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PAPER

DABCO-Promoted three-component regioselective synthesis of functionalized chromen-5-ones and pyrano[3,2-*c*]chromen-5-ones *via* direct annulation of α-oxoketene-*N*,*S*-arylaminoacetals under solvent-free conditions†

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An efficient and convergent route to 3-aroyl-4-aryl-2-arylamino-4,6,7,8-tetrahydrochromen-5-ones and hitherto unreported 3-aroyl-4-aryl-2-arylamino-4*H*-pyrano[3,2-*c*]chromen-5-ones has been developed by an one-pot three-component domino coupling of α-oxoketene-*N*,*S*-arylamino-acetals, aromatic aldehydes, and dimedone/4-hydroxycoumarin in the presence of DABCO under solvent-free conditions in high yields. Further, suitably substituted pyrano[3,2-*c*]chromen-5-ones undergo intramolecular aromatic nucleophilic substitution (S_NAr) to give pentacyclic pyrano[3,2-*c*]chromenoquinolines in excellent yields. The merit of this cascade Knoevenagel condensation/Michael addition/cyclization sequence is highlighted by its high atom-economy, good yields, efficiency of producing three new bonds (two C–C and one C–O), and one stereocenter in a single operation. The protocol avoids the use of expensive catalysts, toxic organic reagents/solvents, and anhydrous condition. In particular the attractive feature of this approach is the synthesis of three important bioactive heterocyclic frameworks from the same α-oxoketene-*N*,*S*-arylaminoacetal under the similar reaction conditions making this new strategy highly useful in diversity oriented synthesis (DOS).

Introduction

The development of chemical methodologies that provide maximum structural complexity and diversity with a minimum number of synthetic steps to assemble compounds with interesting properties is a key facet of modern drug discovery.[1] The synthetic strategies regarding how to construct and cleave the carbon–carbon (C–C) and carbon–heteroatom (C–X) bond(s) represent the central theme in organic synthesis. Due to growing environmental concerns, a pressing challenge to organic chemists is to develop new methods that are not only efficient, selective, and high yielding but also eco-compatible. For reasons of economy and pollution prevention, one approach to address this challenge involves the development of multicomponent procedures in organic synthesis. Multicomponent reactions[2–4] (MCRs) have emerged as a highly valuable tools for the rapid generation of molecular complexity and diversity with predefined functionality in chemical biology and drug discovery, due to its straightforward reaction design, convergent, and atom-efficient nature resulting in substantial minimization of waste, labor, time, and cost.[5–7] As a consequence, multicomponent as well as domino or related reactions are witnessing a new spring.[8] Because of the increasing public concern for the harmful effects of organic solvents on the environment and human body, solvent-free reactions[9] have gained the attention of organic chemists due to their more efficient and less labour-intense methodologies. Furthermore, solvent-free multicomponent reactions have encompassed wide areas of the chemical enterprise and are attractive, because they incorporate many green chemistry principles.

Chromene and it's benzo-/hetero-fused analogues represent a class of important heterocycles due to their presence in a broad spectrum of synthetic and natural products such as alkaloids, flavonoids, tocopherols, and anthocyanins with diverse biological properties.[10] Chromene systems are of particular importance as they belong to privileged medicinal scaffolds with highly pronounced spasmolytic, diuretic, anticoagulant, anticancer, and antianaphylactic activities.[11] Moreover, these moieties have the potential application in the treatment of human inflammatory TNFα-mediated diseases such as rheumatoid, psoriatic arthritis, apoptosis inducer, and as an inhibitor of excitatory amino acid transporter.[12] Further, these compounds also find applications as pigments and as potential biodegradable agrochemicals.[13]

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† Electronic supplementary information (ESI) available: Detailed experimental procedure, spectral, analytical data of all the compounds and their ^1H and ^{13}C spectra. See DOI: 10.1039/c1gc16129f

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The pyranochromenes have been used as cognitive enhancers for the treatment of neurodegenerative diseases, including Alzheimer's disease, amyotrophic lateral sclerosis, Parkinson's disease, Huntington's disease, AIDS associated dementia and Down's syndrome as well as for the treatment of schizophrenia and myoclonus.[14] In addition, aminochromene derivatives exhibit a wide spectrum of biological activities including antihypertensive and anti-ischemic behavior.[15] Suitably substituted chromenes are particularly versatile compounds that bind to the Bcl-2 protein (B-cell lymphoma 2) and induce apoptosis in tumor cells.[16] Bcl-2 protein binding compounds provide a promising lead for the development of potential anticancer agents and direct methods for their synthesis are highly desirable.

As a result, numerous synthetic routes to chromene derivatives have been reported.[17] Recently, synthesis of 2-arylaminochromene derivatives has been developed *via* a multicomponent approach,[18] which required a long reaction time (20–25 h). Albeit the reported approaches are useful tools for the synthesis of chromene derivatives, most of them suffer from significant limitations such as harsh reaction conditions, expensive catalysts/reagents, prolonged reaction times, and multistep synthesis. Therefore, exploration of more general, efficient, rapid, and viable routes are very desirable, and would be of great relevance to both synthetic and medicinal chemists due to their broad array of applications in the areas of biology, material science, and medicinal chemistry.

Results and discussion

The vast biological importance of chromene derivatives inspired us to develop a novel protocol for their efficient synthesis. Synthons containing both electrophilic and nucleophilic sites (ambiphilic synthons) have great potential in developing new reaction pathways. One such synthon is α-oxoketene-*N*,*S*-arylaminoacetal, and its utility as versatile intermediates in organic synthesis has been well recognized.[19] It has four active sites as shown in the Fig. 1. Two nucleophilic centres are localised on the nitrogen and α-carbon atoms, whereas two electrophilic centres are associated with the carbonyl and thiomethyl carbon atoms. Thus, the reaction of α-oxoketene-*N*,*S*-arylaminoacetal with dielectrophilic reagents may lead to the formation of various important heterocyclic compounds, depending on the structure of the dielectrophile and the reaction conditions.

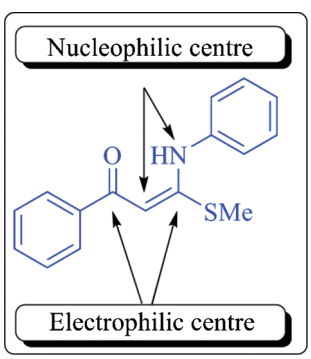
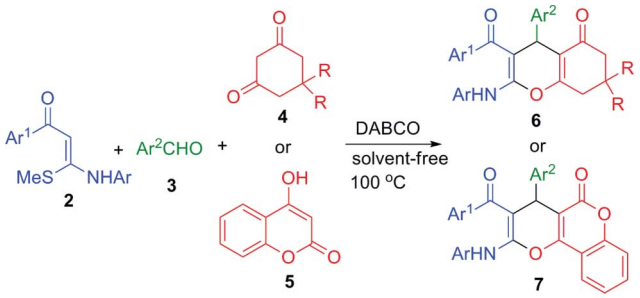
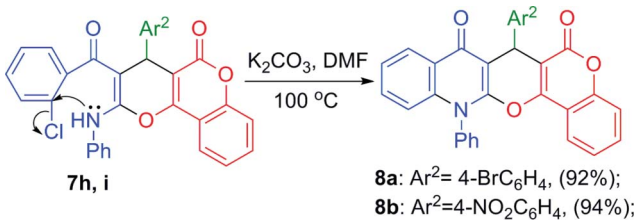


Fig. 1 The reaction profile of *N*,*S*-acetal.

As a part of our continuous efforts toward the development of new synthetic methods for important heterocyclic compounds,[20,21] in this paper, we wish to disclose a facile chemo- and regioselective synthesis of chromen-5-ones and 4*H*-pyrano[3,2-*c*]chromen-5-ones by one-pot three-component coupling of α-oxoketene-*N*,*S*-arylaminoacetals, aromatic aldehydes, and dimedone/4-hydroxycoumarin under solvent-free conditions at 100 °C in the presence of DABCO (Scheme 1). The reactions were completed within 40–50 min and the pure products were isolated in high yields simply by addition of ethanol to the reaction mixture. We also represent two interesting examples of fused pentacyclic heterocycles, which have been synthesized by an intramolecular aromatic nucleophilic substitution reaction (Scheme 2). The synthetic route is facile, convergent, and allows easy placement of a variety of substituents around the periphery of the heterocyclic ring system.



Scheme 1 Synthesis of chromen-5-ones **6** and pyrano[3,2-*c*]chromen-5-ones **7**.



Scheme 2 Synthesis of pyrano[3,2-*c*]chromenoquinolines.

The precursor α-oxoketene-*N*,*S*-arylaminoacetals were not commercially sourced and were synthesized in good yields (70–75%) by the reaction of active methylene ketones with phenyl isothiocyanate in the presence of NaH in DMF followed by the addition of methyl iodide according to a reported procedure[22] (Table 1).

Our careful literature survey at this stage revealed that there is no report on the use of DABCO as a catalyst in the synthesis of chromen-5-one and pyranochromen-5-one derivatives utilizing α-oxoketene-*N*,*S*-arylaminoacetals under solvent-free conditions. Thus, coupling of **2** with aromatic aldehydes **3** and active methylene compounds **4** or **5** in the presence of DABCO under solvent-free conditions provided chromen-5-ones **6** and pyrano[3,2-*c*]chromen-5-ones **7**, respectively in high yields (Scheme 1).

The synthesis of 3-aroyl/heteroaroyl-4-aryl-2-arylamino-4,6,7,8-tetrahydrochromen-5-ones **6** was first undertaken. α-Oxoketene-*N*,*S*-acetal **2c** (1.0 mmol), 4-nitrobenzaldehyde (1.0 mmol), and dimedone (1.0 mmol) were selected as test

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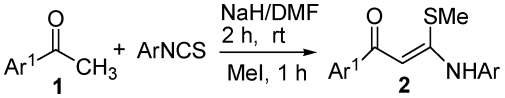
Table 1 Synthesis of α-oxoketene-*N*,*S*-arylaminoacetals **2**



Entry	Ar^1	Ar	Product	Yield[a] (%)
1	C_6H_5	4-$MeOC_6H_4$	**2a**	72
2	4-$MeOC_6H_4$	4-$MeOC_6H_4$	**2b**	70
3	2-Furyl	C_6H_5	**2c**	73
4	2-Thienyl	C_6H_5	**2d**	72
5	2-ClC_6H_4	C_6H_5	**2e**	75
6	4-$MeOC_6H_4$	C_6H_5	**2f**	74

[a] Isolated pure yields.

Table 2 Optimization of the reaction conditions[a] for the synthesis of chromen-5-ones **6**

Entry	Reaction conditions	Product **6** yield[b] (%)
1	No catalyst, EtOH, reflux, 24 h	15
2	TEA (1.0 eq.), EtOH, reflux, 10 h	67
3	DABCO (1.0 eq.), EtOH, reflux, 7 h	74
4	DMAP (1.0 eq.), EtOH, reflux, 24 h	55
5	L-proline (1.0 eq.), EtOH, reflux, 20 h	58
6	No catalyst, solvent-free, 100 °C, 7 h	65
7	TEA (1.0 eq.), solvent-free, 100 °C, 1.5 h	78
8	DABCO (1.0 eq.), solvent-free, 100 °C, 40 min	83
9	DMAP (1.0 eqv.), solvent-free, 100 °C, 3 h	65
10	L-proline (1.0 eqv.), solvent-free, 100 °C, 2.5 h	63
11	DABCO (0.5 eq.), solvent-free, 100 °C, 2.5 h	51
12	DABCO (1.5 eq.), solvent-free, 100 °C, 45 min	75
13	DABCO (1.0 eq.), solvent-free, 80 °C, 2.5 h	66
14	DABCO (1.0 eq.), solvent-free, 120 °C, 40 min	81

[a] The reaction of 4-nitrobenzaldehyde (1.0 mmol), α-oxoketene-*N*,*S*-acetal **2c** (1.0 mmol), and dimedone (1.0 mmol). [b] Isolated pure yields.

substrates to optimize the reaction conditions. Initially, the above three-component coupling has been carried out in EtOH under reflux without any catalyst to establish the real effectiveness of the catalyst. Only 15% conversion to the product was observed even after 24 h of reflux. Next, the above test reaction was investigated in the presence of various catalysts such as triethylamine (TEA), DABCO, 4-dimethylaminopyridine (DMAP), and L-proline separately in refluxing EtOH and the results are summarized in Table 2. All the catalysts did catalyze the reaction, albeit in low efficiency. In recent years, solvent-free reactions have been much utilized and have become a powerful tool in organic synthesis. As a consequence, to get better reaction conditions, the above test reaction was used to screened through the above catalysts separately under solvent-free conditions. To our delight, the reaction was completed quickly providing good yield of the desired product. The main notable observation of this reaction is that the product was obtained in 65% yield, even in the absence of catalyst (Table 2, entry 6). Though the catalytic activity of all the catalysts increased under solvent-free conditions, DABCO was found to be the catalyst of choice for this transformation (Table 2, entry 8).

With DABCO base as a good promoter in hand, we next intended to optimize its loading, and it was found that the use of 1.0 equiv. of DABCO provided the best result. Reducing the equivalent of DABCO increased the reaction time and lowered the yield drastically (Table 2, entry 11). The reaction efficiency was also assessed with varying reaction temperatures. The results demonstrated that 100 °C was found to be the optimum temperature. Lowering the temperature (80 °C) became detrimental to the reaction, while increasing the temperature (120 °C) had no significant effect on the reaction (Table 2, entries 13, 14). Thus, the best yield, cleanest reaction, and most facile workup were achieved employing 1.0 equiv. of DABCO under solvent-free conditions at 100 °C.

With the optimized conditions in hand, to delineate this approach, the scope and generality of this protocol was next examined by employing various α-oxoketene-*N*,*S*-acetals and aromatic aldehydes. Notably, a wide range of Ar^1 groups (aromatic and heteroaromatic) were well tolerated and incorporated providing a functional handle for further manipulation. No obvious electronic effects of the aldehyde were observed, and the products were obtained in high yields (Table 3).

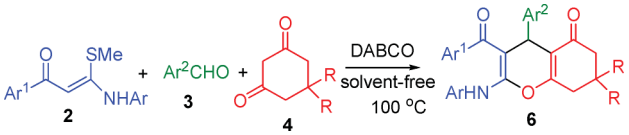
After successful coupling of α-oxoketene-*N*,*S*-acetals, aromatic aldehydes and dimedone under solvent-free conditions, 4-hydroxycoumarin was also utilized in place of dimedone in order to gain further insight about this transformation, and to show versatility of this protocol. Thus, coupling of **2**, **3**, and **5** provided easy access to pyrano[3,2-*c*]chromen-5-ones **7** in good yields (Table 4). The capacity of the reaction was fruitfully proved for a wide range of Ar^1 and Ar^2.

It is important to highlight that, recently, an intramolecular nucleophilic aryl substitution reaction (S_NAr) of the *ortho*-halo group into the aryl ring of 2-benzoylthioacetanilides was reported by Li and coworkers.[18] Interestingly, the S_NAr may occur in our pyrano[3,2-*c*]chromen-5-ones **7**, if there is a halogen group present at the *ortho*-position of the Ar^1 ring. Pyrano[3,2-*c*]chromen-5-ones **7h** and **7i** containing *ortho*-chlorine, when heated to 100 °C in DMF in the presence of K_2CO_3 for 40 min underwent S_NAr reaction to give pentacyclic pyrano[3,2-*c*]chromenoquinolines **8a** and **8b** as exclusive products in 92 and 94% yields, respectively (Scheme 2).

The main advantage of this procedure is the simple work up, and the product was obtained in high purity simply by addition of ethanol to the reaction mixture, which makes this methodology facile, practical, and rapid to execute. The purity of the product was high enough for spectroscopic analysis without any further purification, but all the compounds were nevertheless crystallized from ethanol. The structures of all the newly synthesized compounds **6**, **7** and **8** were well characterized from their satisfactory elemental and spectral (IR, ^1H, ^{13}C NMR, and MS) studies. The mass spectra of these compounds displayed molecular ion peaks at the appropriate *m*/*z* values.

Taking into consideration the entire outcome, a plausible mechanistic pathway for the domino coupling is depicted in Scheme 3. The first step is the Knoevenagel condensation between aldehyde **3** and active methylene compound **4** to give the Knoevenangel adduct **A**, which acts as a Michael acceptor. The adduct **A** immediately undergoes Michael-type addition with α-oxoketene-*N*,*S*-acetal **2** to generate the open chain intermediate **B**. The intermediate **B** undergoes intramolecular *O*-cyclization *via* route **I** to give compound **6** with elimination of MeSH. The intermediate **B** may exist in its two rotameric forms $\mathbf{B_1}$ and $\mathbf{B_2}$, which could probably undergo *N*- or *O*-cyclizations *via* routes **II** or **III** to give compounds **9** and **10**, respectively. During

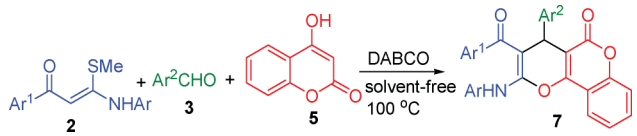
Table 3 Scope exploration: variation of Ar^1 and Ar^2



Entry	Ar^1	Ar	Ar^2	*R*	Time (min)	Yield[a] (%)
6a	C_6H_5	4-$OMeC_6H_4$	4-$NO_2C_6H_4$	Me	40	78
6b	C_6H_5	4-$OMeC_6H_4$	4-$OMeC_6H_4$	Me	50	73
6c	C_6H_5	4-$OMeC_6H_4$	C_6H_5	Me	45	76
6d	4-$OMeC_6H_4$	4-$OMeC_6H_4$	4-$NO_2C_6H_4$	Me	50	82
6e	4-$OMeC_6H_4$	4-$OMeC_6H_4$	3-$NO_2C_6H_4$	Me	45	84
6f	4-$OMeC_6H_4$	4-$OMeC_6H_4$	4-BrC_6H_4	Me	45	80
6g	2-Furyl	C_6H_5	4-$NO_2C_6H_4$	Me	40	80
6h	2-Furyl	C_6H_5	3-$NO_2C_6H_4$	Me	45	83
6i	2-Furyl	C_6H_5	2-$NO_2C_6H_4$	Me	50	76
6j	2-Furyl	C_6H_5	4-ClC_6H_4	Me	40	78
6k	2-Furyl	C_6H_5	C_6H_5	H	45	76
6l	2-Thienyl	C_6H_5	3-$NO_2C_6H_4$	Me	45	82
6m	2-Thienyl	C_6H_5	2,4-$Cl_2C_6H_3$	Me	55	72
6n	2-Thienyl	C_6H_5	4-BrC_6H_4	Me	40	81
6o	2-Thienyl	C_6H_5	4-$OMeC_6H_4$	Me	50	70
6p	2-ClC_6H_4	C_6H_5	4-BrC_6H_4	Me	60	82
6q	2-ClC_6H_4	C_6H_5	3-$NO_2C_6H_4$	H	55	84
6r	2-ClC_6H_4	C_6H_5	4-$OMeC_6H_4$	H	65	74

[a] Isolated pure yields.

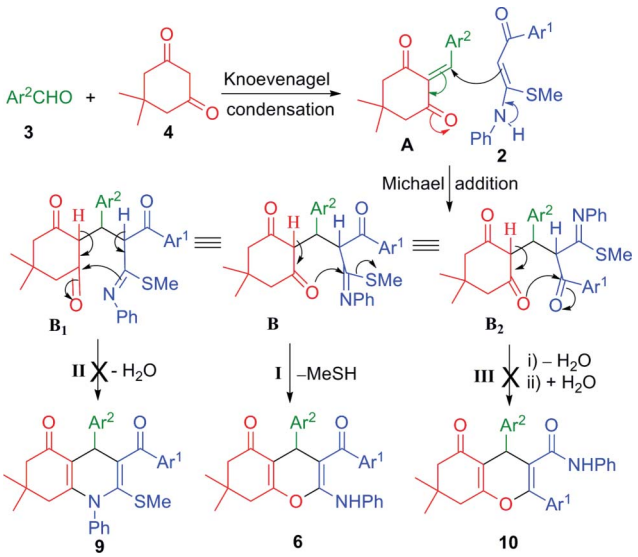
Table 4 The synthesis of pyrano[3,2-*c*]chromen-5-ones **7**



Entry	Ar^1	Ar^2	Time (min)	Yield[a] (%)
7a	2-Furyl	4-ClC_6H_4	55	69
7b	2-Furyl	C_6H_5	60	76
7c	2-Thienyl	3-$NO_2C_6H_4$	55	68
7d	2-Thienyl	4-FC_6H_4	60	82
7e	4-$OMeC_6H_4$	4-MeC_6H_4	65	72
7f	4-$OMeC_6H_4$	3-$NO_2C_6H_4$	55	80
7g	4-$OMeC_6H_4$	3-F-4-ClC_6H_4	70	80
7h	2-ClC_6H_4	4-BrC_6H_4	70	83
7i	2-ClC_6H_4	4-$NO_2C_6H_4$	65	76

[a] Isolated yield.

our investigation, we did not observe even a trace of **9** or **10**, and only **6** was obtained exclusively, suggesting *O*-cyclization through route **I**, making the protocol highly chemo- and regioselective.



Scheme 3 Plausible reaction scenario for the formation of **6**.

Conclusions

In summary, we have developed a convenient, efficient, chemoselective, and regioselective synthesis of tetrahydrochromen-5-one and pyrano[3,2-*c*]chromen-5-one frameworks by the reaction of α-oxoketene-*N*,*S*-acetals, aromatic aldehydes, and dimedone/4-hydroxycoumarin in the presence of DABCO under solvent-free conditions. In addition, the suitably synthesized pyrano[3,2-*c*]chromen-5-ones could be efficiently converted into pyrano[3,2-*c*]chromenoquinoline by intramolecular aromatic nucleophilic substitution (S_NAr). In this experimentally simple process three new bonds (two C–C and one C–O), and one stereocenter are generated in a single operation with all reactants efficiently utilized. Moreover, the arylamine and aroyl substituents in the 2- and 3-positions of the chromene ring are quite reactive; this makes these compounds good candidates as precursors for further synthetic transformations to meet the need for various useful purposes. The short reaction time, excellent yield, low-cost, operational simplicity, and more importantly the purification of compounds by a non-chromatographic method make this process very significant for academic research and practical applications. Further studies on the extension of

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the scope of the use of α-oxoketene-*N*,*S*-arylaminoacetals in synthetic applications are currently under way in our laboratory.

Experimental Section

General

The starting materials were commercially available and used as received without further purification. α-oxoketene-*N*,*S*-arylaminoacetal **2** were prepared following the known procedure. Thin-layer chromatography (TLC) was performed using silica gel 60 F254 precoated plates. Infrared (IR) spectra are measured in KBr, and wavelengths (ν) are reported in cm^{-1}. ^1H and ^{13}C NMR spectra were recorded on NMR spectrometers operating at 300 and 75.5 MHz, respectively. Chemical shifts (δ) are given in parts per million (ppm) using the residue solvent peaks as reference relative to TMS. *J* values are given in Hz. Mass spectra were recorded using electrospray ionization (ESI) mass spectrometry. The C, H, and N analyses were performed from microanalytical laboratory. The melting points are uncorrected.

General procedure for synthesis of tetrahydrochromen-5-one (6a-r) and pyrano[3,2-*c*]chromen-5-one (7a–i)

An oven-dried 10 ml round bottom flask was charged with the appropriate aldehyde (1.0 mmol), cyclic 1,3-dicarbonyl compound (1.0 mmol), α-oxoketene-*N*,*S*-arylaminoacetal (1.0 mmol), and DABCO (1.0 mmol), and the reaction mixture was heated in an oil bath at 100 °C for the stipulated period of time till the completion of the reaction (monitored by TLC). Ethanol (2 mL) was added to the reaction mixture. The product appeared as a solid, which was filtered out and washed with another 2 mL of EtOH to remove the DABCO and other impurities. Finally, the products were recrystallized from ethanol.

General procedure for the synthesis of pyrano[3,2-*c*]chromenoquinolines (8a–b)

To a 5 ml dimethylformamide solution of 3-(2-halobenzoyl)-pyrano[3,2-*c*]chromen-5-one (**7h** or **7i**, 1.0 mmol), K_2CO_3 (0.138 g, 1.0 mmol) was added and the reaction mixture was heated to 100 °C. After completion of the reaction as indicated by TLC (about 40 min), the mixture was cooled to room temperature and cold water was added to precipitate the product, which was then collected by filtration and washed with cold water to afford the pure compound **8**.

The spectral and analytical data of all the compounds are given as follows.

3-Benzoyl-2-(4-methoxyphenylamino)-7,7-dimethyl-4-(4-nitrophenyl)-4,6,7,8-tetrahydrochromen-5-one (6a)

White solid; mp 256–257 °C. ^1H NMR (300 MHz, $CDCl_3$): δ 13.14 (s, 1H), 7.91 (d, J = 8.7 Hz, 2H), 7.38 (d, J = 7.5 Hz, 1H), 7.34–7.25 (m, 4H), 7.06 (d, J = 7.2 Hz, 2H), 6.96–6.88 (m, 4H), 4.94 (s, 1H), 3.85 (s, 3H), 2.54 (d, J = 18.0 Hz, 1H), 2.44 (d, J = 18.0 Hz, 1H), 2.27 (d, J = 16.2 Hz, 1H), 2.15 (d, J = 16.2 Hz, 1H), 1.12 (s, 3H), 0.91 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 195.8, 194.7, 161.3, 157.9, 157.2, 152.6, 146.1, 140.5, 129.4, 129.2, 128.6, 128.3, 126.0, 124.3, 123.2, 116.3, 114.4, 88.6, 55.5, 50.5, 40.3, 35.5, 32.2, 29.1, 27.1. IR (KBr, cm^{-1}): 3055, 2954, 1683, 1666, 1631, 1590, 1562, 1373; MS: m/z = 547 (M^++Na). Elemental analysis for $C_{31}H_{28}N_2O_6$: calc. C, 70.98; H, 5.38; N, 5.34. Found: C, 70.74; H, 5.53; N, 5.47.

3-Benzoyl-4-(4-methoxyphenyl)-2-(4-methoxyphenylamino)-7,7-dimethyl-4,6,7,8-tetrahydrochromen-5-one (6b)

White solid; mp 160–161 °C. ^1H NMR (300 MHz, $CDCl_3$): δ 13.1 (s, 1H), 7.37–7.28 (m, 5H), 7.10 (d, J = 7.2 Hz, 2H), 6.92 (d, J = 8.7 Hz, 2H), 6.71 (d, J = 8.7 Hz, 2H), 6.60 (d, J = 8.4 Hz, 2H), 4.74 (s, 1H), 3.84 (s, 3H), 3.71 (s, 3H), 2.52–2.39 (m, 2H), 2.24 (d, J = 16.2 Hz, 1H), 2.15 (d, J = 16.2 Hz, 1H), 1.10 (s, 3H), 0.91 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 196.1, 194.9, 160.5, 158.1, 157.7, 156.9, 140.8, 137.7, 129.8, 129.0, 128.6, 128.0, 126.3, 124.1, 118.0, 114.3, 113.3, 90.1, 55.4, 55.0, 50.7, 40.3, 34.2, 32.2, 29.2, 27.1. IR (KBr, cm^{-1}): 3057, 2975, 1683, 1667, 1625, 1581, 1559, 1401; MS: m/z = 532 (M^++Na). Elemental analysis for $C_{32}H_{31}NO_5$: calc. C, 75.42; H, 6.13; N, 2.75. Found: C, 75.58; H, 5.98; N, 2.63.

3-Benzoyl-2-(4-methoxyphenylamino)-7,7-dimethyl-4-phenyl-4,6,7,8-tetrahydrochromen-5-one (6c)

White solid; mp 182–183 °C. ^1H NMR (300 MHz, $CDCl_3$): δ 13.13 (s, 1H), 7.37–7.25 (m, 6H), 7.11–7.05 (m, 4H), 6.92 (d, J = 8.7 Hz, 2H), 6.79 (d, J = 5.7 Hz, 2H), 4.81 (s, 1H), 3.84 (s, 3H), 2.53–2.40 (m, 2H), 2.25 (d, J = 15 Hz, 1H), 2.16 (d, J = 15 Hz, 1H), 1.10 (s, 3H), 0.91 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 196.1, 195.0, 160.8, 158.3, 157.0, 145.4, 140.9, 129.9, 129.2, 128.2, 128.1, 127.7, 126.4, 126.2, 124.3, 118.0, 114.4, 90.1, 55.6, 50.8, 40.5, 35.1, 32.4, 29.3, 27.2. IR (KBr, cm^{-1}): 3041, 2929, 1675, 1670, 1624, 1571, 1558, 1385; MS: m/z = 502 (M^++Na). Elemental analysis for $C_{31}H_{29}NO_4$: calc. C, 77.64; H, 6.10; N, 2.92. Found: C, 77.82; H, 6.01; N, 2.83.

3-(4-Methoxybenzoyl)-2-(4-methoxyphenylamino)-7,7-dimethyl-4-(4-nitrophenyl)-4,6,7,8-tetrahydrochromen-5-one (6d)

White solid; mp 209–210 °C. ^1H NMR (300 MHz, $CDCl_3$): δ 13.05 (s, 1H), 7.93 (d, J = 8.7 Hz, 2H), 7.27 (d, J = 9.3 Hz, 2H), 7.10 (d, J = 8.7 Hz, 2H), 6.97–6.92 (m, 4H), 6.84 (d, J = 8.4 Hz, 2H), 5.05 (s, 1H), 3.85 (s, 3H), 3.84 (s, 3H), 2.53 (d, J = 17.7 Hz, 1H), 2.45 (d, J = 17.7 Hz, 1H), 2.28 (d, J = 16.2 Hz, 1H), 2.17 (d, J = 16.2 Hz, 1H), 1.13 (s, 3H), 0.92 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 195.9, 194.2, 161.5, 160.6, 157.7, 157.1, 152.7, 146.2, 133.0, 129.4, 128.5, 128.2, 124.2, 123.3, 116.4, 114.4, 113.6, 88.6, 55.5, 55.3, 50.5, 40.3, 35.6, 32.3, 29.2, 27.1. IR (KBr, cm^{-1}): 3056, 2978, 1688, 1661, 1628, 1589, 1559, 1368; MS: m/z = 577 (M^++Na). Elemental analysis for $C_{32}H_{30}N_2O_7$: calc. C, 69.30; H, 5.45; N, 5.05. Found: C, 69.13; H, 5.60; N, 5.12.

3-(4-Methoxybenzoyl)-2-(4-methoxyphenylamino)-7,7-dimethyl-4-(3-nitrophenyl)-4,6,7,8-tetrahydrochromen-5-one (6e)

White solid; mp 199–200 °C. ^1H NMR (300 MHz, $CDCl_3$): δ 13.02 (s, 1H), 7.89 (d, J = 7.8 Hz, 1H), 7.58 (s, 1H), 7.29–7.18 (m, 3H), 7.10–7.05 (m, 3H), 6.93 (d, J = 8.7 Hz, 2H), 6.84 (d, J = 8.4 Hz, 2H), 5.03 (s, 1H), 3.85 (s, 3H), 3.84 (s, 3H), 2.51 (s, 2H), 2.27 (d, J = 16.2 Hz, 1H), 2.16 (d, J = 16.2 Hz, 1H), 1.13 (s, 3H), 0.94 (s, 3H); 13 C NMR (75 MHz, $CDCl_3$):

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δ 196.0, 193.3, 166.3, 165.4, 164.7, 163.8, 155.3, 149.1, 139.5, 135.9, 134.0, 132.4, 128.0, 124.4, 118.3, 116.4, 116.3, 114.4, 113.7, 110.2, 91.7, 55.5, 55.3, 50.6, 40.3, 35,5, 32.3, 29.6, 27.2. IR (KBr, cm^{-1}): 3072, 2925, 1685, 1664, 1629, 1593, 1561, 1362; MS: m/z = 577 (M^++Na). Elemental analysis for $C_{32}H_{30}N_2O_7$: calc. C, 69.30; H, 5.45; N, 5.05. Found: C, 69.09; H, 5.38; N, 5.13.

4-(4-Bromophenyl)-3-(4-methoxybenzoyl)-2-(4-methoxyphenylamino)-7,7-dimethyl-4,6,7,8-tetrahydrochromen-5-one (6f)

White solid; mp 205–206 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.03 (s, 1H), 7.60 (s, 1H), 7.13 (d, J = 8.7 Hz, 2H), 6.93–6.82 (m, 6H), 6.73–6.70 (m, 3H), 4.89 (s, 1H), 3.83 (s, 6H), 2.53–2.42 (m, 2H), 2.29–2.17 (m, 2H), 1.11 (s, 3H), 0.92 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): 196.1, 195.0, 161.3, 133.3, 131.2, 129.4, 128.4, 124.2, 117.4, 114.4, 113.6, 90.1, 55.6, 55.4, 50.7, 40.5, 32.4, 31.0, 29.3, 27.2. IR (KBr, cm^{-1}): 3052, 2974, 1691, 1656, 1620, 1579, 1552, 1357; MS: m/z = 610 (M^++Na). Elemental analysis for $C_{32}H_{30}BrNO_5$: calc. C, 65.31; H, 5.14; N, 2.38. Found: C, 65.53; H, 5.01; N, 2.19.

3-(2-Furoyl)-7,7-dimethyl-4-(4-nitrophenyl)-2-phenylamino-4,6,7,8-tetrahydrochromen-5-one (6g)

White solid; mp 210–211 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.74 (s, 1H), 8.04 (d, J = 8.7 Hz, 2H), 7.54–7.35 (m, 7H), 7.21 (t, J = 6.9 Hz, 1H), 7.01 (d, J = 3.6 Hz, 1H), 6.45 (d, J = 1.5 Hz, 1H), 5.88 (s, 1H), 2.54 (d, J = 17.7 Hz, 1H), 2.46 (d, J = 17.7 Hz, 1H), 2.32 (d, J = 16.2 Hz, 1H), 2.23 (d, J = 16.2 Hz, 1H), 1.13 (s, 3H), 0.91 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 195.9, 178.0, 161.5, 159.0, 153.4, 153.0, 146.3, 144.4, 136.6, 129.3, 128.5, 125.2, 123.5, 122.6, 116.9, 116.8, 112.0, 88.5, 50.6, 40.4, 33.1, 32.3, 29.1, 27.1. IR (KBr, cm^{-1}): 3054, 2925, 1688, 1665, 1619, 1572, 1556, 1383; MS: m/z = 507 (M^++Na). Elemental analysis for $C_{28}H_{24}N_2O_6$: calc. C, 69.41; H, 4.99; N, 5.78. Found: C, 69.25; H, 5.10; N, 5.88.

3-(2-Furoyl)-7,7-dimethyl-4-(3-nitrophenyl)-2-phenylamino-4,6,7,8-tetrahydrochromen-5-one (6h)

White solid; mp 201–202 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.71 (s, 1H), 8.14 (s, 1H), 7.94 (d, J = 7.5 Hz, 1H), 7.65–7.58 (m, 2H), 7.43–7.31 (m, 5H), 7.21 (t, J = 6.9 Hz, 1H), 7.02 (d, J = 3.6 Hz, 1H), 6.45 (s, 1H), 5.89 (s, 1H), 2.52 (s, 2H), 2.32 (d, J = 16.2 Hz, 1H), 2.23 (d, J = 16.2 Hz, 1H), 1.13 (s, 3H), 0.92 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 196.0, 178.1, 161.3, 158.9, 153.5, 148.1, 147.8, 144.4, 136.6, 134.0, 129.2, 128.9, 125.2, 122.7, 122.7, 121.5, 116.9, 112.0, 88.7, 50.6, 40.3, 33.0, 32.3, 29.1, 27.1. IR (KBr, cm^{-1}): 3054, 2976, 1686, 1666, 1624, 1583, 1551, 1388; MS: m/z = 507 (M^++Na). Elemental analysis for $C_{28}H_{24}N_2O_6$: calc. C, 69.41; H, 4.99; N, 5.78. Found: C, 69.19; H, 5.10; N, 5.87.

3-(2-Furoyl)-7,7-dimethyl-4-(2-nitrophenyl)-2-phenylamino-4,6,7,8-tetrahydrochromen-5-one (6i)

White solid; mp 159–160 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.25 (s, 1H), 7.52–7.30 (m, 8H), 7.20–7.15 (m, 2H), 6.91 (d, J = 3.3 Hz, 1H), 6.40 (s, 1H), 6.18 (s, 1H), 2.49 (br, 2H), 2.26 (br, 2H), 1.11 (s, 3H), 0.98 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 195.3, 180.6, 164.6, 160.6, 158.4, 157.4, 146.4, 144.5, 136.9, 136.6, 129.6, 125.2, 125.1, 121.2, 120.8, 118.9, 118.3, 115.0, 112.7, 95.6, 49.3, 42.6, 36.8, 36.5, 33.8, 30.3. IR (KBr, cm^{-1}): 3061, 2931, 1682, 1666, 1621, 1576, 1554, 1375; MS: m/z = 507 (M^++Na). Elemental analysis for $C_{28}H_{24}N_2O_6$: calc. C, 69.41; H, 4.99; N, 5.78. Found: C, 69.63; H, 4.84; N, 5.64.

4-(4-Chlorophenyl)-3-(2-furoyl)-7,7-dimethyl-2-phenylamino-4,6,7,8-tetrahydrochromen-5-one (6j)

White solid; mp 199–200 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.72 (s, 1H), 7.54 (s, 1H), 7.42–7.35 (m, 5H), 7.25–7.13 (m, 4H), 6.98 (d, J = 3.3 Hz, 1H), 6.44 (q, J = 1.5 Hz, 1H), 5.71 (s, 1H), 2.54–2.41 (m, 2H), 2.31 (d, J = 16.2 Hz, 1H), 2.23 (d, J = 16.2 Hz, 1H), 1.12 (s, 3H), 0.92 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 196.1, 178.2, 161.0, 159.1, 153.2, 144.4, 144.0, 136.8, 131.9, 129.2, 128.9, 128.4, 124.9, 122.4, 117.7, 116.6, 111.8, 89.3, 50.7, 40.3, 32.3, 29.1, 27.1. IR (KBr, cm^{-1}): 3065, 2926, 1679, 1656, 1618, 1574, 1558, 1370; MS: m/z = 496 (M^++Na). Elemental analysis for $C_{28}H_{24}ClNO_4$: calc. C, 70.96; H, 5.10; N, 2.96. Found: C, 71.14; H, 4.98; N, 2.85.

3-(2-Furoyl)-4-phenyl-2-phenylamino-4,6,7,8-tetrahydrochromen-5-one (6k)

White solid; mp 187–188 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.7 (s, 1H), 7.54 (s, 1H), 7.38–7.10 (m, 10H), 6.96 (d, J = 3.3 Hz, 1H), 6.42 (s, 1H), 5.73 (s, 1H), 2.63–2.61 (m, 2H), 2.43–2.38 (m, 2H), 2.05–2.01 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 196.4, 178.4, 162.7, 159.3, 153.2, 145.6, 144.5, 137.1, 129.3, 128.4, 127.6, 126.4, 124.9, 122.5, 119.6, 116.6, 111.8, 89.8, 36.9, 32.8, 26.8, 20.1. IR (KBr, cm^{-1}): 3071, 2923, 1672, 1654, 1620, 1581, 1556, 1361; MS: m/z = 434 (M^++Na). Elemental analysis for $C_{26}H_{21}NO_4$: calc. C, 75.90; H, 5.14; N, 3.40. Found: C, 75.75; H, 5.28; N, 3.48.

7,7-Dimethyl-4-(3-nitrophenyl)-2-phenylamino-3-(2-thienoyl)-4,6,7,8-tetrahydrochromen-5-one (6l)

White solid; mp 217–218 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.43 (s, 1H), 7.99–7.96 (m, 2H), 7.53–7.32 (m, 8H), 7.21 (t, J = 6.6 Hz, 1H), 7.03 (t, J = 4.2 Hz, 1H), 5.54 (s, 1H), 2.55 (d, J = 18.6 Hz, 1H), 2.48 (d, J = 18.6 Hz, 1H), 2.33 (d, J = 16.5 Hz, 1H), 2.24 (d, J = 16.5 Hz, 1H), 1.13 (s, 3H), 0.92 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 195.9, 184.3, 161.8, 158.8, 148.3, 146.9, 143.5, 136.4, 133.9, 130.0, 129.2, 128.8, 127.3, 125.2, 122.6, 122.3, 121.7, 116.8, 88.8, 50.5, 40.3, 34.3, 32.3, 29.1, 27.1. IR (KBr, cm^{-1}): 3073, 2952, 1689, 1670, 1619, 1591, 1564, 1381; MS: m/z = 523 (M^++Na). Elemental analysis for $C_{28}H_{24}N_2O_5S$: calc. C, 67.18; H, 4.83; N, 5.60. Found: C, 67.26; H, 4.63; N, 5.39.

4-(2,4-Dichlorophenyl)-7,7-dimethyl-2-phenylamino-3-(2-thienoyl)-4,6,7,8-tetrahydrochromen-5-one (6m)

White solid; mp 155–156 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.02 (s, 1H), 7.41–7.31 (m, 6H), 7.21–7.16 (m, 2H), 7.04 (t, J = 4.2 Hz, 1H), 6.87 (m, 1H), 6.74 (d, J = 8.7 Hz, 1H), 5.50 (s, 1H), 2.55 (d, J = 17.4 Hz, 1H), 2.47 (d, J = 17.4 Hz, 1H), 2.28 (d, J = 16.5 Hz, 1H), 2.19 (d, J = 16.5 Hz, 1H), 1.14 (s, 3H), 1.01 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 196.2, 186.1, 161.4, 157.9,

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142.7, 138.7, 136.6, 133.7, 133.3, 132.6, 130.1, 129.2, 128.7, 127.9, 126.8, 126.2, 125.0, 122.6, 114.0, 88.4, 50.6, 40.3, 35.1, 32.1, 29.2, 27.3. IR (KBr, cm^{-1}): 3056, 2943, 1684, 1671, 1621, 1586, 1561, 1380; MS: m/z = 546 (M^++Na). Elemental analysis for $C_{28}H_{23}Cl_2NO_3S$: calc. C, 64.12; H, 4.42; N, 2.67. Found: C, 64.29; H, 4.27; N, 2.59.

4-(4-Bromophenyl)-7,7-dimethyl-2-phenylamino-3-(2-thienoyl)-4,6,7,8-tetrahydrochromen-5-one (6n)

White solid; mp 207–208 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.55 (s, 1H), 7.45 (d, J = 1.5 Hz, 1H), 7.39–7.32 (m, 7H), 7.21–7.12 (m, 3H), 7.00 (t, J = 4.2 Hz, 1H), 5.40 (s, 1H), 2.53–2.39 (m, 2H), 2.34–2.22 (m, 2H), 1.11 (s, 3H), 0.91 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 196.1, 183.8, 161.5, 159.2, 144.1, 143.7, 136.7, 131.6, 130.1, 129.2, 129.1, 127.4, 125.0, 122.4, 120.4, 117.8, 89.2, 50.7, 40.3, 33.5, 32.3, 29.2, 27.0. IR (KBr, cm^{-1}): 3035, 2942, 1687, 1670, 1629, 1592, 1563; MS: m/z = 556 (M^++Na). Elemental analysis for $C_{28}H_{24}BrNO_3S$: calc. C, 62.92; H, 4.53; N, 2.62. Found: C, 63.13; H, 4.42; N, 2.51.

7,7-dimethyl-4-(4-Methoxyphenyl)-2-phenylamino-3-(2-thienoyl)-4,6,7,8-tetrahydrochromen-5-one (6o)

White solid; mp 175–176 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.59 (s, 1H), 7.44 (d, J = 5.1 Hz, 1H), 7.38–7.35 (m, 5H), 7.20–7.17 (m, 3H), 6.98 (t, J = 4.2 Hz, 1H), 6.77–6.74 (m, 2H), 5.37 (s, 1H), 3.73 (s, 3H), 2.51–2.39 (m, 2H), 2.33–2.22 (m, 2H), 1.10 (s, 3H), 0.90 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 196.3, 183.8, 161.1, 159.4, 158.0, 144.4, 136.9, 130.0, 129.5, 129.2, 128.3, 127.5, 124.8, 122.4, 118.7, 113.9, 89.9, 55.1, 50.8, 40.3, 33.0, 32.3, 29.2, 27.0. IR (KBr, cm^{-1}): 3059, 2927, 1685, 1673, 1620, 1581, 1562, 1383; MS: m/z = 508 (M^++Na). Elemental analysis for $C_{29}H_{27}NO_4S$: calc. C, 71.73; H, 5.60; N, 2.88. Found: C, 71.56; H, 5.81; N, 3.01.

4-(4-Bromophenyl)-3-(2-chlorobenzoyl)-7,7-dimethyl-2-phenylamino-4,6,7,8-tetrahydrochromen-5-one (6p)

White solid; mp 235–236 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.08 (s, 1H), 7.41–7.01 (m, 10H), 6.62–6.44 (m, 3H), 4.44 (s, 1H), 2.56 (d, J = 18.0 Hz, 1H), 2.46 (d, J = 18.0 Hz, 1H), 2.26 (d, J = 16.5 Hz, 1H), 2.14 (d, J = 18.0 Hz, 1H), 1.15 (s, 3H), 0.90 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 195.7, 192.4, 160.3, 157.9, 136.5, 130.8, 129.8, 129.2, 126.6, 125.1, 122.5, 120.1, 117.1, 90.8, 50.5, 40.3, 34.7, 32.2, 29.2, 27.0. IR (KBr, cm^{-1}): 3053, 2941, 1684, 1670, 1627, 1593, 1561; MS: m/z = 584 (M^++Na). Elemental analysis for $C_{30}H_{25}BrClNO_3$: calc. C, 64.01; H, 4.48; N, 2.49. Found: C, 64.12; H, 4.29; N, 2.57.

3-(2-Chlorobenzoyl)-4-(3-nitrophenyl)-2-phenylamino-4,6,7,8-tetrahydrochromen-5-one (6q)

White solid; mp 240–241 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.09 (s, 1H), 7.93 (d, J = 7.2 Hz, 1H), 7.58–6.91 (m, 12H), 4.66 (s, 1H), 2.70–2.66 (m, 2H), 2.34–2.32 (m, 2H), 2.10–1.97 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 195.8, 192.3, 162.4, 157.6, 147.8, 136.2, 134.6, 130.1, 129.2, 128.5, 126.6, 125.4, 123.1, 122.7, 121.4, 117.5, 90.2, 36.6, 35.3, 26.7, 20.0. IR (KBr, cm^{-1}): 3060, 2931, 1684, 1673, 1621, 1593, 1555, 1376; MS: m/z = 523 (M^++Na). Elemental analysis for $C_{28}H_{21}ClN_2O_5$: calc. C, 67.14; H, 4.23; N, 5.59. Found: C, 67.02; H, 4.45; N, 5.50.

3-(2-Chlorobenzoyl)-4-(4-methoxyphenyl)-2-phenylamino-4,6,7,8-tetrahydrochromen-5-one (6r)

White solid; mp 190–192 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.05 (s, 1H), 7.40–7.25 (m, 7H), 6.68–6.58 (m, 6H), 4.43 (s, 1H), 3.72 (s, 3H), 2.64 (br, 2H), 2.33 (br, 2H), 2.06–1.90 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 193.9, 186.4, 161.5, 157.9, 136.8, 129.6, 129.2, 126.4, 124.9, 122.4, 119.2, 113.2, 86.6, 55.1, 36.8, 29.6, 26.7, 20.1. IR (KBr, cm^{-1}): 3067, 2935, 1685, 1671, 1620, 1595, 1557; MS: m/z = 508 (M^++Na). Elemental analysis for $C_{29}H_{24}ClNO_4$: calc. C, 71.67; H, 4.98; N, 2.88. Found: C, 71.85; H, 4.89; N, 2.78.

4-(4-Chlorophenyl)-3-(2-furoyl)-2-phenylamino-4*H*-pyrano[3,2-*c*]chromen-5-one (7a)

White solid; mp 232–233 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.62 (s, 1H), 7.57–7.17 (m, 14H), 7.07 (d, J = 3.0 Hz, 1H), 6.47 (d, J = 1.8 Hz, 1H), 5.96 (s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 178.2, 159.1, 158.4, 153.2, 152.8, 152.6, 144.6, 142.7, 141.5, 136.2, 132.7, 132.4, 129.3, 129.2, 128.6, 125.9, 124.5, 123.9, 122.3, 117.2, 116.9, 112.0, 108.5, 88.5, 34.2. IR (KBr, cm^{-1}): 3056, 2976, 1751, 1739, 1690, 1606, MS: m/z = 518 (M^++Na). Elemental analysis for $C_{29}H_{18}ClNO_5$: calc. C, 70.24; H, 3.66; N, 2.82. Found: C, 70.43; H, 3.49; N, 2.72.

3-(2-Furoyl)-4-phenyl-2-phenylamino-4*H*-pyrano[3,2-*c*]chromen-5-one (7b)

White solid; mp 215–216 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.64 (s, 1H), 7.58–7.43 (m, 9H), 7.33–7.21 (m, 5H), 7.16–7.05 (m, 2H), 6.45 (t, J = 1.8 Hz, 1H), 5.97 (s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 178.3, 160.7, 158.6, 153.2, 152.8, 152.5, 144.6, 144.1, 136.3, 132.2, 129.3, 128.5, 127.7, 127.0, 125.8, 124.4, 123.9, 122.2, 117.0, 116.8, 113.5, 111.8, 109.1, 88.9, 34.7. IR (KBr, cm^{-1}): 3076, 2939, 1755, 1742, 1686, 1609, 1571; MS: m/z = 484 (M^++Na). Elemental analysis for $C_{29}H_{19}NO_5$: calc. C, 75.48; H, 4.15; N, 3.04. Found: C, 75.31; H, 4.33; N, 2.91.

4-(3-Nitrophenyl)-2-phenylamino-3-(2-thienoyl)-4*H*-pyrano[3,2-*c*]chromen-5-one (7c)

White solid; mp 203–204 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.33 (s, 1H), 8.12 (s, 1H), 8.02 (d, J = 8.1 Hz, 1H), 7.68 (d, J = 7.8 Hz, 1H), 7.57–7.29 (m, 12H), 7.06 (t, J = 4.2 Hz, 1H), 5.74 (s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 184.5, 160.5, 158.2, 153.5, 152.6, 148.4, 145.5, 143.0, 135.8, 134.1, 132.8, 130.3, 129.4, 129.3, 129.0, 127.4, 126.2, 124.7, 124.1, 122.6, 122.5, 122.2, 116.9, 113.0, 107.4, 88.1, 36.3. IR (KBr, cm^{-1}): 3075, 2924, 1752, 1741, 1681, 1601, 1582; MS: m/z = 545 (M^++Na). Elemental analysis for $C_{29}H_{18}N_2O_6S$: calc. C, 66.66; H, 3.47; N, 5.36. Found: C, 66.78; H, 3.61; N, 5.19.

4-(4-Fluorophenyl)-2-phenylamino-3-(2-thienoyl)-4*H*-pyrano[3,2-*c*]chromen-5-one (7d)

White solid; mp 203–204 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.45 (s, 1H), 7.56–7.23 (m, 13H), 7.04–6.92 (m, 3H), 5.61 (s,

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1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 184.2, 160.7, 158.6, 153.1, 152.5, 143.7, 139.2, 136.1, 132.4, 130.4, 129.4, 129.3, 129.1, 127.5, 125.9, 124.6, 123.9, 122.3, 116.9, 115.8, 115.5, 113.3, 108.8, 88.8, 35.4. IR (KBr, cm^{-1}): 3054, 2971, 1750, 1734, 1684, 1610, 1591; MS: m/z = 518 (M^++Na). Elemental analysis for $C_{29}H_{18}FN_4S$: calc. C, 70.29; H, 3.66; N, 2.83. Found: C, 70.10; H, 3.54; N, 3.04.

3-(4-Methoxybenzoyl)-2-phenylamino-4-*p*-tolyl-4*H*-pyrano[3,2-*c*]chromen-5-one (7e)

White solid; mp 187–188 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 12.99 (s, 1H), 7.60–7.47 (m, 6H), 7.32–7.21 (m, 5H), 6.98–6.85 (m, 6H), 5.11 (s, 1H), 3.86 (s, 3H), 2.24 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 194.8, 160.8, 157.3, 152.9, 152.5, 140.9, 136.6, 136.5, 132.8, 132.1, 131.3, 129.2, 129.1, 128.5, 127.6, 125.5, 124.4, 123.6, 122.3, 116.8, 113.6, 113.5, 109.1, 89.8, 55.3, 36.6, 21.0. IR (KBr, cm^{-1}): 3065, 2936, 1753, 1738, 1680, 1608, 1578; MS: m/z = 538 (M^++Na). Elemental analysis for $C_{33}H_{25}NO_5$: calc. C, 76.88; H, 4.89; N, 2.72. Found: C, 77.05; H, 4.75; N, 2.63.

3-(4-Methoxybenzoyl)-4-(3-nitrophenyl)-2-phenylamino-4*H*-pyrano[3,2-*c*]chromen-5-one (7f)

White solid; mp 210–212 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 12.97 (s, 1H), 7.95 (d, J = 7.2 Hz, 1H), 7.71 (s, 1H), 7.62–7.47 (m, 7H), 7.34–7.24 (m, 5H), 7.14 (d, J = 8.4 Hz, 1H), 6.87 (d, J = 8.4 Hz, 2H), 5.27 (s, 1H), 3.87 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$ + DMSO-d_6): δ 193.6, 160.0, 159.2, 155.6, 152.3, 151.6, 146.7, 145.0, 135.1, 133.3, 132.0, 131.6, 128.4, 128.3, 127.1, 124.9, 123.9, 122.7, 122.0, 121.6, 120.8, 115.9, 112.7, 112.0, 105.7, 87.8, 54.4, 28.5. IR (KBr, cm^{-1}): 3067, 2934, 1757, 1738, 1681, 1601, 1582; MS: m/z = 569 (M^++Na). Elemental analysis for $C_{32}H_{22}N_2O_7$: calc. C, 70.32; H, 4.06; N, 5.13. Found: C, 70.14; H, 4.19; N, 5.26.

4-(4-Chloro-3-fluorophenyl)-3-(4-methoxybenzoyl)-2-phenylamino-4*H*-pyrano[3,2-*c*]chromen-5-one (7g)

White solid; mp 226–227 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 12.95 (s, 1H), 7.59–7.43 (m, 6H), 7.34–7.12 (m, 6H), 6.88 (d, J = 8.1 Hz, 2H), 6.78–6.70 (m, 2H), 5.14 (s, 1H), 3.87 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 194.8, 161.0, 160.4, 157.1, 153.2, 152.6, 144.8, 144.7, 136.2, 132.6, 130.2, 129.3, 128.3, 125.8, 124.6, 124.2, 123.8, 122.4, 117.0, 116.2, 115.9, 113.7, 113.2, 111.2, 107.6, 88.7, 55.4, 36.7. IR (KBr, cm^{-1}): 3089, 2954, 1743, 1745, 1689, 1603, 1582; MS: m/z = 576 (M^++Na). Elemental analysis for $C_{32}H_{21}ClFNO_5$: calc. C, 69.38; H, 3.82; N, 2.53. Found: C, 69.20; H, 3.98; N, 2.61.

4-(4-Bromophenyl)-3-(2-chlorobenzoyl)-2-phenylamino-4*H*-pyrano[3,2-*c*]chromen-5-one (7h)

White solid; mp 202–204 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.0 (s, 1H), 7.59–7.51 (m, 6H), 7.31–7.03 (m, 8H), 6.76–6.46 (m, 3H), 4.67 (s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 192.7, 160.1, 157.3, 152.5, 152.4, 135.8, 132.5, 131.1, 130.1, 129.3, 126.7, 126.1, 124.6, 124.0, 122.4, 120.8, 116.9, 113.2, 108.0, 89.8, 36.3. IR (KBr, cm^{-1}): 2978, 1750, 1737, 1679, 1606, 1583; MS: m/z = 606 (M^++Na). Elemental analysis for $C_{31}H_{19}BrClNO_4$: calc. C, 63.66; H, 3.27; N, 2.39. Found: C, 63.75; H, 3.04; N, 2.50.

3-(2-Chlorobenzoyl)-4-(4-nitrophenyl)-2-phenylamino-4*H*-pyrano[3,2-*c*]chromen-5-one (7i)

White solid; mp 265–266 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 13.04 (s, 1H), 7.95 (d, J = 8.4 Hz, 2H), 7.61–7.25 (m, 12H), 7.04 (m, 2H), 6.41 (s, 1H), 4.86 (s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): 192.4, 160.0, 157.2, 152.8, 152.7, 146.7, 135.5, 132.9, 130.3, 129.4, 126.8, 126.4, 124.7, 124.1, 123.2, 122.5, 117.0, 112.9, 107.0, 89.2, 36.9. IR (KBr, cm^{-1}): 2967, 1746, 1725, 1683, 1599; MS: m/z = 573 (M^++Na). Elemental analysis for $C_{31}H_{19}ClN_2O_6$: calc. C, 67.58; H, 3.48; N, 5.08. Found: C, 67.77; H, 3.24; N, 5.21.

7-(4-Bromophenyl)-13-phenyl-7,13-dihydro-5,14-dioxa-13-azabenzo[*a*]naphthacene-6,8-dione (8a)

White solid; mp >300 °C. ^{1}H NMR (300 MHz, $CDCl_3$): 8.26 (d, J = 7.5 Hz, 1H), 8.17 (d, J = 7.5 Hz, 1H), 7.67–7.35 (m, 13H), 7.17 (d, J = 7.5 Hz, 1H), 6.74 (d, J = 8.4 Hz, 1H), 5.27 (s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): 174.4, 160.4, 156.8, 156.7, 154.2, 152.6, 144.8, 131.4, 131.2, 130.8, 130.2. 129.1, 128.8, 124.5, 122.7, 122.5, 122.2, 116.3, 110.8, 105.9, 34.8. IR (KBr, cm^{-1}): 3091, 2926, 1743, 1668, 1618, 1591, 1541, 1366; MS: m/z = 570 (M^++Na). Elemental analysis for $C_{31}H_{18}BrNO_4$: calc. C, 67.90; H, 3.31; N, 2.55. Found: C, 68.11; H, 3.21; N, 2.40.

7-(4-Nitrophenyl)-13-phenyl-7,13-dihydro-5,14-dioxa-13-azabenzo[*a*]naphthacene-6,8-dione (8b)

White solid; mp >300 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.28 (d, J = 7.5 Hz, 1H), 8.19 (d, J = 7.5 Hz, 1H), 8.12–8.09 (m, 2H), 7.67–7.41 (m, 11H), 7.14 (d, J = 6.9 Hz, 1H), 6.76 (d, J = 8.4 Hz, 1H), 5.40 (s, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 173.9, 169.1, 159.4, 150.8, 147.6, 146.2, 139.5, 137.4, 135.4, 134.4, 129.4, 125.7, 124.1, 123.3, 122.2, 118.4, 117.8, 116.0, 115.8, 108.6, 36.9. IR (KBr, cm^{-1}): 3063, 2954, 1749, 1663, 1610, 1581, 1550, 1363; MS: m/z = 537 (M^++23). Elemental analysis for $C_{31}H_{18}N_2O_6$: calc. C, 72.37; H, 3.53; N, 5.44. Found: C, 72.42; H, 3.31; N, 5.63.

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