1H, thionyl), 6.88 (m, 2H, thionyl), 6.81 (brd, $J = 7.6$ Hz, 1H, ArH), 6.74 (t, $J = 2$ Hz, 1H, ArH), 6.64 (ddd, $J = 8.0$, 2.0, 0.8 Hz, 1H, ArH), 6.60 (s, 1H, −NH), 5.31 (dd, $J_{3,4} = 5.6$, $J_{3,\text{thionyl3}} = 1.4$ Hz, 1H, olefinic), 5.04 (d, $J = 5.6$ Hz, 1H, allylic), 3.63 (brs, 2H, $-NH_2$) 2.36 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.26 (d, $J = 16.4$ Hz, Hz, B part of AB system, 1H, $-CH_2$), 2.22 (d, $J = 16.2$ Hz, A part of AB system, 1H, $-CH_2$), 2.16 (d, $J = 16.2$ Hz, B part of AB system, 1H, $-CH_2$), 1.06 (s, 3H), 1.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 195.68$, 152.73, 151.32, 146.90, 136.73, 135.12, 129.74, 126.64, 123.48, 123.04, 115.47, 115.44, 112.15, 107.89, 105.33, 50.68, 41.64, 32.38, 32.09, 29.54, 27.17; IR (KBr disc) cm^{-1}: 3342, 3066, 3006, 2956, 2869, 1587, 1486, 1388, 1332, 1253, 754, 696. Anal. calcd. for $C_{21}H_{22}N_2OS$: C, 71.97; H, 6.33; N, 7.99; S, 9.15. Found: C, 72.02; H, 5.99; N, 8.04; S, 9.35.

2-(3-Methoxyphenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(1H,4H-,6H)-one (5d): Yellowish liquid; 71%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.29$ (t, $J = 8.0$ Hz, 1H, ArH), 7.18 (dd, $J = 3.6$, 1.6 Hz, 1H, thionyl), 7.09 (m, 1H, ArH), 7.03 (d, $J = 8.0$ Hz, 1H, ArH), 6.99

(t, $J = 2.4$ Hz, 1H, ArH), 6.89 (m, 2H, ArH and thionyl), 6.49 (brs, 1H, −NH), 5.37 (dd, $J_{3,4} = 5.2$, $J_{3,\text{thionyl3}} = 1.6$ Hz, 1H, olefinic), 5.04 (d, $J = 5.2$ Hz, 1H, allylic), 3.81 (s, 3H, -OCH_3), 2.38 (d, $J = 16.4$ Hz, A part of AB system, 1H, −CH_2), 2.27 (d, $J = 16.4$ Hz, B part of AB system, 1H, −CH_2), 2.25 (d, $J = 16.2$ Hz, A part of AB system, 1H, −CH_2), 2.20 (d, $J = 16.2$ Hz, B part of AB system, 1H, −CH_2), 1.07 (s, 3H), 1.01 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 195.62$, 159.90, 152.47, 137.08, 134.79, 129.92, 126.63, 123.52, 123.11, 117.79, 114.10, 111.33, 105.85, 55.45, 50.65, 41.71, 32.41, 32.07, 29.53, 28.30, 27.16; IR (KBr disc) cm^{-1}: 3253, 3068, 2958, 2888, 2870, 2835, 1684, 1577, 1488, 1252, 1044, 784, 697. Anal. calcd. for $C_{22}H_{23}NO_2S$: C, 72.30; H, 6.34; N, 3.83; S, 8.77. Found: C, 72.23; H, 6.52; N, 3.55; S, 8.92.

2-(3-Chlorophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(1H,4H,-6H)-one (5e): Yellowish liquid; 64%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.44$ (m, 1H, ArH), 7.31 (m, 3H, ArH), 7.10 (m, 1H, thionyl), 6.88 (m, 2H, thionyl), 6.74 (s, 1H, −NH), 5.35 (dd, $J =$ 5.2, 1.8 Hz, 1H, olefinic), 5.02 (d, $J = 5.2$ Hz, 1H, allylic), 2.39 (d, $J = 16.8$ Hz, A part of AB system, 1H, −CH_2), 2.29 (d, $J = 16.8$ Hz, B part of AB system, 1H, −CH_2), 2.20 (d, $J = 16.4$ Hz, A part of AB system, 1H, −CH_2), 2.14 (d, $J = 16.4$ Hz, B part of AB system, 1H, −CH_2), 1.07 (s, 3H), 1.01 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 195.72$, 152.23, 134.72, 133.84, 130.07, 128.70, 127.60, 126.69, 125.74, 125.46, 123.81, 123.59, 123.10, 107.96, 106.79, 50.63, 41.58, 32.38, 32.11, 29.53, 27.16; IR (KBr disc) cm^{-1}: 3245, 3070, 2958, 2869, 1594, 1494, 1388, 1241, 1058, 786, 761, 694. Anal. calcd. for $C_{21}H_{20}ClNOS$: C, 68.19; H, 5.45; N, 3.79; S, 8.67. Found: C, 67.89; H, 4.93; N, 4.15; S, 8.48.

2-(3-Nitrophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(1H,4H,-6H)-one (5f): Yellowish liquid; 60%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 8.32$ (t, $J = 1.8$ Hz, 1H, ArH), 8.15 (brt, $J = 8.4$ Hz, 1H, ArH), 7.80 (d, $J = 8.0$ Hz, 1H, ArH), 7.75 (s, 1H, −NH), 7.49 (t, $J = 8.4$ Hz, 1H, ArH), 7.08 (dd, $J = 4.8$, 1.3 Hz, 1H, thionyl), 6.86 (m, 2H, thionyl), 5.41 (dd, $J_{3,4} = 5.5$, $J_{3,\text{thionyl3}} = 1.3$ Hz, 1H, olefinic), 4.98 (d, $J = 5.5$ Hz, 1H, allylic), 2.40 (d, $J = 16.8$ Hz, A part of AB system, 1H, −CH_2), 2.32 (d, $J = 16.8$ Hz, B part of AB system, 1H, −CH_2), 2.19 (d, $J = 16.4$ Hz, A part of AB system, 1H, −CH_2), 2.13 (d, $J = 16.4$ Hz, B part of AB system, 1H, −CH_2), 1.06 (s, 3H), 1.01 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 195.89$, 152.11, 148.31, 137.24, 133.31, 131.94, 129.95, 129.72, 126.77, 123.68, 123.20, 123.06, 120.53, 107.97, 107.59, 50.69, 41.18, 32.30, 32.25, 29.62, 27.12; IR (KBr disc) cm^{-1}: 3289, 3085, 2958, 2888, 2869, 1592, 1531,

1496, 1348, 1243, 754, 694. Anal. calcd. for $C_{21}H_{20}N_2O_3S$: C, 66.29; H, 5.30; N, 7.36; S, 8.43. Found: C, 61.94; H, 4.97; N, 7.40; S, 7.28.

7,7-Dimethyl-2-(pyridin-3-yl)-4-(thiophen-2-yl)-7,8-dihydroquinolin-5(1H,-4H,6H)-one (5g): Yellowish crystal; mp 157–159 °C; 57%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 8.51$ (d, $J = 4.8$ Hz, 1H, ArH), 8.01 (s, 1H, −NH), 7.68 (m, 2H, ArH), 7.23 (m, 1H, thionyl), 7.09 (d, $J = 4.8$ Hz, 1H, ArH), 6.93 (d, $J = 3.2$ Hz, 1H, thionyl), 6.88 (t, $J = 4.8$ Hz, 1H, thionyl), 5.91 (d, $J = 5.4$ Hz, 1H, olefinic), 5.16 (d, $J = 5.4$ Hz, 1H, allylic), 2.46 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.40 (d, $J = 16.4$ Hz, B part of AB system, 1H, $-CH_2$), 2.30 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.25 (d, $J = 16.4$ Hz, B part of AB system, 1H, -CH_2), 1.11 (s, 3H), 1.07 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 195.37$, 151.97, 150.71, 149.95, 149.01, 136.75, 132.19, 126.67, 123.67, 123.28, 123.07, 118.73, 107.50, 106.24, 50.77, 41.79, 32.56, 32.26, 29.42, 27.40; IR (KBr disc) cm^{-1}: 3365, 3066, 2958, 2888, 2869, 1631, 1565, 1469, 1436, 1386, 1282, 1122, 910, 782, 732, 696. Anal. calcd. for $C_{20}H_{20}N_2OS$: C, 71.40; H, 5.99; N, 8.33; S, 9.53. Found: C, 71.67; H, 5.89; N, 8.43; S, 9.68.

2-(Furan-3-yl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5(1H,-4H,6H)-one (5h): Yellowish liquid; 73%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.41$ (m, 1H, furyl), 7.10 (d, $J = 4.8$ Hz, 1H, thionyl), 6.89 (m, 2H), 6.50 (d, $J = 3.2$ Hz, 1H, thionyl), 6.45 (m, 1H, furyl), 6.34 (s, 1H, −NH), 5.56 (d, $J = 5.2$ Hz, 1H, olefinic), 5.07 (d, $J = 5.2$ Hz, 1H, allylic), 2.41 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.30 (d, $J = 16.4$ Hz, B part of AB system, 1H, $-CH_2$), 2.26 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.20 (d, $J = 16.4$ Hz, B part of AB system, 1H, $-CH_2$), 1.11 (s, 3H), 1.06 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 196.01$, 151.96, 141.85, 126.63, 126.27, 123.61, 123.26, 118.77, 110.47, 108.27, 105.39, 103.38, 101.56, 50.68, 41.88, 32.53, 31.43, 29.40, 27.32; IR (KBr disc) cm^{-1}: 3297, 2958, 2927, 2869, 1592, 1498, 1382, 1247, 1153, 754, 696. Anal. calcd. for $C_{19}H_{19}NO_2S$: C, 70.12; H, 5.88; N, 4.30; S, 9.85. Found: C, 70.33; H, 6.15; N, 4.33; S, 9.91.

2-(4-Methylphenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5(1H,-4H,-6H)-one (5i): Yellowish liquid; 65%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 8.11$ (s, 1H, −NH), 7.24 (d, $J = 7.8$ Hz, AA′ part of AA′BB′ system, 2H, ArH), 7.03 (d, $J = 7.8$ Hz, BB′ part of AA′BB′ system, 2H, ArH), 6.92 (m, 1H, thionyl), 6.72 (m, 2H, thionyl), 5.09 (d, $J = 5.4$ Hz, 1H, olefinic), 4.84 (d, $J = 5.4$ Hz, 1H, allylic), 2.30 (d, $J = 16.2$ Hz, A part of AB system, 1H, $-CH_2$), 2.23 (d, $J = 16.2$ Hz, B part of AB system, 1H, $-CH_2$), 2.21 (s, 3H, $-CH_3$), 2.10 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.01 (d, $J = 16.4$ Hz, B part of AB system, 1H, $-CH_2$), 1.17

(s, 3H), 0.96 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 194.09$, 152.53, 151.48, 137.37, 134.50, 131.94, 128.17 (2C), 125.57, 125.07 (2C), 122.25, 121.67, 106.07, 103.79, 49.94, 40.03, 31.30, 31.15, 28.73, 26.20, 20.25; IR (KBr disc) cm^{-1}: 3415, 2956, 1683, 1610, 1535, 1245, 1025, 1002, 825, 700. Anal. calcd. for $C_{22}H_{23}NOS$: C, 75.61; H, 6.63; N, 4.01; S, 9.17. Found: C, 75.14; H, 6.57; N, 4.43; S, 9.23.

2-(4-Chlorophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(1H,4H,-6H)-one (5j): Yellowish crystal; mp 206–208 °C; 67%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.37$ (brd, $J = 5.2$ Hz, AA′ part of AA′BB′ system, 2H, ArH), 7.34 (brd, $J = 5.2$ Hz, BB′ part of AA′BB′ system, 2H, ArH), 7.10 (brd, $J = 4.8$ Hz, 1H, thionyl), 6.99 (m, 2H, thionyl), 6.30 (s, 1H, −NH), 5.35 (dd, $J = 5.2$, 1.6 Hz, 1H, olefinic), 5.05 (d, $J = 5.2$ Hz, 1H, allylic), 2.41 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.29 (d, $J = 16.4$ Hz, B part of AB system, 1H, $-CH_2$), 2.25 (d, $J = 16.4$ Hz, A part of AB system, 1H, $-CH_2$), 2.20 (d, $J = 16.4$ Hz, B part of AB system, 1H, $-CH_2$), 1.10 (s, 3H), 1.03 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 195.51$, 152.23, 150.66, 134.59, 134.11, 133.90, 129.03 (2C), 126.81 (2C), 126.70, 123.60, 123.16, 108.25, 106.28, 50.67, 41.81, 32.46, 32.08, 29.54, 27.18; IR (KBr disc) cm^{-1}: 3426, 2958, 2869, 1658, 1612, 1490, 1388, 1051, 1025, 1006, 825, 761, 696. Anal. calcd. for $C_{21}H_{20}ClNOS$: C, 68.19; H, 5.45; N, 3.79; S, 8.67. Found: C, 68.66; H, 5.47; N, 4.11; S, 8.32.

General Procedure for Synthesis of 2-Aryl-4-thionylquinolines (6a–j)

DDQ (0.35 g, 1.58 mmol) was added to a stirred solution of 2-aryl-4-thionylquinolines (0.28 g, 0.79 mmol) in 10 mL of benzene and stirred at room temperature for 2 h. The solvent (benzene) was removed under reduced pressure. CH_2Cl_2 (50 mL) was added to the residue and filtered to remove precipitated material. The extract was washed with water (50 mL) and dried over $MgSO_4$. After the solvent was evaporated, the residue was chromatographed on a silica-gel column, eluting with EtOAc/hexane (1:9).

Data

2-(4-Hydroxyphenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(6H)-one (6a): Yellowish liquid; 75%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.94$ (brd, $J = 8.8$ Hz, AA′ part of AA′BB′ system, 2H, ArH), 7.56 (s, 1H, H3), 7.45 (d, $J = 4.8$ Hz, 1H, thionyl), 7.27 (s, 1H, -OH), 7.19 (d, $J = 3.6$ Hz, 1H, thionyl), 7.11 (dd, $J = 4.8$, 3.6 Hz, 1H, thionyl), 6.88 (brd, $J = 8.8$ Hz, BB′ part of AA′BB′ system, 2H, ArH), 3.44

(s, 1H, -OH), 3.17 (s, 2H), 2.59 (s, 2H), 1.16 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 197.96, 163.62, 159.23, 158.28, 144.62, 140.62, 129.24 (2C), 127.63, 127.08, 126.90, 123.55, 121.86, 115.97 (2C), 53.82, 47.57, 32.64, 29.70, 28.28 (2C); IR (KBr disc) cm^{-1}: 3072,3018, 2956, 2869, 1666, 1577, 1531, 1519, 1278, 1207, 1170, 836, 754. Anal. calcd. for $C_{21}H_{19}NO_2S$: C, 72.18; H, 5.48; N, 4.01; S, 9.18. Found: C, 72.58; H, 5.22; N, 3.95; S, 9.02.

2-(3-Bromophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(6H)-one (6b): Yellowish liquid; 88%; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.27 (s, 1H, ArH), 7.97 (d, J = 8.0 Hz, 1H, ArH), 7.61 (s, 1H, H3), 7.57 (d, J = 8.0 Hz, 1H, ArH), 7.45 (d, J = 5.2 Hz, 1H, thionyl), 7.34 (t, J = 7.8 Hz, 1H, ArH), 7.20 (bd, J = 3.6 Hz, 1H, thionyl), 7.11 (t, J = 4.2 Hz, 1H, thionyl), 3.18 (s, 2H), 2.60 (s, 2H), 1.72 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 197.54, 163.73, 157.54, 144.65, 140.28, 139.93, 132.95, 130.50, 130.38, 128.21, 127.98, 127.14, 125.90, 124.56, 123.20, 122.31, 53.88, 47.82, 32.65, 28.34, 28.24; IR (KBr disc) cm^{-1}: 3070, 3016, 2956, 2869, 1689, 1562, 1535, 1238, 1095, 1072, 856, 698. Anal. calcd. for $C_{21}H_{18}BrNOS$: C, 61.17; H, 4.40; N, 3.40; S, 7.78. Found: C, 60.87; H, 4.77; N, 3.39; S, 7.55.

2-(3-Aminophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5(6H)-one (6c): Yellowish liquid; 77%; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.60 (s, 1H, H3), 7.44 (m, 1H, ArH), 7.41–7.17 (m, 3H, 2ArH and thionyl), 7.18 (d, J = 4.0 Hz, 1H, thionyl), 6.88 (t, J = 1.2 Hz, 1H, ArH), 6.79 (dd, J = 4.4, 1.2 Hz, 1H, thionyl), 3.18 (s, 2H), 2.59 (s, 2H), 1.16 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 190.03, 163.48, 161.88, 146.97, 144.30, 139.01, 129.80, 128.69, 127.62, 127.04, 126.84, 125.77, 117.72, 116.90, 114.01, 113.90, 53.89, 47.87, 32.63, 28.30, 26.70; IR (KBr disc) cm^{-1}: 3419, 2923, 2852, 1758, 1697, 1677, 1560, 1465, 1172, 796, 719. Anal. calcd. for $C_{21}H_{20}N_2OS$: C, 71.38; H, 5.79; N, 8.04; S, 9.20. Found: C, 71.02; H, 5.30; N, 8.45; S, 9.30.

2-(3-Methoxyphenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(6H)-one (6d): Yellowish liquid; 85%; ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.64 (m, 3H, 2ArH and H3), 7.46 (d, J = 4.8 Hz, 1H, thionyl), 7.41 (t, J = 8.0 Hz, 1H, ArH), 7.20 (d, J = 2.4 Hz, 1H, thionyl), 7.12 (t, J = 4.8 Hz, 1H, thionyl), 7.03 (dd, J = 8.0, 2.0 Hz, 1H, ArH), 3.92 (s, 3H, -OCH_3), 3.21 (s, 2H), 2.60 (s, 2H), 1.18 (s, 3H), 1.15 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ = 197.72, 163.57, 160.11, 144.49, 140.54, 139.34, 129.91, 127.70, 127.09, 126.96, 124.27, 122.57, 119.87, 116.11, 112.67, 110.92, 55.45, 53.91, 47.80, 32.66, 28.31; IR (KBr disc) cm^{-1}: 2956, 2869, 2834, 1687, 1573, 1536, 1492, 1278, 1253, 1045,

784, 700. Anal. calcd. for $C_{22}H_{21}NO_2S$: C, 72.70; H, 5.82; N, 3.85; S, 8.82. Found: C, 72.41; H, 6.22; N, 4.25; S, 8.92.

2-(3-Chlorophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(6H)-one (6e): Yellowish liquid; 87%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 8.11$ (s, 1H, ArH), 7.93 (m, 1H, ArH), 7.63 (s, 1H, H3), 7.47 (d, $J = 5.2$ Hz, 1H, thionyl), 7.41 (m, 2H, ArH), 7.22 (d, $J = 2.8$ Hz, 1H, thionyl), 7.12 (dd, $J = 4.8$, 3.6 Hz, 1H, thionyl), 3.19 (s, 2H), 2.61 (s, 2H), 1.17 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 197.60$, 163.73, 157.73, 144.73, 140.26, 139.68, 135.05, 130.11, 130.06, 127.83, 127.61, 127.13 (2C), 125.45, 124.58, 122.40, 53.88, 47.79, 32.65, 28.30 (2C); IR (KBr disc) cm^{-1}: 2956, 2869, 1689, 1567, 1536, 1369, 1278, 790, 742, 696. Anal. calcd. for $C_{21}H_{18}ClNOS$: C, 68.56; H, 4.93; N, 3.81; S, 8.72. Found: C, 68.29; H, 5.32; N, 4.15; S, 8.84.

2-(3-Nitrophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5(6H)-one (6f): Yellowish liquid; %85; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 8.96$ (t, $J = 1.5$ Hz, 1H, ArH), 8.42 (d, $J = 7.8$ Hz, 1H, ArH), 8.32 (dd, $J = 8.1$, 1.5 Hz, 1H, ArH), 7.72 (s, 1H, H3), 7.68 (t, $J = 8.1$ Hz, 1H, ArH), 7.48 (d, $J = 5.02$ Hz, 1H, thionyl), 7.21 (d, $J = 5.0$ Hz, 1H, thionyl), 7.13 (dd, $J = 5.0$, 3.2 Hz, 1H, thionyl), 3.2 (s, 2H), 2.62 (s, 2H), 1.16 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 197.47$, 163.97, 156.36, 148.82, 145.04, 139.95, 139.62, 133.04, 129.87, 128.04, 127.40, 127.33, 125.03, 123.15, 122.37, 122.32, 53.87, 47.78, 32.66, 28.30 (2C); IR (KBr disc) cm^{-1}: 3085, 2956, 2869, 1691, 1587, 1573, 1531, 1349, 1110, 1043, 723, 703. Anal. calcd. for $C_{21}H_{18}N_2O_3S$: C, 66.65; H, 4.79; N, 7.40; S, 8.47. Found: C, 66.44; H, 4.79; N, 7.71; S, 8.81.

7,7-Dimethyl-2-(pyridin-3-yl)-4-(thiophen-2-yl)-7,8-dihydroquinolin-5(6H)-one (6g): Yellowish crystal; mp 156–158 °C; 90%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 8.71$ (d, $J = 4.8$ Hz, 1H, ArH), 8.49 (d, $J = 8.0$ Hz, 1H, ArH), 8.36 (s, 1H, H3), 7.86 (dt, $J = 6.4$, 1.6 Hz, 1H, ArH), 7.44 (d, $J = 5.2$ Hz, 1H, thionyl), 7.36 (bt, $J = 6.4$ Hz, 1H, ArH), 7.24 (bd, $J = 3.6$ Hz, 1H, thionyl), 7.11 (bt, $J = 3.6$ Hz, 1H, thionyl), 3.19 (s, 2H), 2.62 (s, 2H), 1.18 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 212.07$, 163.21, 157.73, 154.84, 149.40, 144.71, 140.54, 137.02, 127.85, 127.02, 126.98, 125.39, 124.54, 122.90, 122.11, 53.94, 47.85, 32.67, 28.32 (2C); IR (KBr disc) cm^{-1}: 3062, 2925, 2854, 1687, 1540, 1272, 1245, 1095, 790, 732. Anal. calcd. for $C_{20}H_{18}N_2OS$: C, 71.83; H, 5.42; N, 8.38; S, 9.59. Found: C, 71.90; H, 5.74; N, 8.47; S, 10.01.

2-(Furan-3-yl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5(6H)-one (6h): Yellowish liquid; 92%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.60$

(brs, 2H, H3 and furyl), 7.45 (d, $J = 5.2$ Hz, 1H, thionyl), 7.24 (m, 1H, furyl), 7.19 (d, $J = 3.6$ Hz, 1H, thionyl), 7.10 (t, $J = 4.8$ Hz, 1H, thionyl), 6.58 (dd, $J = 4.8$, 1.4 Hz, 1H, furyl), 3.15 (s, 2H), 2.51 (s, 2H), 1.15 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 197.30$, 163.85, 144.84, 144.59, 140.37, 127.76, 127.04 (2C), 123.87, 120.37 (2C), 112.54 (2C), 110.91, 52.49, 47.66, 32.56, 29.70, 28.25; IR (KBr disc) cm^{-1}: 3114, 2956, 2925, 2867, 1687, 1600, 1536, 1278, 1099, 1008, 746, 700. Anal. calcd. for $C_{19}H_{17}NO_2S$: C, 70.56; H, 5.30; N, 4.33; S, 9.91. Found: C, 70.55; H, 5.69; N, 4.33; S, 9.54.

2-(4-Methylphenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(6H)-one (6i): Yellowish liquid; 76%; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 7.98$ (d, $J = 8.0$ Hz, 2H, ArH, AA′ part of AA′XX′ system), 7.63 (s, 1H, H3), 7.44 (d, $J = 5.2$ Hz, 1H, thionyl), 7.30 (d, $J = 8.0$ Hz, 2H, ArH, XX′ part of AA′XX′ system), 7.19 (d, $J = 3.2$ Hz, 1H, thionyl), 7.11 (t, $J = 5.2$ Hz, 1H, thionyl), 3.18 (s, 2H), 2.59 (s, 2H), 2.44 (s, 3H, $-CH_3$), 1.17 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 197.14$, 163.61, 159.41, 144.36, 140.72, 140.43, 135.15, 129.64 (2C), 127.89, 127.57, 127.36 (2C), 127.05, 126.81, 122.07, 53.89, 47.87, 32.64, 28.32, 28.23, 21.42; IR (KBr disc) cm^{-1}: 3070, 3014, 2956, 2927, 2869, 1687, 1573, 1536, 1371, 1276, 1184, 823, 755. Anal. calcd. for $C_{22}H_{21}NOS$: C, 76.04; H, 6.09; N, 4.03; S, 9.23. Found: C, 75.84; H, 6.47; N, 4.27; S, 9.49.

2-(4-Chlorophenyl)-7,7-dimethyl-4-(thiophen-2-yl)-7,8-dihydroquinolin-5-(6H)-one (6j): Yellowish crystal; mp 119–120 °C; %83; ^{1}H NMR (400 MHz, $CDCl_3$) $\delta = 8.03$ (d, $J = 8.8$ Hz, AA′ part of AA′BB′ system, 2H, ArH), 7.67 (s, 1H, H3), 7.46 (d, $J = 8.8$ Hz, BB′ part of AA′BB′ system, 2H, ArH), 7.46 (m, 1H, thionyl), 7.20 (d, $J = 3.2$ Hz, 1H, thionyl), 7.11 (dd, $J = 4.4$, 3.2 Hz, 1H, thionyl), 3.18 (s, 2H), 2.60 (s, 2H), 1.17 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) $\delta = 197.56$, 163.71, 157.99, 144.62, 140.36, 136.37, 136.33, 129.09 (2C), 128.72 (2C), 127.77, 127.12, 127.03, 124.33, 122.08, 53.88, 47.84, 32.63, 28.32 (2C); IR (KBr disc) cm^{-1}: 3072, 3016, 2956, 2927, 2869, 1687, 1579, 1536, 1492, 1276, 1093, 1012, 853, 755. Anal. calcd. for $C_{21}H_{18}ClNOS$: C, 68.56; H, 4.93; N, 3.81; S, 8.72. Found: C, 68.69; H, 5.23; N, 4.27; S, 8.54.

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