Michael Addition of Dimedone with α,β-unsaturated Ketones: Synthesis of Quinoline and Chromene Derivatives

Dhananjay B. Kendre, Raghunath B. Toche and Madhukar N. Jachak*

Organic Chemistry Research Center, Department of Chemistry, K. R. T. Arts, B. H. Commerce and A. M. Science College,
Gangapur road, Nashik-422002, (M. S.), India
dken10@gmail.com

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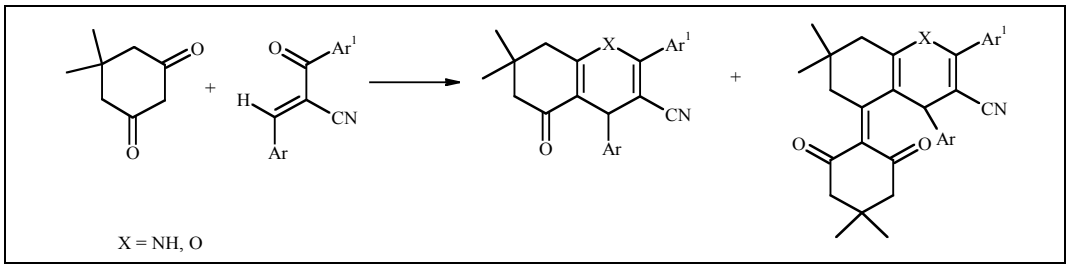

A series of quinoline and chromene derivatives has been synthesized by Michael addition of dimedone **1** with 2-aroyl-3-arylacrylonitrile **2** and study of absorption and fluorescence maxima of quinolines.

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INTRODUCTION

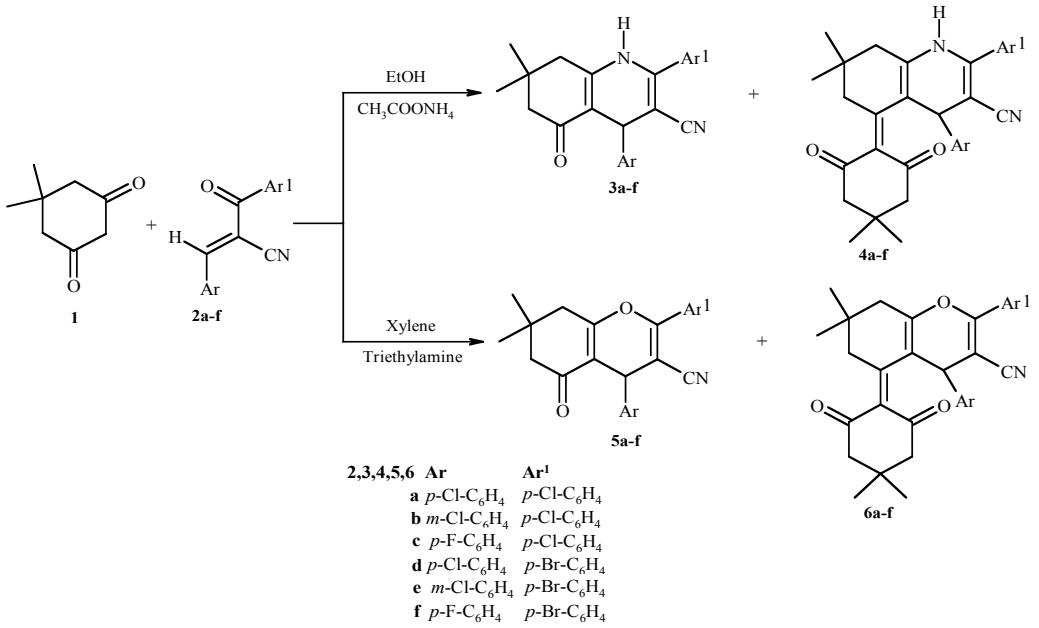
The *Michael* addition is an extremely useful and versatile method for the direct construction of pyridine and pyran ring in organic synthesis. In recent years an increasing interest has been focused on the synthesis of fluorescent compounds owing to their significant biological applications in the medicinal chemistry [1,2]. In particular these compounds have important application in the field of dyes [3] and are used in the security papers[4]. Nowadays the fluorescent compounds are extensively used as a small molecule organic antennas in the study of luminescence resonance transfer (LRET) techniques [5]. The remarkable applications of these compounds not only attracted many chemists to synthesize such type of compounds but also became an active research area of continuing interest [6]. Several naturally occurring and synthetic compounds containing the quinoline [7] derivatives possess interesting pharmaceutical properties for example non-nucleoside reverse transcriptase inhibitor of human immunodeficiency virus-1 (HIV-1) [8,9]. Quinolines are also reported to posses antitumor, antibacterial [10] and cardiovascular activities [11,12].

On the other hand chromenes are an important class of compounds which have received considerable attention in recent years due to their wide range of biological activities [13]. Compounds with these ring systems have diverse pharmacological activities such as anticoagulant, anti-cancer, spasmolytic, diuretic, anti-anacaphylactia [14]. The 4*H*-chromens also constitute the structural unit of series of natural products [15]. These literature reports encourage us to develop a new route towards the synthesis of quinoline and chromene derivatives in a single step reaction. As part of our continued interest [16,17] in the synthesis of novel heterocyclic compo- unds, recently we have reported the synthesis of pyrazolo[3,4-*b*]pyridine, pyrazolopyridopyrimidine and pyrazolo- quinoline by the *Friedländer* condensation of 5-amino- pyrazole-4-carbaldehyde with various reactive methylene compounds and the synthesis of benzo[*h*]quinolines, benzo[*h*]chromenes [18] by *Michael* addition of 6-meth-oxy-1-tetralone with 2-aroyl-3-arylacrylonitrile and ben-zylidenemalononitrile. In this communication we wish to report a very simple route for the synthesis of quinoline and chromene derivatives by *Michael* addition of dime- done **1** with 2-aroyl-3-arylacry-lonitrile **2** and the study of photophysical properties of quinoline derivatives.

RESULTS AND DISCUSSION

Thus the *Michael* addition of dimedone **1** with 2-aroyl-3-arylacrylonitrile **2** by refluxing with ammonium- acetete in absolute ethanol, containing catalytic amount of acetic acid for 6 hours afforded a mixture of compo- unds **3** and **4** in good yield. This mixture of compound **3** and **4** were separated by column chromatography using acetone/ toluene as the eluent in 1:9 ratio afforded the compounds **3** and **4** in the ratio 30:55 % yield respectively. The structures of **3a** and **4a** were confirmed by ir, ^{1}H nmr, ^{13}C nmr and elemental analysis for example the ir spectrum of **3a** showed bands at 3280, 2198 and 1622 for N-H, CN and carbonyl stretching respectively. The ^{1}H nmr spectrum of compound **3a** showed a singlet at δ 1.01 and 1.12 for 6 protons of two methyl groups, multiplet at δ 2.14 due to the 4 protons of two methylene groups, a singlet at δ 4.74 corresponding to C_4H and the broad singlet at δ 6.21 for N-H proton. The ^{13}C nmr spectrum of this compound exhibits

Scheme 1



2,3,4,5,6	Ar	Ar^1
a	*p*-Cl-C_6H_4	*p*-Cl-C_6H_4
b	*m*-Cl-C_6H_4	*p*-Cl-C_6H_4
c	*p*-F-C_6H_4	*p*-Cl-C_6H_4
d	*p*-Cl-C_6H_4	*p*-Br-C_6H_4
e	*m*-Cl-C_6H_4	*p*-Br-C_6H_4
f	*p*-F-C_6H_4	*p*-Br-C_6H_4

peaks at δ 22, 32, 40, 44, 50, 116 for *gem* dimethyl and C_4, C_6, C_7, C_8 and cyanide carbons respectively and carbonyl carbon appears at δ 190. The elemental analysis obtained is in agreement with the molecular formula. Similarly the structure of compound **4a** was confirmed by ir, ^{1}H nmr, ^{13}C nmr and elemental analysis for example the ir spectrum of compound **4a** showed bands at 3178, 2214, 1641 for N-H, CN and carbonyl group. The ^{1}H nmr spectrum of **4a** showed a singlet at δ 1.01 and 1.09 for 12 protons of four methyl groups, multiplet at δ 2.17 for the 8 protons of four methylene groups, a singlet at δ 5.07 corresponding to the C_4H and a broad singlet at δ 6.78 due to the N-H proton. Further this structure was confirmed by ^{13}C nmr which is in agreement with the structure proposed. Similarly, the structures of bromo- derivatives **3d** and **4d** were confirmed.

Analogously the *Michael* addition of dimedone **1** with 2-aroyl-3-arylacrylonitrile **2** by refluxing in xylene cont-aining catalytic amount of triethylamine also afforded a mixture of compounds **5** and **6** in good yield. This mixture of compounds **5** and **6** were separated by column chromatography using acetone/toluene as the eluent in 1:10 ratio afforded the titled compounds **5** and **6** in the ratio 25:55 % yield respectively. The structures of **5a** and **6a** were confirmed by ir, ^{1}H nmr, ^{13}C nmr and elemental analysis for example the ir spectrum of **5a** showed bands at 2215, 1622 for CN and carbonyl group. The ^{1}H nmr spectrum of compound **5a** showed a singlet at δ 1.03 and 1.17 for 6 protons of two methyl groups, multiplet at δ 2.16 due to the 4 protons of two methylene groups and a singlet at δ 4.73 corresponding to C_4H. The ^{13}C nmr spectrum of this compound exhibit a peaks at δ 25, 31, 40, 44, 52, 116 for gemdimethyl and C_4, C_6, C_7, C_8 and cyanide carbon respectively and carbonyl carbon appears at δ 198. The elemental analysis obtained is in agreement with the molecular formula. Analogously the structure of compound **6a** was confirmed by ir, ^{1}H nmr, ^{13}C nmr and elemental analysis for instance the ir spectrum of compound **6a** showed bands at 2210, 1641 for CN and carbonyl group. The ^{1}H nmr spectrum of **6a** showed a singlet at δ 1.03 and 1.06 for 12 protons of four methyl groups, multiplet at δ 2.11 for the 8 protons of four methylene groups and a singlet at δ 5.07 corresponding to the C_4H. Further this structure was confirmed by ^{13}C nmr which is given in the experimental part and the elemental analysis is in agreement with the molecular formula. Similarly, the structures of bromo derivatives **5d** and **6d** were confirmed.

After synthesis of all these compounds, it was noted that the quinoline derivatives showed good fluorescence properties. So we further studied the photo- physical properties of quinoline derivatives **3** and **4**. It was noted that compounds **3** showed UV absorption in the range 357-369 nm and fluorescence maxima in the range 405-420 nm. While the compounds **4** showed slightly better absorption and emission values. The absorption and emission data of quinolines **3** and **4** are given in the Table 1.

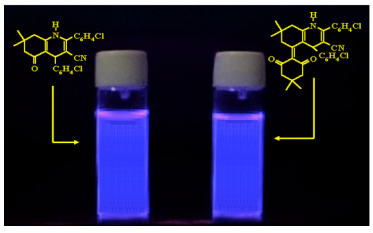


Figure 1. Tubes showing the fluorescence of **3a** and **4a** in methanol under the UV light.

The sample tubes showing the fluorescence of **3a** and **4a** in methanol under the UV light are shown in Figure 1.

Table 1

The Absorbance, Emission λ_{max} and Quantum yield of quinolines (**3a-f** and **4a-f**).

Compd.	Absorbance λ_{max} (nm)	Emission λ_{max} (nm)	Quantum Yield (Φ_F)
(**3a**)	369	405	0.112
(**3b**)	359	412	0.123
(**3c**)	362	420	0.145
(**3d**)	353	408	0.122
(**3e**)	360	417	0.126
(**3f**)	364	418	0.129
(**4a**)	369	426	0.149
(**4b**)	372	420	0.132
(**4c**)	383	419	0.131
(**4d**)	375	422	0.139
(**4e**)	384	435	0.149
(**4f**)	383	440	0.151

The reactions reported here represents new synthetic methods towards synthesis of novel quinoline and chromen derivatives with simple workup and clean products.

EXPERIMENTAL

Melting points were determined on a Gallenkamp Melting Point Apparatus, Mod. MFB-595 in open capillary tubes and are uncorrected. The ^1H and ^{13}C nmr spectra were recorded on a Varian XL-300 spectrometer (300 MHz). Chemical shifts are reported in ppm from internal tetramethylsilane standard and are given δ-units. The solvents for nmr spectra was duterio-chloroform unless otherwise stated. Infrared spectra were taken on Shimadzu IR-408, a Shimadzu FTIR instrument in potassium bromide pellets unless otherwise stated. UV Spectra were recorded on a Shimadzu UV-1601 UV–visible Spectrophotometer. Compounds for UV scan were dissolved in methanol. Fluorescence spectra were recorded using RF-5301 PC Spectrofluorophotometer. Compounds for fluorescence measurements were dissolved in methanol. UV and fluorescence scans were recorded from 200 to 500 nm. Elemental analysis was performed on a Hosli CH-Analyzer and are within ± 0.4 of the theoretical percentage. All reactions were monitored by thin layer chromatography, carried out on 0.2 mm silica gel 60 F-254 (Merk) plates using UV light (254 and 366 nm) for detection. Common reagents-grade chemicals are either commercially available and were used without further purification or prepared by standard literature procedures.

2-Aroyl-3-arylacrylonitrile (2a-f). These compounds were synthesized from *p*-chloro-, *p*-bromo- benzoylacetonitrile and aromatic aldehydes in excellent yields by heating together for 1 hr according to reference [19].

General Procedure for the Preparation of 2-(4-halophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-oxo-4-halophenyl-qinoline-3-carbonitrile (3) and 2-(4-Halophenyl)-1,4,5,-6,7,8-hexahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexyl-idene)-4-halophenylquinoline-3-carbonitrile (4). A mixture of the equimolar amount of dimedone (**1**) (10 mmol), 2-aroyl-3-arylacrylonitrile (**2**) (10 mmol) and ammonium acetate (20 mmol) in absolute ethanol (20 mL) containing catalytic amount of acetic acid (5 mL) was heated under reflux for 6 hours. The completion of reaction was monitored by thin layer chromatography (TLC). Then the solution was allowed to cool and poured in cold water (100 mL). A colorless solid precipitated out was filtered, washed with water and dried. It contained two compounds, the mixture obtained were separated by column chromatography using acetone/toluene as eluent in 1:10 ratio afforded the compounds (**3**) and (**4**) in 30:55 % yield respectively.

2,4-Bis(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-oxoquinoline-3-carbonitrile (3a). This compound was obtained as colorless prism (methanol), 0.84 g (20 %), mp 185-186 °C; ir: (potassium bromide): 3280, 3084, 2823, 2198, 1622, 1153, 842 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.01 (s, 3H, CH_3), 1.12 (s, 3H, CH_3), 2.14 (m, 4H, $2CH_2$), 4.74 (s, 1H, C_4H), 6.21 (bs, 1H, N-H), 7.01 (m, 8H, Ar); ^{13}C nmr: ($CDCl_3$) δ 22, 28, 32, 40, 44, 50, 92, 116, 118, 119, 123, 124, 126, 129, 131, 135, 138, 156, 160, 190. *Anal.* Calcd. for $C_{24}H_{20}Cl_2N_2O$: C, 68.09; H, 4.76; N, 6.62. Found: C, 68.19; H, 4.84; N, 6.70.

4-(3-Chlorophenyl)-2-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-oxoquinoline-3-carbonitrile (3b). This compound was obtained as colorless prism (methanol), 0.93 g (22 %), mp 196-197 °C; ir: (potassium bromide): 3270, 3054, 2843, 2218, 1629, 1151, 859 cm^{-1}; ^1H nmr: ($CDCl_3$) δ: 1.03 (s, 3H, CH_3), 1.14 (s, 3H, CH_3), 2.15 (m, 4H, $2CH_2$), 4.70 (s, 1H, C_4H), 6.22 (bs, 1H, N-H), 7.11 (m, 8H, Ar); *Anal.* Calcd. for $C_{24}H_{20}Cl_2N_2O$: C, 68.09; H, 4.76; N, 6.62. Found: C, 68.25; H, 4.80; N, 6.81.

2-(4-Chlorophenyl)-4-(4-fluorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-oxoquinoline-3-carbonitrile (3c). This compound was obtained as colorless prism (methanol), 0.85 g (21 %), mp 205-206 °C; ir: (potassium bromide): 3267, 3054, 2839, 2248, 1628, 1142, 822 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.00 (s, 3H, CH_3), 1.11 (s, 3H, CH_3), 2.12 (m, 4H, $2CH_2$), 4.73 (s, 1H, C_4H), 6.43 (bs, 1H, N-H), 7.00 (m, 8H, Ar); *Anal.* Calcd. for $C_{24}H_{20}ClFN_2O$: C, 70.85; H, 4.95; N, 6.88. Found: C, 70.91; H, 4.90; N, 6.96.

2-(4-Bromophenyl)-4-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-oxoquinoline-3-carbonitrile (3d). This compound was obtained as colorless prism (methanol), 1.16 g (25 %), mp 191-192 °C; ir: (potassium bromide): 3210, 3014, 2813, 2218, 1612, 1142, 854 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.02 (s, 3H, CH_3), 1.11 (s, 3H, CH_3), 2.15 (m, 4H, $2CH_2$), 4.72 (s, 1H, C_4H), 6.23 (bs, 1H, N-H), 7.09 (m, 8H, Ar); ^{13}C nmr: ($CDCl_3$) δ 22, 27, 31, 41, 44, 51, 92, 116, 117, 119, 125, 125.1, 126, 128, 131, 134, 136, 155, 161, 190. *Anal.* Calcd. for $C_{24}H_{20}BrClN_2O$: C, 61.62; H, 4.31; N, 5.99. Found: C, 61.69; H, 4.44; N, 5.90.

2-(4-Bromophenyl)-4-(3-chlorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-oxoquinoline-3-carbonitrile (3e). This compound was obtained as colorless prism (methanol), 1.12g (24 %), mp 208-209 °C; ir: (potassium bromide): 3081, 2842, 2228, 1629, 1155, 887 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.00 (s, 3H, CH_3), 1.10 (s, 3H, CH_3), 2.13 (m, 4H, $2CH_2$), 4.73 (s, 1H, C_4H), 6.19 (bs, 1H, N-H), 7.15 (m, 8H, Ar); *Anal.* Calcd. for $C_{24}H_{20}BrClN_2O$: C, 61.62; H, 4.31; N, 5.99. Found: C, 61.75; H, 4.48; N, 6.08.

2-(4-Bromophenyl)-4-(4-fluorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-oxoquinoline-3-carbonitrile (3f). This compound was obtained as colorless prism (methanol), 1.17 g (26 %), mp 219-220 °C; ir: (potassium bromide): 3220, 3034,

2843, 2225, 1645, 1133, 812 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.06 (s, 3H, CH_3), 1.09 (s, 3H, CH_3), 2.12 (m, 4H, $2CH_2$), 4.69 (s, 1H, C_4H), 6.18 (bs, 1H, N-H), 7.08 (m, 8H, Ar); *Anal*. Calcd. for $C_{24}H_{20}BrFN_2O$: C, 63.87; H, 4.47; N, 6.21. Found: C, 63.99; H, 4.65; N, 6.09.

2,4-Bis(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene)quinoline-3-carbonitrile (4a). This compound was obtained as colorless prism (ethanol), 2.18 g (40 %), mp 200-201 °C; ir: (potassium bromide): 3178, 3064, 2954, 2877, 2214, 1641, 1604, 1145 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.01 (s, 6H, $2CH_3$), 1.09 (s, 6H, $2CH_3$), 2.17 (m, 8H, $4CH_2$), 5.07 (s, 1H, C_4H), 6.78 (bs, 1H, N-H), 7.07 (m, 8H, Ar); ^{13}C nmr: ($CDCl_3$) δ 22, 24, 27, 32, 37, 40, 44, 50, 52, 92, 108, 116, 117, 118, 122, 123, 124, 126, 128, 135, 140, 142, 144, 160, 184. *Anal*. Calcd. for $C_{32}H_{30}Cl_2N_2O_2$: C, 70.46; H, 5.54; N, 5.14. Found: C, 70.60; H, 5.48; N, 5.08.

4-(3-Chlorophenyl)-2-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene) quinoline-3-carbonitrile (4b). This compound was obtained as colorless prism (ethanol), 2.28 g (42 %), mp 210-211 °C; ir: (potassium bromide): 3158, 3055, 2944, 2877, 2210, 1648, 1609, 1145, 785 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.02 (s, 6H, $2CH_3$), 1.10 (s, 6H, $2CH_3$), 2.19 (m, 8H, $4CH_2$), 5.03 (s, 1H, C_4H), 6.75 (bs, 1H, N-H), 7.09 (m, 8H, Ar); *Anal*. Calcd. for $C_{32}H_{30}Cl_2N_2O_2$: C, 70.46; H, 5.54; N, 5.14. Found: C, 70.55; H, 5.69; N, 5.28.

2-(4-Chlorophenyl)-4-(4-fluorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene) quinoline-3-carbonitrile (4c). This compound was obtained as colorless prism (ethanol), 2.16 g (41 %), mp 217-218 °C; ir: (potassium bromide): 3180, 3056, 2954, 2867, 2244, 1648, 1609, 1133, 887 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.04 (s, 6H, $2CH_3$), 1.08 (s, 6H, $2CH_3$), 2.16 (m, 8H, $4CH_2$), 5.05 (s, 1H, C_4H), 6.75 (bs, 1H, N-H), 7.17 (m, 8H, Ar); *Anal*. Calcd. for $C_{32}H_{30}ClFN_2O_2$: C, 72.65; H, 5.72; N, 5.30. Found: C, 72.79; H, 5.78; N, 5.48.

2-(4-Bromophenyl)-4-(4-chlorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene) quinoline-3-carbonitrile (4d). This compound was obtained as colorless prism (ethanol), 2.65 g (45 %), mp 214-215 °C; ir: (potassium bromide): 3161, 3035, 2967, 2842, 2215, 1639, 1601, 1143, 785 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.03 (s, 6H, $2CH_3$), 1.06 (s, 6H, $2CH_3$), 2.20 (m, 8H, $4CH_2$), 5.03 (s, 1H, C_4H), 6.72 (bs, 1H, N-H), 7.10 (m, 8H, Ar); ^{13}C nmr: ($CDCl_3$) δ 23, 24, 28, 32, 38, 41, 44, 48, 51, 92, 107, 117, 118, 120, 122, 123, 124, 126, 128, 135, 137, 141, 146, 161, 183. *Anal*. Calcd. for $C_{32}H_{30}BrClN_2O_2$: C, 65.15; H, 5.13; N, 4.75. Found: C, 65.26; H, 5.28; N, 4.88.

2-(4-Bromophenyl)-4-(3-chlorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene) quinoline-3-carbonitrile (4e). This compound was obtained as colorless prism (ethanol), 2.70 g (46 %), mp 225-226 °C; ir: (potassium bromide): 3174, 3062, 2951, 2873, 2224, 1640, 1601, 1142, 791 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.07 (s, 6H, $2CH_3$), 1.12 (s, 6H, $2CH_3$), 2.14 (m, 8H, $4CH_2$), 5.04 (s, 1H, C_4H), 6.71 (bs, 1H, N-H), 7.06 (m, 8H, Ar); *Anal*. Calcd. for $C_{32}H_{30}BrClN_2O_2$: C, 65.15; H, 5.13; N, 4.75. Found: C, 65.32; H, 5.18; N, 4.90.

2-(4-Bromophenyl)-4-(4-fluorophenyl)-1,4,5,6,7,8-hexahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene) quinoline-3-carbonitrile (4f). This compound was obtained as colorless prism (ethanol), 2.75 g (48 %), mp 232-233 °C (ethanol); ir: (potassium bromide): 3187, 3046, 2945, 2877, 2233, 1635, 1600, 1145, 775 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.03 (s, 6H, $2CH_3$), 1.07 (s, 6H, $2CH_3$), 2.20 (m, 8H, $4CH_2$), 5.13 (s, 1H, C_4H), 6.79 (bs, 1H, N-H), 7.19 (m, 8H, Ar); *Anal*. Calcd. for $C_{32}H_{30}BrFN_2O_2$: C, 67.02; H, 5.27; N, 4.88. Found: C, 67.16; H, 5.43; N, 4.97.

General Procedure for the Preparation of 2-(4-halophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4-halophenyl-4*H*-chromene-3-carbonitrile (5) and 2-(4-Halophenyl)-5,6, 7,8-tetrahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene)-4-halophenyl-4*H*-chromene-3-carbonitrile (6). A mixture of the appropriate amount of dimedone (**1**) (10 mmol) and 2-aroyl-3-arylacrylonitrile (**2**) (10 mmol) in xylene (20 mL) containing catalytic amount of triethylamine (1 mL) was heated under reflux for 5 hours. The completion of reaction was monitored by thin layer chromatography (TLC). The solvent was removed under reduced pressure, the obtained solid was stirred in methanol. A colorless solid precipitated out was filtered, washed with methanol and dried. It contained two compounds, the mixture obtained was separated by column chromatography using acetone/toluene as eluent in 1:10 ratio afforded the compounds (**5**) and (**6**) in 25:55 % yield respectively.

2,4-Bis(4-chlorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4*H*-chromene-3-carbonitrile (5a). This compound was obtained as colorless prism (methanol), 1.06 g (25 %), mp 190-191 °C; ir: (potassium bromide): 2215, 1635, 1156, 858cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.03 (s, 3H, CH_3), 1.17 (s, 3H, CH_3), 2.16 (m, 4H, $2CH_2$), 4.73 (s, 1H, C_4H), 7.07 (m, 8H, Ar); ^{13}C nmr: ($CDCl_3$) δ 22, 24, 28, 42, 44, 52, 93, 116, 118, 119, 123, 124, 127, 128, 131, 136, 137, 156, 160, 198. *Anal*. Calcd. for $C_{24}H_{19}Cl_2NO_2$: C, 67.93; H, 4.51; N, 3.30. Found: C, 67.99; H, 4.63; N, 3.47.

4-(3-Chlorophenyl)-2-(4-chlorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4*H*-chromene-3-carbonitrile (5b). This compound was obtained as colorless prism (methanol), 1.10 g (26 %), mp 199-200 °C; ir: (potassium bromide): 2225, 1641, 1439, 1365, 1165, 886 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.02 (s, 3H, CH_3), 1.18 (s, 3H, CH_3), 2.18 (m, 4H, $2CH_2$), 4.76 (s, 1H, C_4H), 7.09 (m, 8H, Ar); *Anal*. Calcd. for $C_{24}H_{19}Cl_2NO_2$: C, 67.93; H, 4.51; N, 3.30. Found: C, 68.09; H, 4.70; N, 3.41.

2-(4-Chlorophenyl)-4-(4-fluorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4*H*-chromene-3-carbonitrile (5c). This compound was obtained as colorless prism (methanol), 1.01 g (25 %), mp 216-217 °C; ir: (potassium bromide): 2235, 1644, 1409, 1333, 1124, 846 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.01 (s, 3H, CH_3), 1.12 (s, 3H, CH_3), 2.19 (m, 4H, $2CH_2$), 4.71 (s, 1H, C_4H), 7.17 (m, 8H, Ar); *Anal*. Calcd. for $C_{24}H_{19}ClFNO_2$: C, 70.67; H, 4.70; N, 3.43. Found: C, 70.84; H, 4.68; N, 3.50.

2-(4-Bromophenyl)-4-(4-chlorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4*H*-chromene-3-carbonitrile (5d). This compound was obtained as colorless prism (methanol), 1.40 g (30 %), mp 209-210 °C; ir: (potassium bromide): 2248, 1605, 1479, 1344, 1126, 828 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.06 (s, 3H, CH_3), 1.14 (s, 3H, CH_3), 2.11 (m, 4H, $2CH_2$), 4.78 (s, 1H, C_4H), 7.20 (m, 8H, Ar); ^{13}C nmr: δ 25, 27, 31, 40, 44, 52, 92, 116, 117, 118, 123, 124, 127, 128, 132, 135, 137, 155, 161, 198. *Anal*. Calcd. for $C_{24}H_{19}BrClNO_2$: C, 61.49; H, 4.09; N, 2.99. Found: C, 61.68; H, 4.13; N, 2.92.

2-(4-Bromophenyl)-4-(3-chlorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4*H*-chromene-3-carbonitrile (5e). This compound was obtained as colorless prism (methanol), 1.31 g (28 %), mp 222-223 °C; ir: (potassium bromide): 2240, 1620, 1419, 1324, 1116, 868 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.05 (s, 3H, CH_3), 1.15 (s, 3H, CH_3), 2.15 (m, 4H, $2CH_2$), 4.75 (s, 1H, C_4H), 7.05 (m, 8H, Ar); *Anal*. Calcd. for $C_{24}H_{19}BrClNO_2$: C, 61.49; H, 4.09; N, 2.99. Found: C, 61.65; H, 4.24; N, 3.12.

2-(4-Bromophenyl)-4-(4-fluorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-oxo-4*H*-chromene-3-carbonitrile (5f). This compound was obtained as colorless prism (methanol), 1.44 g (32 %), mp 234-235 °C; ir: (potassium bromide): 2235, 1645, 1415, 1375, 1155, 889 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.00 (s, 3H, CH_3), 1.13 (s, 3H, CH_3), 2.13 (m, 4H, $2CH_2$), 4.70 (s, 1H, C_4H), 7.17 (m, 8H, Ar); *Anal*. Calcd. for $C_{24}H_{19}BrFNO_2$: C, 63.73; H, 4.23; N, 3.10. Found: C, 63.78; H, 4.42; N, 3.22.

2,4-Bis(4-chlorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene)-4*H*-chromene-3-carbonitrile (6a). This compound was obtained as colorless prism (ethanol), 2.45 g (45 %), mp 220-221 °C; ir: (potassium bromide): 2210, 1641, 1604, 1487, 1145, 889, 765 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.03 (s, 6H, $2CH_3$), 1.06 (s, 6H, $2CH_3$), 2.11 (m, 8H, $4CH_2$), 5.07 (s, 1H, C_4H), 7.08 (m, 8H, Ar); ^{13}C nmr: ($CDCl_3$) δ 22, 24, 27, 30, 32, 37, 40, 44, 52, 92, 108, 116, 118, 119, 122, 124, 125, 126, 128, 135, 138, 140, 145, 160, 184. *Anal*. Calcd. for $C_{32}H_{29}Cl_2NO_3$: C, 70.33; H, 5.35; N, 2.56. Found: C, 70.45; H, 5.46; N, 2.66.

4-(3-Chlorophenyl)-2-(4-chlorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene)-4*H*-chromene-3-carbonitrile (6b). This compound was obtained as colorless prism (ethanol), 2.56 g (47 %), mp 229-230 °C; ir: (potassium bromide): 2210, 1643, 1603, 1483, 1143, 883, 763 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 0.99 (s, 6H, $2CH_3$), 1.05 (s, 6H, $2CH_3$), 2.14 (m, 8H, $4CH_2$), 5.09 (s, 1H, C_4H), 7.15 (m, 8H, Ar); *Anal*. Calcd. for $C_{32}H_{29}Cl_2NO_3$: C, 70.33; H, 5.35; N, 2.56. Found: C, 70.42; H, 5.42; N, 2.74.

2-(4-Chlorophenyl)-4-(4-fluorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene)-4*H*-chromene-3-carbonitrile (6c). This compound was obtained as colorless prism (ethanol), 2.54 g (48 %), mp 239-240 °C; ir: (potassium bromide), 2215, 1645, 1605, 1485, 1145, 885, 765 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 0.98 (s, 6H, $2CH_3$), 1.08 (s, 6H, $2CH_3$), 2.13 (m, 8H, $4CH_2$), 5.05 (s, 1H, C_4H), 7.04 (m, 8H, Ar); *Anal*. Calcd. for $C_{32}H_{29}ClFNO_3$: C, 72.51; H, 5.51; N, 2.64. Found: C, 72.65; H, 5.46; N, 2.76.

2-(4-Bromophenyl)-4-(4-chlorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene)-4*H*-chromene-3-carbonitrile (6d). This compound was obtained as colorless prism (ethanol), 2.95 g (50 %), mp 231-232 °C; ir: (potassium bromide): 2235, 1638, 1610, 1477, 1159, 891, 755 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.09 (s, 6H, $2CH_3$), 1.14 (s, 6H,2 CH_3), 2.12 (m, 8H, $4CH_2$), 5.11 (s, 1H, C_4H), 7.14 (m, 8H, Ar); ^{13}C nmr: ($CDCl_3$) δ 18, 24, 25, 32, 36, 42, 44, 51, 92, 107, 118, 118.2, 119, 124, 124, 126, 126.1, 128, 135, 136, 141, 145, 159, 187. *Anal*. Calcd. for $C_{32}H_{29}BrClNO_3$: C, 65.04; H, 4.95; N, 2.37. Found: C, 65.15; H, 4.90; N, 2.54.

2-(4-Bromophenyl)-4-(3-chlorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene)-4*H*-chromene-3-carbonitrile (6e). This compound was obtained as colorless prism (ethanol), 3.06 g (52 %), mp 241-242 °C; ir: (potassium bromide): 2233, 1621, 1608, 1467, 1133, 879, 745 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.00 (s, 6H, $2CH_3$), 1.10 (s, 6H, $2CH_3$), 2.16 (m, 8H, $4CH_2$), 5.08 (s, 1H, C_4H), 7.17 (m, 8H, Ar); *Anal*. Calcd. for $C_{32}H_{29}BrClNO_3$: C, 65.04; H, 4.95; N, 2.37. Found: C, 65.20; H, 5.10; N, 2.50.

2-(4-Bromophenyl)-4-(4-fluorophenyl)-5,6,7,8-tetrahydro-7,7-dimethyl-5-(4,4-dimethyl-2,6-dioxocyclohexylidene)-4*H*-chromene-3-carbonitrile (6f). This compound was obtained as colorless prism (ethanol), 3.15 g (55 %), mp 248-249 °C; ir: (potassium bromide): 2211, 1641, 1601, 1481, 1141, 881, 761 cm^{-1}; ^1H nmr: ($CDCl_3$) δ 1.03 (s, 6H, $2CH_3$), 1.13 (s, 6H, $2CH_3$), 2.17 (m, 8H, $4CH_2$), 5.08 (s, 1H, C_4H), 7.20 (m, 8H, Ar); *Anal*. Calcd. for $C_{32}H_{29}BrFNO_3$: C, 66.90; H, 5.09; N, 2.44. Found: C, 66.99; H, 5.20; N, 2.55.

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