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Synthesis and *in vitro* evaluation of antioxidant activity of diverse naphthopyranopyrimidines, diazaanthra[2,3-*d*][1,3]dioxole-7,9-dione and tetrahydrobenzo[*a*]xanthen-11-ones†

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A green and efficient one pot three component protocol has been developed for the synthesis of naphthopyranopyrimidines, diazaanthra[2,3-*d*][1,3]dioxole-7,9-dione and tetrahydrobenzo[*a*]xanthen-11-ones in PEG-400 catalyzed by alum ($KAl(SO_4)_2{\cdot}12H_2O$). Single crystal X-ray diffraction studies have been performed for naphthopyranopyrimidine (**5**). The synthesized compounds were screened for *in vitro* antioxidant activity by DPPH scavenging assay and compounds **3** and **4** manifested profound antioxidant potential.

Introduction

Development of novel synthetic methodologies to facilitate the preparation of libraries of compounds is important for modern medicinal and combinatorial chemistry.[1] Multicomponent reactions (MCRs) have become an important tool for the creation of molecular complexity and diversity.[2] *N*- and *O*-Heterocycles hold a position of prominence due to their applications as biologicals, pharmacophores, pharmaceuticals and agrochemicals. Pyranopyrimidines show wide range of useful physiological,[3] antimicrobial,[4] analgesic, and anticonvulsant activities.[5] Moreover, naphthopyranopyrimidines and its derivatives are important structural motifs in medicinal and pharmaceutical chemistry[6] as they show antibacterial and antifungal activities.[7,8] Furthermore, xanthenes have also attracted a great deal of interest due to their wide gamut of biological properties like antiviral,[9] antibacterial,[10] and anti-inflammatory[11] activities as well as sensitizers in photodynamic therapy[12] and antagonists for the paralyzing action of zoxazolamine.[13] Recently, several multicomponent strategies have been reported for the synthesis of napthopyranopyrimidines and tetrahydrobenzo[*a*]xanthen-11-ones utilizing different types of catalysts.[14] The reported methods show varying degrees of successes as well as limitations. Therefore, there still remains a high demand for the development of more general, efficient, economically viable, and eco-compatible protocol to assemble such scaffolds.

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Recently, alum ($KAl(SO_4)_2{\cdot}12H_2O$) which is inexpensive, water-soluble and nontoxic has emerged as economic and excellent catalyst for the synthesis of organic compounds.[15] Polyethylene glycol (PEG) has been reported as an interesting solvent system, which is non-toxic, inexpensive and non-ionic liquid solvent of low volatility, for a variety of reactions.[16] Therefore, we decided to investigate a green and efficient protocol for the synthesis of series of novel naphthopyranopyrimidines, diazaanthra[2,3-*d*][1,3]dioxole-7,9-dione and tetrahydrobenzo[*a*]xanthen-11-ones in PEG-400 catalyzed by $KAl(SO_4)_2{\cdot}2H_2O$.

The generation of free radicals during metabolic processes is responsible for human conditions such as aging, cancer, atherosclerosis, arthritis, viral infection stroke, myocardial infraction *etc.* Antioxidants act as a major defense against radical mediated toxicity by inhibiting the free radicals. In recent years, compounds which exhibit DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity are receiving attention.[17] It can be inferred from the literature that phenolic compounds usually possess potential antioxidant activity because of phenolic hydroxy groups which act as a hydrogen or electron donors[18] but little attention has been paid to explore the antioxidant activity of substituted naphthopyranopyrimidines and xanthene derivatives. Therefore, the synthesized compounds were evaluated for *in vitro* antioxidant activity by DPPH radical scavenging assay method.

Results and discussion

Chemistry

In the present study, we have reported $KAl(SO_4)_2{\cdot}2H_2O$ catalyzed PEG-400 mediated synthesis of diversely substituted

napthopyranopyrimidines (**3a–o**, **4a–b** and **5a–d**) and diazaanthra[2,3-*d*] [1,3]dioxole-7,9-dione (**6a–f**) by one pot condensation of aldehydes and *N*,*N*-dimethylbarbituric acid with 2,7-dihydroxynaphthalene (**1a**) or 2,6-dihydroxynaphthalene (**1b**) or 2-hydroxynaphthalene (**1c**) or benzo[1,3]dioxol-5-ol (**1d**) respectively. The protocol has been also applied for the synthesis of tetrahydrobenzo[*a*]xanthen-11-ones (**7a–e** and **8a–e**) by condensation of 2,7-dihydroxynaphthalene, aldehydes and cyclic-1,3-dicarbonyl compounds, namely 5-methyl-cyclohexane-1,3-dione (**1e**) and cyclohexane-1,3-dione (**1f**).

Initially, the three component cyclocondensation of 4-chlorobenzaldehyde (1.0 mmol), 2,7-dihydroxynaphthalene **1a** (1.0 mmol) and *N*,*N*-dimethylbarbituric acid (1.2 mmol) was examined in PEG-400 without any catalyst. After 3 h of heating at 60 °C, two new products were observed on TLC but the reaction remained incomplete even after 24 h of heating. The newly formed products were separated by column chromatography and were identified to be 12-(4-chlorophenyl)-2-hydroxy-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*] pyrimidine-9,11-(10*H*)-dione (**3a**) and 5-(4-chlorobenzylidene)-1,3-dimethylpyrimidine-2,4,6-trione (**2**) by spectral analysis. However, the desired product naphthopyranopyrimidine (**3a**) was formed only in 20% while the Knoevenagel condensation product (**2**) was formed as the major one in 58% yield (Table 1, entry 1). The above reaction was then attempted in presence of Lewis acids *i.e.* NaBr, TMSCl, LiCl, La(OTf)$_3$, $CeCl_3{\cdot}7H_2O$ and $KAl(SO_4)_2{\cdot}12H_2O$ in PEG-400 at 60 °C (Table 1). We observed that reaction using 15 mol% of $KAl(SO_4)_2{\cdot}12H_2O$ proceeded efficiently and gave 92% of the desired product **3a**. In view of its ease to handle and cost effectiveness we decided to pursue the reactions with $KAl(SO_4)_2{\cdot}12H_2O$ (alum). The reaction using 10 mol% of alum gave inferior yield while reaction with 20 mol% of alum was not affected (entries **6** and **7**, Table 1). The reactions attempted in PEG-200 and PEG-600 in an analogous manner resulted in the formation of the desired product **3a** in 71% and 82% respectively (entries 10–11, Table 1).

The condensation of *N*,*N*-dimethylbarbituric acid, aromatic aldehydes and 2,7-dihydroxynaphthalene (**1a**)/2,6-dihydroxy naphthalene (**1b**)/2-hydroxynaphthalene (**1c**) or benzo[1,3]-dioxol-5-ol (**1d**) was then carried out under the above optimized conditions (Scheme 1). All the reactions proceeded smoothly and resulted in the synthesis of 12-aryl-2-hydroxy-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (**3a–o**, Table 1), 3-hydroxy-12-aryl-2-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6] pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (**4a–b**, Table 2), 12-aryl-8,12-dihydro-8,10-dimethyl-9*H*-naphtho [1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (**5a-d**, Table 2) and 10-(4-chlorophenyl)-6,8-dimethyl-6,10-dihydro-5-oxa-6,8-diazaanthra [2,3-*d*][1,3]dioxole-7,9-dione (**6a–f**, Table 2). This protocol tolerates a variety of aromatic aldehydes containing electron-withdrawing and electron-donating substituents.

Additionally, the structure of the synthesized derivative (**5a**) has been confirmed by single crystal X-ray diffraction analysis (Fig. 1), see ESI.†

We further extended this synthetic protocol for one pot, three component condensation of aldehydes (1.0 mmol), 2,7-dihydroxy naphthalene **1a** (1.0 mmol) and cyclic-1,3-dicarbonyl compounds (5,5-dimethylcyclohexane-1,3-dione (**1e**) and cyclohexane-1,3-dione (**1f**)) (1.2 mmol) using $KAl(SO_4)_2{\cdot}12H_2O$ in PEG-400 at 60 °C. The reactions yielded 2-hydroxy-9,9-dimethyl-12-aryl-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-ones (Table 1, **7a–e**) and 12-aryl-2-hydroxy-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-ones (Table 1, **8a–e**) in good yields (Scheme 2).

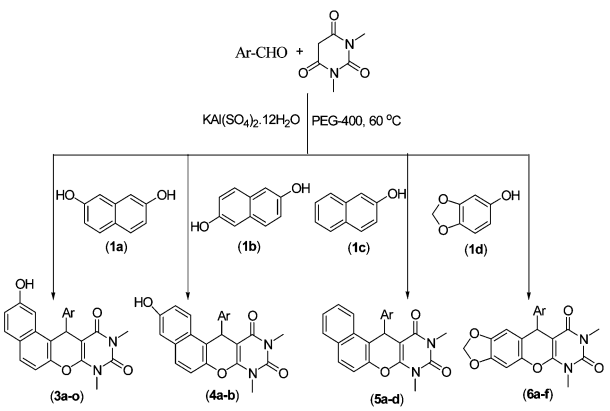
The plausible mechanism for the formation of naphthopyranopyrimidines is proposed in Scheme 3. The reaction proceeded *via ortho*-quinone methide intermediate, which was formed by the nucleophilic addition of β-naphthol to aldehydes catalyzed by $KAl(SO_4)_2{\cdot}12H_2O$. Michael addition between *ortho*-quinone methide **(1)** and *N*,*N*-dimethylbarbituric acid and subsequent intramolecular cyclization and elimination of H_2O afforded the desired product **5**. The proposed mechanism was supported by the fact that when the reaction of 5-(4-chlorobenzylidene)-1,3-dimethylpyrimidine-2,4,6-trione **(2)** and 2-naphthol was carried out under similar reaction conditions, no reaction was observed (Scheme 4) which supports our proposed mechanism.

The recyclability of PEG-400 was also investigated during the synthesis of **3a**. After completion, the reaction was quenched

Table 1 Effect of catalyst on the condensation of 4-chlorobenzaldehyde, 2,7-dihydroxynaphthalene and *N*,*N*-dimethylbarbituric acid (molar ratio 1 : 1 : 1.2)

Entry	Solvent	Catalyst	Loading (mol%)	Time	Yield **3a** (%)
1	PEG-400	None	—	24 h	20[a,b]
2	PEG-400	NaBr	15	7 h	50[b]
3	PEG-400	TMSCl	15	7 h	—[c]
4	PEG-400	LiCl	15	6 h	40[b]
5	PEG-400	La(OTf)$_3$	15	7 h	53[b]
6	PEG-400	$CeCl_3{\cdot}7H_2O$	15	45 min	85
7	PEG-400	$KAl(SO_4)_2{\cdot}12H_2O$	15	45 min	92
8	PEG-400	$KAl(SO_4)_2{\cdot}12H_2O$	10	70 min	60
9	PEG-400	$KAl(SO_4)_2{\cdot}12H_2O$	20	45 min	91
10	PEG-200	$KAl(SO_4)_2{\cdot}12H_2O$	15	4 h	71
11	PEG-600	$KAl(SO_4)_2{\cdot}12H_2O$	15	3 h	82

[a] Incomplete reaction. [b] Yields after column chromatography. [c] Mixture of products.



Scheme 1 Synthesis of naphthopyranopyrimidines and diazaanthra[2,3-*d*][1,3]dioxole-7,9-diones.

Table 2 Synthesis of naphthopyranopyrimidines, diazaanthra[2,3-*d*][1,3]dioxole-7,9-diones and tetrahydrobenzo[*a*]xanthen-11-ones

Entry	Ar	Product	Yield (%)	Time (min)
1	4-ClC_6H_4	**3a**	92	45
2	2-ClC_6H_4	**3b**	87	40
3	3-ClC_6H_4	**3c**	84	40
4	2,4-$Cl_2C_6H_3$	**3d**	86	60
5	4-$OMeC_6H_4$	**3e**	82	70
6	2-$OMeC_6H_4$	**3f**	82	90
7	3,4,5-$(OMe)_3C_6H_2$	**3g**	76	90
8	4-MeC_6H_4	**3h**	82	70
9	4-$O_2NC_6H_4$	**3i**	89	40
10	3-$O_2NC_6H_4$	**3j**	83	45
11	2-$O_2NC_6H_4$	**3k**	89	60
12	4-CNC_6H_4	**3l**	78	50
13	4-$F_3CC_6H_4$	**3m**	85	60
14	C_6H_5	**3n**	85	90
15	4-FC_6H_4	**3o**	87	35
16	4-ClC_6H_4	**4a**	83	45
17	4-$O_2NC_6H_4$	**4b**	89	35
18	4-ClC_6H_4	**5a**	84	50
19	4-$O_2NC_6H_4$	**5b**	86	50
20	4-FC_6H_4	**5c**	84	60
21	4-$F_3CC_6H_4$	**5d**	78	45
22	4-ClC_6H_4	**6a**	75	90
23	3-ClC_6H_4	**6b**	72	60
24	4-MeC_6H_4	**6c**	80	50
25	4-FC_6H_4	**6d**	72	60
26	4-$O_2NC_6H_4$	**6e**	75	90
27	C_6H_5	**6f**	75	75
28	4-ClC_6H_4	**7a**	86	45
29	4-$CF_3C_6H_4$	**7b**	84	60
30	4-FC_6H_4	**7c**	82	50
31	4-$O_2NC_6H_4$	**7d**	87	50
32	4-$OMeC_6H_4$	**7e**	85	75
33	4-ClC_6H_4	**8a**	83	60
34	4-$O_2NC_6H_4$	**8b**	86	40
35	C_6H_5	**8c**	89	75
36	4-$F_3CC_6H_4$	**8d**	88	45
37	4-MeC_6H_4	**8e**	84	60

with water and the solid product was collected by filtration. The filtrate containing polyethylene glycol was rinsed with ether and further vacuumed to dryness at 90 °C for 2 h to remove any trapped water, to afford PEG-400 which was reused directly for the next run. The reaction proceeded with nearly

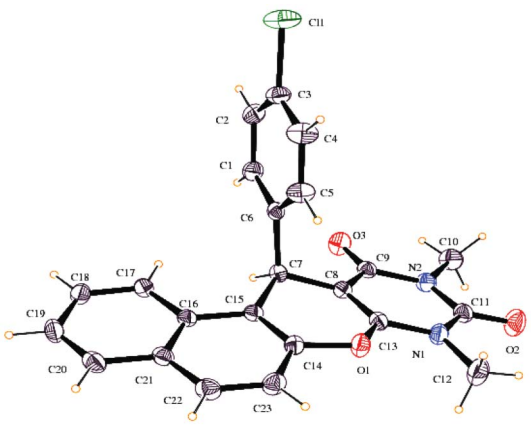
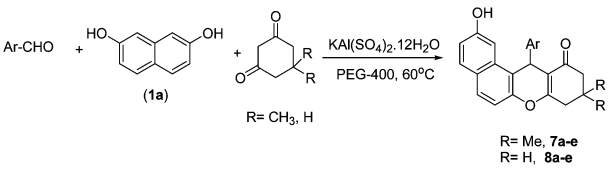
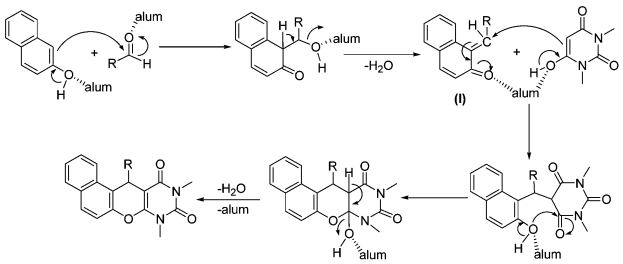


Fig. 1 Ortep diagram of compound **5a** drawn with 50% probability ellipsoid.



Scheme 2 Synthesis of tetrahydrobenzo[*a*]xanthen-11-ones.



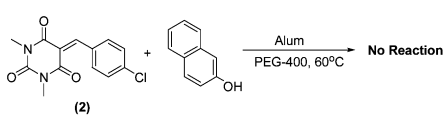
Scheme 3 Mechanism for the synthesis of napthopyranopyrimidines.

consistent results for three runs. The results are summarized in Fig. 2.

Radical scavenging assay

The electronic absorption spectra of solutions of **3a–o**, **4a–b**, **5a–d**, **6a–f**, **7a–e** and **8a–e** (2×10^{-4} M) were measured in DMSO. All the compounds showed two absorption maxima (λ_{max}) located between 310 and 350 nm. All these compounds were screened for their antioxidant activity by measuring their scavenging ability towards 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical. The disappearance of DPPH was measured spectrophotometrically at 517 nm using butylated hydroxy toluene (BHT) as standard. All the results are summarized in Fig. 3.

It can be inferred from Fig. 3 that the majority of compounds **3** and **4** showed higher radical scavenging activity compared to BHT whereas compounds **5**, **6**, **7** and **8** showed lower scavenging activity except **5b**. The higher scavenging activity in **3** could be attributed to the formation of two radicals **I** and **II** (Scheme 5) both of which are stabilized by resonance. Similarly compounds **4** also give two resonance stabilized radicals and show comparable activity to compounds **3**. The OH position does not seem to have any significant effect. The difference in the activity of **3a–o** could be due to the difference in the stability of the radicals **I** and **II**. Compounds bearing electron-withdrawing groups, **3a**, **3d**, **3i**, **3j**, **3k**, **3l** and **3o**, showed a higher hydrogen donor ability



Scheme 4 Reaction of 5-(4-chlorobenzylidene)-1,3-dimethyl-pyrimidine-2,4,6-trione with 2-naphthol.

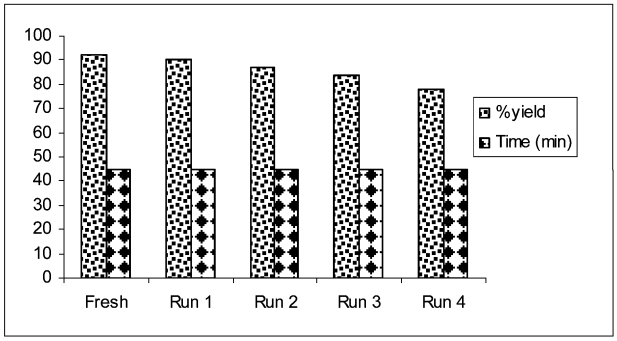
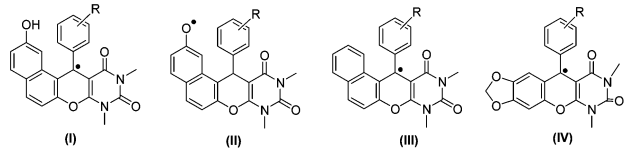


Fig. 2 Recycling yields. Reactions of 2,7-dihydroxynaphthalene, 4-chlorobenzaldehyde, *N*,*N*-dimethylbarbituric acid, $KAl(SO_4)_2{\cdot}12H_2O$ and PEG-400.

towards DPPH radical compared to compounds **3e**, **3h** and **3g** having electron donating groups. On the other hand, compounds **5** and **6** do not have any phenolic OH groups and therefore can form only benzylic radicals (**III**) and (**IV**) respectively that results in the lower activity. The lower activity in xanthenes **7** and **8**, though they contain a phenolic hydroxyl group, could be attributed to the absence of the pyrimidine moiety in which the lone pair on the nitrogen stabilizes the free radical.

Experimental

All the chemicals used were purchased from Sigma-Aldrich and were used as received. Silica gel 60 F_{254} (Precoated aluminium plates) from Merck was used to monitor reaction progress. Melting points were determined on a Tropical Labequip apparatus and are uncorrected. IR (KBr) spectra were recorded on a Perkin-Elmer FTIR spectrophotometer and the values are expressed as ν_{max} cm^{-1}. Absorbance measurements were made using a Analytikjena Specord 250 Spectrophotometer. Mass spectral data were recorded on JEOL-AccuTOF mass spectrometer having a DART source. The ^1H NMR and ^{13}C NMR spectra were recorded on a Jeol



Scheme 5

JNM ECX-400P at 400 MHz and Bruker Avance Spectrospin 300 MHz, using TMS as an internal standard. The chemical shift values are recorded on the δ scale and the coupling constants (J) are in Hertz. Elemental analysis was performed by a Vario EL III Elementar analyzer. X-Ray intensity data was collected on an Oxford Diffraction Xcalibur CCD diffractometer with graphite monochromated Mo-Kα radiation (λ = 0.71073 Å) at temperature 298 K.

General procedure for the synthesis of naphthopyranopyrimidines and diazaanthra[2,3-*d*][1,3]dioxole-7,9-diones

A mixture of aldehyde (1.0 mmol), **1a**/**1b**/**1c**/**1d** (1.0 mmol), *N*,*N*-dimethylbarbituric acid (1.2 mmol), alum (15 mol%) and 5 mL of PEG-400 was placed in a 50 mL round-bottomed flask. The mixture was stirred at 60 °C for the appropriate time as mentioned in Table 1. After completion of the reaction as monitored by TLC using ethyl acetate : petroleum ether (30 : 70, v/v) as eluent, the mixture was allowed to cool at room temperature and quenched with water (10–15 mL). The precipitate thus formed was collected by filtration at pump, washed with water and then with ethanol : water (1 : 1) to afford pure diazabenzo[*a*]anthracene-9,11-diones.

General procedure for the synthesis of tetrahydrobenzo[*a*]xanthen-11-ones

In a 50 mL round bottomed flask, aldehyde (1.0 mmol), 2,7-dihydroxynaphthalene (1.0 mmol), **1e** or **1f** (1.0 mmol), alum (15 mol%) and 5 mL of PEG-400 were taken. The reaction mixture was heated at 60 °C for the appropriate time as mentioned in Table 1. The progress of the reaction was monitored by TLC using ethyl acetate : petroleum ether

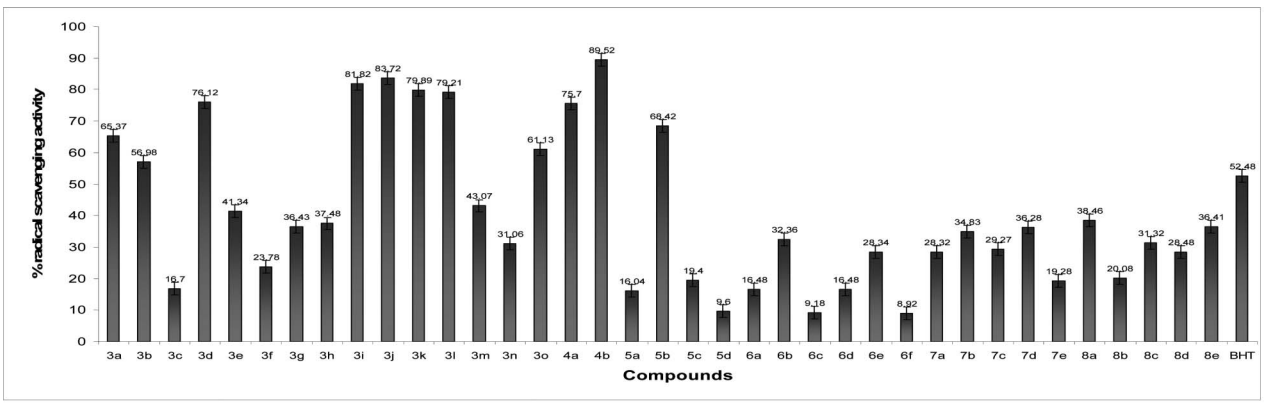


Fig. 3 (%) DPPH radical scavenging activity.

(40 : 70, v/v) as eluent. After completion of the reaction, the reaction mixture was allowed to cool to room temperature and quenched with water (~10–15 mL). The precipitate formed was collected by filtration at pump, washed with water and then ethanol : water (1 : 1) to yield pure tetrahydrobenzo[*a*]xanthen-11-ones.

DPPH free radical scavenging assay

A methanol solution of 2,2-diphenyl-1-picrylhydrazyl (DPPH) was used as a reagent for the spectrophotometric assay with modifications.[19] 3 mM solutions of naphthopyranopyrimidines, diazaanthra[2,3-*d*][1,3]dioxole-7,9-diones and tetrahydrobenzo[*a*]xanthen-11-ones were prepared using DMSO. 1 mL of 0.1 mM methanolic solution of DPPH was added to a 3 mL solution of the compound and the mixture was shaken vigorously using a vortex mixer. Absorbance was read against a blank at 517 nm after incubation of the reaction mixtures for 60 min in the dark at room temperature. Butylated hydroxyl toluene (BHT) was used as a reference compound. The radical scavenging activities were expressed as the inhibition percentage and were calculated using the formula:

$$\text{Radical scavenging activity (\%)} = [(A_0 - A_1)/A_0) \times 100]$$

where A_0 is absorbance of the control (blank, without compound) and A_1 is the absorbance of the compound. All the tests were carried out in triplicate and the results were averaged.

12-(4-Chlorophenyl)-2-hydroxy-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3a, $C_{23}H_{17}ClN_2O_4$)

White solid; Yield = 92%; M.p.: >300 °C (decom.); R_f 0.40 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d$_6$): δ = 9.94 (s, 1H, OH), 7.83–7.75 (m, 2H, Ar), 7.31–7.23 (m, 5H, Ar), 7.12 (s, 1H, Ar), 7.00 (dd, $^{1,2}J$ = 2.2 Hz, $^{1,3}J$ = 8.6 Hz, 1H, Ar), 5.39 (s, 1H, ArC$\underline{H}$), 3.45 (s, 3H, NC$\underline{H}_3$), 3.13 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d$_6$): δ = 161.18, 156.75, 152.28, 150.12, 147.26, 143.10, 132.03, 131.16, 130.50, 130.13, 129.55, 128.20, 125.82, 117.70, 114.46, 113.39, 105.48, 89.68, 39.29, 28.99, 27.81 ppm; IR (KBr): $\nu_{max,}$ cm^{-1} = 3277, 1670, 1641, 1525, 1448, 1348, 1230; MS (ESI) *m*/*z* Calcd. for $C_{23}H_{17}ClN_2O_4$: 420.09, Found: 421.16 [M$^+$ + H], 423.15 [M$^+$ + H + 2]; Anal. Calcd. for $C_{23}H_{17}ClN_2O_4$: C, 65.64; H, 4.07; N, 6.66; Found: C, 65.62; H, 4.06, N, 6.62; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.323 × 10^4 L mol^{-1} cm^{-1}), 337 (0.411 × 10^4 L mol^{-1} cm^{-1}).

12-(2-Chlorophenyl)-2-hydroxy-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3b, $C_{23}H_{17}ClN_2O_4$)

White solid; Yield = 87% ; M.p.: >300 °C (decom.); R_f 0.45 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d$_6$): δ = 9.99 (s, 1H, OH), 7.86 (d, *J* = 8.8 Hz, 1H, Ar), 7.75 (d, *J* = 8.8 Hz, 1H, Ar), 7.33–7.26 (m, 4H, Ar), 7.18–7.09 (m, 2H, Ar), 7.03 (dd, $^{1,2}J$ = 2.2 Hz, $^{1,3}J$ = 8.8 Hz, 1H, Ar), 5.70 (s, 1H, ArC$\underline{H}$), 3.48 (s, 3H, NC$\underline{H}_3$), 3.11 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d$_6$): δ 160.84, 156.66, 152.46, 150.06, 147.32, 141.05, 132.44, 132.31, 132.11, 130.34, 129.63, 129.57, 128.25, 127.22, 125.66, 117.49, 114.27, 113.31, 105.79, 89.05, 33.94, 28.95, 27.68 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3225, 1660, 1620, 1458, 1220; MS (ESI) *m*/*z* Calcd. for $C_{23}H_{17}ClN_2O_4$: 420.09, Found: 421.16 [M$^+$ + H], 423.10 [M$^+$ + H + 2]; Anal. Calcd. for $C_{23}H_{17}ClN_2O_4$: C, 65.64; H, 4.07; N, 6.66; Found: C, 65.61; H, 4.04; N, 6.64; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) : 314 nm (0.315 × 10^4 L mol^{-1} cm^{-1}), 326 (0.441 × 10^4 L mol^{-1} cm^{-1}).

12-(3-Chlorophenyl)-2-hydroxy-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3c, $C_{23}H_{17}ClN_2O_4$)

White solid; Yield = 84%; M.p.: >300 °C (decom.); R_f 0.40 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d$_6$): δ = 9.99 (s, 1H, OH), 7.86 (d, *J* = 8.8 Hz, 1H, Ar), 7.79 (d, *J* = 8.8 Hz, 1H, Ar), 7.35 (d, *J* = 8.8 Hz, 2H, Ar), 7.24–7.14 (m, 4H, Ar), 7.01 (dd, $^{1,2}J$ = 2.2, $^{1,3}J$ = 8.8 Hz, 1H, Ar), 5.42 (s, 1H, ArC$\underline{H}$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.14 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d$_6$): δ = 161.13, 156.75, 152.38, 150.05, 147.32, 146.35, 132.72, 131.94, 130.46, 130.11, 129.60, 127.99, 126.93, 126.63, 125.74, 117.68, 114.17, 113.33, 105.33, 89.41, 35.42, 28.95, 27.76 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3277, 1670, 1525, 1348, 1230; MS (ESI) *m*/*z* Calcd. for $C_{23}H_{17}ClN_2O_4$: 420.09, Found: 421.11 [M$^+$ + H], 423.11 [M$^+$ + H + 2]; Anal. Calcd. for $C_{23}H_{17}ClN_2O_4$: C, 65.64; H, 4.07; N, 6.66; Found: C, 65.63; H, 4.05; N, 6.65; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 324 nm (0.260 × 10^4 L mol^{-1} cm^{-1}), 337 (0.324 × 10^4 L mol^{-1} cm^{-1}).

12-(2,4-Dichlorophenyl)-2-hydroxy-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3d, $C_{23}H_{16}Cl_2N_2O_4$)

White solid; Yield = 86%; M.p.: >300 °C (decom.); R_f 0.35 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d$_6$): δ = 9.92 (s, 1H, OH), 7.80 (d, *J* = 8.8 Hz, 1H, Ar), 7.74 (d, *J* = 8.7 Hz, 1H, Ar), 7.44 (d, *J* = 2.2 Hz, 1H, Ar), 7.31–7.18 (m, 4H, Ar), 7.03 (dd, $^{1,2}J$ = 2.2 Hz, $^{1,3}J$ = 8.8 Hz, 1H, Ar), 5.64 (s, 1H, ArC$\underline{H}$), 3.49 (s, 3H, NC$\underline{H}_3$), 3.10 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d$_6$): δ = 160.92, 156.75, 152.40, 150.02, 147.26, 140.20, 133.42, 132.34, 131.90, 130.42, 129.78, 128.84, 127.40, 125.66, 117.54, 113.63, 113.28, 105.64, 88.57, 33.62, 28.95, 27.68 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3186, 1660, 1621, 1455, 1225; MS (ESI) *m*/*z* Calcd. for $C_{23}H_{16}Cl_2N_2O_4$: 454.05, Found: 453.10 [M$^+$ + H], 455.10 [M$^+$ + H + 2]; Anal. Calcd. for $C_{23}H_{16}Cl_2N_2O_4$: C, 60.67; H, 3.54; N, 6.15; Found: C, 60.66; H, 3.56; N, 6.14; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.354 × 10^4 L mol^{-1} cm^{-1}), 338 (0.440 × 10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-methoxyphenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3e, $C_{24}H_{20}N_2O_5$)

White solid; Yield = 86%; M.p.: >300 °C (decom.); R_f 0.35 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d$_6$): δ = 9.93 (s, 1H, OH), 7.82 (d, *J* = 8.6 Hz, 1H, Ar), 7.77 (d, *J* = 9.1 Hz, 1H, Ar), 7.32 (d, *J* = 9.16 Hz, 1H, Ar), 7.18–7.16 (m, 3H, Ar), 6.99 (dd, $^{1,2}J$ = 1.8 Hz, $^{1,3}J$ = 8.7 Hz, 1H, Ar), 6.75 (d, *J* = 8.7 Hz, 2H, Ar), 5.36 (s, 1H, ArC$\underline{H}$), 3.62 (s, 3H, OC$\underline{H}_3$), 3.46 (s, 3H, NC$\underline{H}_3$), 3.14 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d$_6$): δ = 160.98, 157.65, 151.38, 151.43, 148.29, 141.23,

133.44, 132.35, 131.91, 130.44, 129.68, 128.81, 127.42, 125.69, 117.58, 113.61, 113.29, 105.66, 88.58, 55.69, 33.62, 28.95, 27.68 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3200, 1670, 1638, 1554, 1245; MS (ESI) *m*/*z* Calcd. for $C_{24}H_{20}N_2O_5$: 416.14, Found: 453.1 [M^+ + H], 455.1 [M^+ + H + 2]; Anal. Calcd. for $C_{24}H_{20}N_2O_5$: C, 69.22; H, 4.84; N, 6.73; Found: C, 69.25; H, 4.81; N, 6.72; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) : 324 nm (0.273×10^4 L mol^{-1} cm^{-1}), 337 (0.336×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(2-methoxyphenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3f, $C_{24}H_{20}N_2O_5$)

White solid; Yield = 82%; M.p.: >300 °C (decom.); R_f 0.30 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.82 (s, 1H, OH), 7.76–7.70 (m, 2H, Ar), 7.40 (s, 1H, Ar), 7.32–7.31 (m, 1H, Ar), 7.26 (d, *J* = 8.8 Hz, 1H, Ar), 7.09–7.05 (m, 1H, Ar), 6.99–6.97 (m, 1H, Ar), 6.87–6.79 (m, 2H, Ar), 5.59 (s, 1H, ArC$\underline{H}$), 3.71 (s, 3H, OC$\underline{H}_3$), 3.50 (s, 3H, NC$\underline{H}_3$), 3.14 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 160.81, 156.60, 152.46, 151.06, 147.32, 141.04, 132.44, 132.32, 132.11, 130.34, 129.63, 129.57, 128.25, 127.22, 125.66, 117.49, 114.27, 113.31, 105.79, 89.05, 55.98, 33.94, 28.95, 27.76 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3160, 1660, 1630, 1550, 1240; MS (ESI) *m*/*z* Calcd. for $C_{24}H_{20}N_2O_5$: 416.14, Found: 417.12 [M^+ + H]; Anal. Calcd. for $C_{24}H_{20}N_2O_5$: C, 69.22; H, 4.84; N, 6.73; Found: C, 69.24; H, 4.82; N, 6.71; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.239×10^4 L mol^{-1} cm^{-1}), 337 (0.298×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(3,4,5-trimethoxyphenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3g, $C_{26}H_{24}N_2O_7$)

White solid; Yield = 76%; M.p.: >300 °C (decom.); R_f 0.30 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.96 (s, 1H, OH), 7.84 (d, *J* = 8.8 Hz, 1H, Ar), 7.79 (d, *J* = 8.8 Hz, 1H, Ar), 7.34 (d, *J* = 8.8 Hz, 1H, Ar), 7.25 (s, 1H, Ar), 7.01 (dd, $^{1,2}J$ = 2.2 Hz, $^{1,3}J$ = 8.6 Hz, 1H, Ar), 6.52–6.47 (m, 2H, Ar), 5.37 (s, 1H, ArC$\underline{H}$), 3.63 (s, 6H, 2 × OC$\underline{H}_3$), 3.53 (s, 3H, OC$\underline{H}_3$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.16 (s, 3H, NC$\underline{H}_3$); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.26, 156.61, 152.51, 152.42, 150.13, 147.35, 139.71, 136.13, 132.18, 130.41, 129.28, 125.74, 117.67, 115.01, 113.35, 105.59, 90.08, 59.82, 55.80, 35.78, 28.96, 27.82; IR (KBr) $\nu_{max,}$ cm^{-1} = 3190, 1640, 1615, 1412, 1220; MS (ESI) *m*/*z* Calcd. for $C_{26}H_{24}N_2O_7$: 476.48, Found: 477.23 [M^+ + H]; Anal. Calcd. for $C_{26}H_{24}N_2O_7$ C, 65.54; H, 5.08; N, 5.88; Found: C, 65.52; H, 5.06; N, 5.85; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) = 323 nm (0.307×10^4 L mol^{-1} cm^{-1}), 337 (0.383×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-methylphenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3h, $C_{24}H_{20}N_2O_4$)

White solid; Yield = 82%; M.p.: >300 °C (decom.); R_f 0.40 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.92 (s, 1H, OH), 7.82 (d, *J* = 9.5 Hz, 1H, Ar), 7.77 (d, *J* = 8.8 Hz, 1H, Ar), 7.33 (d, *J* = 8.8 Hz, 1H, Ar), 7.18–7.14 (m, 3H, Ar), 6.99 (d, *J* = 8.0 Hz, 3H, Ar), 5.36 (s, 1H, ArC$\underline{H}$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.13 (s, 3H, NC$\underline{H}_3$), 2.15 (s, 3H, CH_3); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.10, 156.56, 150.09, 147.22, 141.21, 135.47, 132.08, 130.35, 129.16, 128.75, 128.02, 125.75, 117.57, 115.22, 113.33, 105.55, 90.27, 35.17, 28.91, 27.73, 20.52; IR (KBr) $\nu_{max,}$ cm^{-1} = 3170, 1658, 1602, 1492, 1196; MS (ESI) *m*/*z* Calcd. for $C_{24}H_{20}N_2O_4$: 400.14, Found: 401.20 [M^+ + H]; Anal. Calcd. for $C_{24}H_{20}N_2O_4$: C, 71.99; H, 5.03; N, 7.00; Found: C, 71.96; H, 5.01; N, 6.98; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) : 323 nm (0.203×10^4 L mol^{-1} cm^{-1}), 337 (0.250×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-nitrophenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3i, $C_{23}H_{17}N_3O_6$)

Cream solid; Yield = 89%; M.p.: >300 °C (decom.); R_f 0.45 (petroleum ether : EtOAc, 50 : 50 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ 9.99 (s, 1H, OH), 8.07 (d, *J* = 8.6 Hz, 2H, Ar), 7.86 (d, *J* = 8.7 Hz, 1H, Ar), 7.78 (d, *J* = 8.6 Hz, 1H, Ar), 7.56 (d, *J* = 8.7 Hz, 2H, Ar), 7.34 (d, *J* = 8.7 Hz, 1H, Ar), 7.10 (s, 1H, Ar), 6.99–6.97 (m, 1H, Ar), 5.53 (s, 1H, ArC$\underline{H}$), 3.46 (s, 3H, NC$\underline{H}_3$), 3.12 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ 161.11, 156.88, 152.45, 151.40, 150.08, 147.26, 146.14, 131.97, 130.53, 129.91, 129.56, 125.80, 123.49, 117.87, 113.65, 133.29, 105.50, 88.89, 35.79, 29.03, 27.90 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3241, 1660, 1554, 1245; MS (ESI) *m*/*z* Calcd. for $C_{23}H_{17}N_3O_6$: 431.11 Found: 432.11 [M^+ + H]; Anal. Calcd. for $C_{23}H_{17}N_3O_6$:C, 64.04; H, 3.97; N, 9.74; Found: C, 64.06; H, 3.96; N, 9.72; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) : 321 nm (0.223×10^4 L mol^{-1} cm^{-1}), 336 (0.608×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(3-nitrophenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3j, $C_{23}H_{17}N_3O_6$)

Cream solid; Yield = 83%; M.p.: >300 °C (decom.); R_f 0.35 (petroleum ether : EtOAc, 50 : 50 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.97 (s, 1H, OH), 8.12 (s, 1H, Ar), 7.98 (d, *J* = 8.8 Hz, 1H, Ar), 7.88 (d, *J* = 8.7 Hz, 1H, Ar), 7.78 (d, *J* = 8.8 Hz, 1H, Ar), 7.70 (d, *J* = 7.3 Hz, 1H, Ar), 7.51–7.48 (m, 1H, Ar), 7.37 (d, *J* = 8.8 Hz, 1H, Ar), 7.09 (s, 1H, Ar), 6.98–6.96 (m, 1H, Ar), 5.55 (s, 1H, ArC$\underline{H}$), 3.46 (s, 3H, NC$\underline{H}_3$), 3.12 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.15, 156.86, 152.39, 150.05, 147.57, 147.38, 145.96, 134.96, 131.86, 130.52, 129.92, 125.77, 121.78, 117.77, 113.55, 113.29, 105.38, 88.97, 35.61, 28.97, 27.80 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3120, 1668, 1620, 1358, 1203; MS (ESI) *m*/*z* Calcd. for $C_{23}H_{17}N_3O_6$: 431.11, Found: 432.18 [M^+ + H]; Anal. Calcd. for $C_{23}H_{17}N_3O_6$: C, 64.04; H, 3.97; N, 9.74; Found: C, 64.06; H, 3.96; N, 9.72; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) = 323 nm (0.443×10^4 L mol^{-1} cm^{-1}), 337 (0.457×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(2-nitrophenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3k, $C_{23}H_{17}N_3O_6$)

Cream solid; Yield = 89%; M.p.: >300 °C (decom.); R_f 0.30 (petroleum ether : EtOAc, 50 : 50 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.95 (s, 1H, OH), 8.11 (s, 1H, Ar), 7.97 (d, *J* = 8.8 Hz, 1H, Ar), 7.86 (d, *J* = 8.7 Hz, 1H, Ar), 7.76 (d, *J* = 8.8 Hz, 1H, Ar), 7.70 (d, *J* = 7.3 Hz, 1H, Ar), 7.51–7.48 (m, 1H, Ar), 7.32 (d, *J* = 8.8 Hz, 1H, Ar), 7.10 (s, 1H, Ar), 6.97–6.96 (m, 1H, Ar), 5.60 (s, 1H, ArC$\underline{H}$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.11 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.14, 156.82, 152.38, 150.01,

147.56, 147.31, 145.96, 134.98, 131.81, 130.52, 129.92, 125.71, 121.76, 117.77, 113.55, 113.29, 105.38, 88.97, 35.61, 28.97, 27.80 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3124, 1660, 1621, 1350, 1230; MS (ESI) *m/z* Calcd. for $C_{23}H_{17}N_3O_6$: 431.11, Found: 432.16 [M^+ + H]; Anal. Calcd. for $C_{23}H_{17}N_3O_6$:C, 64.04; H, 3.97; N, 9.74; Found: C, 64.03; H, 3.95; N, 9.71; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) = 323 nm (0.313×10^4 L mol^{-1} cm^{-1}), 337 (0.436×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-cyanophenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3l, $C_{24}H_{17}N_3O_4$)

Cream solid; Yield = 78%; M.p.: >300 °C (decom.); R_f 0.40 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.97 (s, 1H, OH), 7.87 (d, *J* = 8.8 Hz, 1H, Ar), 7.79 (d, *J* = 8.8 Hz, 1H, Ar), 7.69 (d, *J* = 8.0 Hz, 2H, Ar), 7.48 (d, *J* = 8.0 Hz, 2H, Ar), 7.35 (d, *J* = 8.8 Hz, 1H, Ar), 7.11–7.10 (m, 1H, Ar), 7.00 (dd, $^{1,2}J$ = 2.2 Hz, $^{1,3}J$ = 8.7 Hz, 1H, Ar), 5.49 (s, 1H, ArC$\underline{H}$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.13 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.06, 156.80, 152.45, 150.02, 149.33, 147.29, 132.18, 131.90, 130.48, 129.76, 129.29, 125.74, 118.64, 117.69, 113.74, 113.33, 109.40, 105.27, 89.00, 35.86, 28.96, 27.73 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3186, 1683, 1621, 1455, 1225; MS (ESI) *m/z* Calcd. for $C_{24}H_{17}N_3O_4$: 411.12 Found: 412.18 [M^+ + H]; Anal. Calcd. for $C_{24}H_{17}N_3O_4$: C, 70.07; H, 4.16; N, 10.21; Found: C, 70.05; H, 4.13; N, 10.18; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.423×10^4 L mol^{-1} cm^{-1}), 337 (0.504×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-trifluoromethylphenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3m, $C_{24}H_{17}F_3N_2O_4$)

White solid; Yield = 85%; M.p.: >300 °C (decom.); R_f 0.35 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.98 (s, 1H, OH), 7.87 (d, *J* = 8.7 Hz, 1H, Ar), 7.79 (d, *J* = 8.8 Hz, 1H, Ar), 7.59 (d, *J* = 8.7 Hz, 2H, Ar), 7.51 (d, *J* = 8.0 Hz, 2H, Ar), 7.36 (d, *J* = 8.8 Hz, 1H, Ar), 7.13 (s, 1H, Ar), 7.01 (d, $^{1,2}J$ = 2.2 Hz, $^{1,3}J$ = 8.8 Hz, 1H, Ar), 5.51 (s, 1H, ArC$\underline{H}$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.13 (s, 3H, NC$\underline{H}_3$); ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.13, 156.80, 152.44, 150.08, 148.53, 147.35, 131.97, 130.52, 129.71, 129.08, 125.78, 125.20, 117.73, 114.08, 113.40, 105.32, 89.31, 35.63, 28.99, 27.78 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3300, 1660, 1629, 1427, 1210 ppm; MS (ESI) *m/z* Calcd. for $C_{24}H_{17}F_3N_2O_4$: 454.11, Found: 455.19 [M^+ + H]; Anal. Calcd. for $C_{24}H_{17}F_3N_2O_4$: C, 63.44; H, 3.77; N, 6.16; Found: C, 63.48; H, 3.74; N, 6.13; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) : 313 nm (0.284×10^4 L mol^{-1} cm^{-1}), 325 (0.356×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-phenyl-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3n, $C_{23}H_{18}N_2O_4$)

White solid; Yield = 85%; M.p.: >300 °C (decom.); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.94 (s, 1H, OH), 7.84 (d, *J* = 8.7 Hz, 1H, Ar), 7.78 (d, *J* = 9.5 Hz, 1H, Ar), 7.34 (d, *J* = 8.7 Hz, 1H, Ar), 7.29 (d, *J* = 7.3 Hz, 2H, Ar), 7.21–7.17 (m, 3H, Ar), 7.10–7.06 (m, 1H, Ar), 6.99 (dd, $^{1,2}J$ = 2.2 Hz, $^{1,3}J$ = 8.8 Hz, 1H, Ar), 5.41 (s, 1H, ArC$\underline{H}$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.14 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.14, 156.63, 152.31, 150.11, 147.31, 144.14, 132.09, 130.40, 129.27, 128.22, 128.18, 126.52, 125.78, 117.63, 115.11, 113.36, 105.50, 90.19, 35.59, 28.94, 27.77 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3145, 1672, 1668, 1548, 1256; MS (ESI) *m/z* Calcd. for $C_{23}H_{18}N_2O_4$: 386.13, Found: 387.15 [M^+ + H]; Anal. Calcd. for $C_{23}H_{18}N_2O_4$: C, 71.49; H, 4.70; N, 7.25; Found: C, 71.47; H, 4.73, N; 7.25; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) = 324 nm (0.293×10^4 L mol^{-1} cm^{-1}), 337 (0.365×10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-fluorophenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (3o, $C_{23}H_{17}FN_2O_4$)

White solid; Yield = 87%; M.p.: >300 °C (decom.); R_f 0.35 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.95 (s, 1H, OH), 7.84 (d, *J* = 8.8 Hz, 1H, Ar), 7.78 (d, *J* = 8.8 Hz, 1H, Ar), 7.33–7.26 (m, 3H, Ar), 7.15–7.14 (m, 1H, Ar), 7.04–6.97 (m, 3H, Ar), 5.42 (s, 1H, ArC$\underline{H}$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.14 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.15, 156.68, 152.27, 150.09, 147.26, 140.25, 132.00, 130.44, 130.04, 129.96, 129.42, 125.78, 117.64, 115.04, 114.83, 113.35, 105.46, 89.94, 34.90, 28.94, 27.76 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3170, 1658, 1620, 1445, 1198; MS (ESI). *m/z* Calcd. for $C_{23}H_{17}FN_2O_4$: 404.09, Found: 405.17 [M^+ + H]; Anal. Calcd. for $C_{23}H_{17}FN_2O_4$: C, 68.31; H, 4.24; N, 6.93; Found: C, 68.28; H, 4.26; N, 6.91; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) = 311 nm (0.300×10^4 L mol^{-1} cm^{-1}), 324 (0.383×10^4 L mol^{-1} cm^{-1}).

12-(4-Chlorophenyl)-3-Hydroxy-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (4a, $C_{23}H_{17}ClN_2O_4$)

Cream solid; Yield = 83%; M.p.: >300 °C (decom.); R_f 0.35 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO-d_6): δ = 9.80 (s, 1H, OH), 7.83 (d, *J* = 9.5 Hz, 1H, Ar), 7.76 (d, *J* = 8.8 Hz, 1H, Ar), 7.48 (d, *J* = 8.7 Hz, 1H, Ar), 7.33–7.30 (m, 2H, Ar), 7.24–7.21 (m, 2H, Ar), 7.15 (d, *J* = 2.9 Hz, 1H, Ar), 7.07–7.04 (m, 1H, Ar), 5.59 (s, 1H, ArC$\underline{H}$), 3.46 (s, 3H, NC$\underline{H}_3$), 3.13 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.10, 156.70, 152.39, 150.05, 147.32, 146.35, 132.72, 131.94, 130.46, 130.12, 129.60, 127.90, 126.93, 126.63, 125.74, 117.69, 114.17, 113.33, 105.33, 89.41, 35.42, 28.95, 27.76 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3120, 1678, 1650, 1300, 1290; MS (ESI) *m/z* Calcd. for $C_{23}H_{17}ClN_2O_4$: 420.09, Found: 421.11 [M^+ + H], 423.11 [M^+ + H+2]; Anal. Calcd. for $C_{23}H_{17}ClN_2O_4$: C, 65.64; H, 4.07; N, 6.66; Found: C, 65.62; H, 4.06; N, 6.65; UV (2×10^{-4} M solution in DMSO) λ_{max} (ε) = 336 nm (0.181×10^4 L mol^{-1} cm^{-1}), 350 (0.208×10^4 L mol^{-1} cm^{-1}).

3-Hydroxy-12-(4-nitrophenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (4b, $C_{23}H_{17}N_3O_6$)

Yellow solid; Yield = 89%; M.p.: >300 °C (decom.); R_f 0.35 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (400 MHz, DMSO): δ = 9.81 (s, 1H, OH), 8.05 (d, *J* = 8.7 Hz, 2H, Ar), 7.82–7.76 (m, 2H, Ar), 7.60 (d, *J* = 8.8 Hz, 2H, Ar), 7.50 (d, *J* = 8.8 Hz, 1H, Ar), 7.15–7.14 (m, 1H, Ar), 7.05–7.03 (m, 1H, Ar), 5.74 (s, 1H, ArC$\underline{H}$), 3.47 (s, 3H, NC$\underline{H}_3$), 3.12 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, DMSO-d_6): δ = 161.04, 155.05, 152.52, 151.70, 150.04, 146.02, 144.67, 133.12, 129.57, 128.24, 125.11, 123.96,

123.36, 119.75, 117.13, 115.61, 110.07, 88.76, 35.59, 28.95, 27.72 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3277, 1670, 1641, 1525, 1348, 1230; MS (ESI) *m/z* Calcd. for $C_{23}H_{17}N_3O_6$: 431.11 Found: 432.18 [M^+ + H]; Anal. Calcd. for $C_{23}H_{17}N_3O_6$: C, 64.04; H, 3.97; N, 9.74; Found: C, 64.02; H, 3.96; N, 9.75; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 336 nm (0.231 × 10^4 L mol^{-1} cm^{-1}), 348 (0.366 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Chlorophenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (5a, $C_{23}H_{17}ClN_2O_3$)

White solid; Yield = 84%; M.p.: 264–266 °C (Lit. 274–276 °C)[14a]; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.86–7.80 (m, 3H, Ar), 7.47–7.36 (m, 3H, Ar), 7.29 (d, *J* = 8.0 Hz, 2H, Ar), 7.15 (d, *J* = 8.0 Hz, 2H, Ar), 5.76 (s, 1H, ArC<u>H</u>), 3.58 (s, 3H, NC<u>H</u>$_3$), 3.31 (s, 3H, NC<u>H</u>$_3$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 161.91, 152.23, 150.56, 147.11, 142.30, 132.51, 131.77, 130.71, 129.77, 129.62, 128.58, 127.58, 125.62, 123.73, 116.75, 116.29, 90.95, 35.47, 29.06, 28.21 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 2960, 1668, 1620, 1358, 1203; MS (ESI) *m/z* Calcd. for $C_{23}H_{17}ClN_2O_3$: 404.09, Found: 405.10 [M^+ + H], 407.10 [M^+ + H+2]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 314 nm (0.088 × 10^4 L mol^{-1} cm^{-1}), 327 (0.067 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Nitrophenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (5b, $C_{23}H_{17}N_3O_5$)

Cream solid; Yield = 86%; M.p.: 280–288 °C (Lit. 291–293 °C)[14a]; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.07 (d, *J* = 8.7 Hz, 2H, Ar), 7.91–7.80 (m, 3H, Ar), 7.55 (d, *J* = 8.7 Hz, 2H, Ar), 7.50–7.43 (m, 3H, Ar), 5.91 (s, 1H, ArC<u>H</u>), 3.63 (s, 3H, NC<u>H</u>$_3$), 3.31 (s, 3H, NC<u>H</u>$_3$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ δ 161.81, 151.21, 150.62, 147.18, 142.42, 133.50, 131.72, 131.70, 129.77, 129.68, 128.58, 126.58, 125.61, 123.71, 116.78, 116.32, 90.98, 35.41, 29.06, 28.26 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 2964, 1670, 1632, 1350, 1230; MS (ESI) *m/z* Calcd. for $C_{23}H_{17}N_3O_5$: 415.12, Found: 416.18 [M^+ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 313 nm (0.085 × 10^4 L mol^{-1} cm^{-1}), 325 (0.072 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Fluorolphenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho [1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (5c, $C_{23}H_{17}FN_2O_3$)

White solid; Yield = 84%; M.p.: 294–296 °C (Lit. 305–307 °C)[14b]; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.88–7.80 (m, 3H, Ar), 7.45–7.37 (m, 3H, Ar), 7.32–7.29 (m, 2H, Ar), 6.88–6.84 (m, 2H, Ar), 5.78 (s, 1H, ArC<u>H</u>), 3.59 (s, 3H, NC<u>H</u>$_3$), 3.32 (s, 3H, NC<u>H</u>$_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 161.96, 152.20, 150.60, 147.11, 139.63, 131.79, 130.75, 129.82, 129.74, 129.68, 128.58, 127.53, 125.59, 123.81, 117.08, 116.31, 115.36, 91.23, 35.30, 29.06, 28.22; IR (KBr) $\nu_{max,}$ cm^{-1} = 2958, 1668, 1635, 1346, 1208; MS (ESI) *m/z* Calcd. for $C_{23}H_{17}FN_2O_3$: 388.12, Found: 389.18 [M^+ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 313 nm (0.085 × 10^4 L mol^{-1} cm^{-1}), 327 (0.049 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Trifluoromethylphenyl)-8,12-dihydro-8,10-dimethyl-9*H*-naphtho[1′,2′ : 5,6]pyrano[2,3-*d*]pyrimidine-9,11-(10*H*)-dione (5d, $C_{24}H_{17}F_3N_2O_3$)

White solid; Yield = 78%; M.p.: 268–270 °C; R_f 0.40 (petroleum ether : EtOAc, 70 : 30 v/v); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.87–7.81 (m, 3H, Ar), 7.48–7.39 (m, 7H, Ar), 5.84 (s, 1H, ArC<u>H</u>), 3.59 (s, 3H, NC<u>H</u>$_3$), 3.31 (s, 3H, NC<u>H</u>$_3$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 161.86, 152.38, 150.53, 147.58, 147.19, 131.79, 130.65, 129.96, 129.07, 128.75, 128.64, 128.61, 127.68, 125.70, 125.45, 125.42, 123.61, 116.40, 116.31, 90.64, 35.91, 29.09, 28.23; IR (KBr) $\nu_{max,}$ cm^{-1} = 2978, 1670, 1635, 1340, 1210; MS (ESI) *m/z* Calcd. for $C_{24}H_{17}F_3N_2O_3$: 438.12, Found: 439.18 [M^+ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 313 nm (0.082 × 10^4 L mol^{-1} cm^{-1}), 327 (0.059 × 10^4 L mol^{-1} cm^{-1}).

10-(4-Chlorophenyl)-6,8-dimethyl-6,10-dihydro-5-oxa-6,8-diazaanthra[2,3-*d*][1,3] dioxole-7,9-dione (6a, $C_{20}H_{15}ClN_2O_5$)

White solid; Yield = 75%; M.p.: 240–242 °C (Lit. 254–255 °C)[14c]; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.24–7.15 (m, 4H, Ar), 6.65 (s, 1H, Ar), 6.45 (s, 1H, Ar), 5.94 (s, 1H, 1H of OC<u>H</u>$_2$), 5.91 (s, 1H, 1H of OC<u>H</u>$_2$), 4.98 (s, 1H, ArC<u>H</u>), 3.52 (s, 3H, NC<u>H</u>$_3$), 3.26 (s, 3H, NC<u>H</u>$_3$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.85, 152.57, 150.62, 147.36, 145.66, 143.57, 142.99, 132.65, 129.24, 128.67, 116.09, 108.02, 101.92, 98.08, 89.55, 38.60, 29.04, 29.10 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 2960, 1668, 1620, 1358, 1203; MS (ESI) *m/z* Calcd. for $C_{20}H_{15}ClN_2O_5$: 398.07, Found: 399.10 [M^+ + H], 401.10 [M^+ + H+2]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 312 nm (0.062 × 10^4 L mol^{-1} cm^{-1}), 325 (0.049 × 10^4 L mol^{-1} cm^{-1}).

10-(3-Chlorophenyl)-6,8-dimethyl-6,10-dihydro-5-oxa-6,8-diazaanthra[2,3-*d*][1,3]dioxole-7,9-dione (6b, $C_{20}H_{15}ClN_2O_5$)

White solid; Yield = 72%; M.p.: 228–230 °C; R_f 0.50 (petroleum ether : EtOAc, 80 : 20 v/v); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.24–7.11 (m, 4H, Ar), 6.66 (s, 1H, Ar), 6.46 (s, 1H, Ar), 5.95 (s, 1H, 1H of OC<u>H</u>$_2$), 5.92 (s, 1H, 1H of OC<u>H</u>$_2$), 4.98 (s, 1H, ArC<u>H</u>), 3.53 (s, 3H, NC<u>H</u>$_3$), 3.26 (s, 3H, NC<u>H</u>$_3$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 161.82, 152.68, 150.65, 147.43, 147.02, 145.69, 142.99, 134.42, 129.72, 127.90, 127.17, 126.27, 115.92, 108.03, 101.94, 98.15, 89.36, 38.94, 29.07, 28.13 ppm; (KBr) $\nu_{max,}$ cm^{-1} = 2921, 1706, 1648, 1490, 1210; MS (ESI) *m/z* Calcd. for $C_{20}H_{15}ClN_2O_5$: 398.07, Found: 399.12[M^+ + H], 401.12 [M^+ + H+2]; Anal. Calcd. for $C_{20}H_{15}ClN_2O_5$: C, 60.23; H, 3.79; N, 7.02; Found: C, 60.27; H, 3.75; N, 7.05; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 312 nm (0.055 × 10^4 L mol^{-1} cm^{-1}), 327 (0.048 × 10^4 L mol^{-1} cm^{-1}).

10-(4-Methylphenyl)-6,8-dimethyl-6,10-dihydro-5-oxa-6,8-diazaanthra[2,3-*d*][1,3]dioxole-7,9-dione (6c, $C_{21}H_{18}N_2O_5$)

White solid; Yield = 80%; M.p.: 236–238 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.13 (d, *J* = 5.8 Hz, 2H, Ar), 7.06 (d, *J* = 6.6 Hz, 2H, Ar), 6.65 (s, 1H, Ar), 6.50 (s, 1H, Ar), 5.93 (s, 1H, 1H of OC<u>H</u>$_2$), 5.89 (s, 1H, 1H of OC<u>H</u>$_2$), 4.98 (s, 1H, ArC<u>H</u>), 3.53 (s, 3H, NC<u>H</u>$_3$), 3.26 (s, 3H, NC<u>H</u>$_3$), 2.25(s, 3H, CH_3) ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 2910, 1708, 1662, 1476, 1215; MS (ESI) *m/z* Calcd. for $C_{21}H_{18}N_2O_5$: 378.12, Found: 379.18 [M^+ + H]; UV (2 × 10^{-4} M

solution in DMSO) λ_{max} (ε) = 313 nm (0.068 × 10^4 L mol^{-1} cm^{-1}), 327 (0.054 × 10^4 L mol^{-1} cm^{-1}).

10-(4-Fluorophenyl)-6,8-dimethyl-6,10-dihydro-5-oxa-6,8-diazaanthra[2,3-*d*][1,3]dioxole-7,9-dione (6d, $C_{20}H_{15}FN_2O_5$)

White solid; Yield = 72%; M.p.: 220–222 °C (decom.); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.20–7.17 (m, 2H, Ar), 6.94–6.89 (m, 2H, Ar), 6.65 (s, 1H, Ar), 6.46 (s, 1H, Ar), 5.94 (s, 1H, 1H of OC$\underline{H}_2$), 5.91 (s, 1H, 1H of OC$\underline{H}_2$), 5.00 (s, 1H, ArC$\underline{H}$), 3.52 (s, 3H, NC$\underline{H}_3$), 3.26 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 161.89, 152.52, 150.66, 147.29, 145.64, 143.07, 140.90, 129.41, 116.46, 115.20, 108.16, 101.90, 98.06, 89.84, 38.52, 29.06, 28.13 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 2921, 1706, 1648, 1490, 1210; MS (ESI) *m*/*z* Calcd. for $C_{20}H_{15}FN_2O_5$: 382.10, Found: 383.20 [M^+ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) : 314 nm (0.085 × 10^4 L mol^{-1} cm^{-1}), 325 (0.060 × 10^4 L mol^{-1} cm^{-1}).

10-(4-Nitrophenyl)-6,8-dimethyl-6,10-dihydro-5-oxa-6,8-diaza anthra[2,3-*d*][1,3]dioxole-7,9-dione (6e, $C_{20}H_{15}N_3O_7$)

White solid; Yield = 75%; M.p.: 240–242 °C (decom.); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.30–7.27 (m, 2H, Ar), 7.00–6.98 (m, 2H, Ar), 6.67 (s, 1H, Ar), 6.54 (s, 1H, Ar), 5.98 (s, 1H, 1H of OC$\underline{H}_2$), 5.94 (s, 1H, 1H of OC$\underline{H}_2$), 5.09 (s, 1H, ArC$\underline{H}$), 3.52 (s, 3H, NC$\underline{H}_3$), 3.26 (s, 3H, NC$\underline{H}_3$) ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 2911, 1708, 1662, 1476, 1214; MS (ESI) *m*/*z* Calcd. for $C_{20}H_{15}N_3O_7$: 409.09, Found: 410.10 [M^+ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 313 nm (0.082 × 10^4 L mol^{-1} cm^{-1}), 327 (0.051 × 10^4 L mol^{-1} cm^{-1}).

6,8-Dimethyl-10-phenyl-6,10-dihydro-5-oxa-6,8-diazaanthra [2,3-*d*][1,3]dioxole-7,9-dione (6f, $C_{20}H_{16}N_2O_5$)

White solid; Yield = 75%; M.p.: 220–222 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.25–7.22 (m, 4H, Ar), 7.17–7.16 (m, 1H, Ar), 6.66 (s, 1H, Ar), 6.50 (s, 1H, Ar), 5.94 (d, *J* = 1.44, 1H, 1H of OC$\underline{H}_2$), 5.90 (d, *J* = 1.48, 1H, 1H of OC$\underline{H}_2$), 5.01 (s, 1H, ArC$\underline{H}$), 3.54 (s, 3H, NC$\underline{H}_3$), 3.27 (s, 3H, NC$\underline{H}_3$) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 161.86, 152.55, 150.70, 147.15, 145.54, 145.06, 143.05, 128.53, 127.80, 126.86, 116.74, 108.16, 101.81, 97.94, 89.99, 39.13, 29.00, 28.08 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 2892, 1702, 1667, 1482, 1210; MS (ESI) *m*/*z* Calcd. For $C_{20}H_{16}N_2O_5$: 364.11, Found: 365.20 [M^+ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 315 nm (0.065 × 10^4 L mol^{-1} cm^{-1}), 324 (0.048 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Chlorophenyl)-2-hydroxy-9,9-dimethyl-8,9,10,12-tetra hydrobenzo[*a*]xanthen-11-one (7a, $C_{25}H_{21}ClO_3$)

White solid; Yield = 86%; M.p. >300 °C (decom.) (Lit. >300 °C)[14d]; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 9.29 (s, 1H, OH), 7.67–7.62 (m, 2H, Ar), 7.31–7.24 (m, 3H, Ar), 7.14–7.09 (m, 3H, Ar), 7.02–6.99 (m, 1H, Ar), 5.50 (s, 1H, ArC$\underline{H}$), 2.57 (s, 2H, C$\underline{H}_2$CMe$_2$), 2.33 (d, *J* = 16.2 Hz, 1H of C$\underline{H}_2$CO), 2.24 (d, *J* = 16.2 Hz, 1H of C$\underline{H}_2$CO), 1.12 (s, 3H, CM$\underline{e}$), 0.95 (s, 3H, CM$\underline{e}$) ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3194, 1631, 1594, 1381, 1235; ^{13}C NMR (300 MHz, $CDCl_3$): δ 199.4, 166.18, 156.30, 147.96, 142.95, 132.87, 132.04, 130.39, 129.87, 129.04, 128.42, 126.49, 117.39, 115.45, 113.87, 113.81, 05.86, 50.40, 41.50, 34.45, 32.51, 29.32, 27.05; MS (ESI) *m*/*z* Calcd. For $C_{25}H_{21}ClO_3$: 404.12 Found: 405.16 [M^+ + H], 407.16 [M^+ + H+2]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.370 × 10^4 L mol^{-1} cm^{-1}), 337 (0.327 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Trifluoromethylphenyl)-2-hydroxy-9,9-dimethyl-8,9, 10,12-tetrahydrobenzo[*a*]xanthen-11-one (7b, $C_{26}H_{21}F_3O_3$)

White solid; Yield = 84%; M.p. >300 °C; R_f 0.35 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (300 MHz, DMSO-d_6): δ = 9.87 (s, 1H, OH), 7.71–7.76 (m, 2H, Ar), 7.24–7.18 (m, 4H, Ar), 6.98–7.03 (m, 3H, Ar), 5.38 (s, 1H, ArC$\underline{H}$), 2.67 and 2.55 (AB system, *J* = 17.8 Hz, 2H, CH_a.H_bCMe$_2$), 2.32 (d, *J* = 16.2 Hz, 1H of C$\underline{H}_2$CO), 2.11 (d, *J* = 16.2 Hz, 1H of C$\underline{H}_2$CO), 1.01 (s, 3H, CM$\underline{e}$), 0.90 (s, 3H, CM$\underline{e}$) ppm; ^{13}C NMR (300 MHz, DMSO-d_6): δ = 195.91, 163.93, 158.80, 156.41, 147.61, 140.80, 131.37, 130.21, 129.82, 128.84, 125.46, 117.13, 115.10, 114.93, 113.50, 113.11, 105.08, 50.03, 40.31, 33.42, 31.81, 28.71, 26.13 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3184, 1629, 1593, 1381, 1236; MS (ESI) *m*/*z* Calcd. for $C_{26}H_{21}F_3O_3$: 438.14 Found: 439.18 [M^+ + H]; Anal. Calcd. for $C_{26}H_{21}F_3O_3$: C, 71.23; H, 4.83; Found: C, 71.20; H, 4.82; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.268 × 10^4 L mol^{-1} cm^{-1}), 337 (0.228 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Fluorophenyl)-2-hydroxy-9,9-dimethyl-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-one (7c, $C_{25}H_{21}FO_3$)

White solid; Yield = 82%; M.p. 278–280 °C (decom.) (Lit. 276–278 °C)[14d]; ^{1}H NMR (300 MHz, DMSO-d_6): δ = 9.88 (s, 1H, OH), 7.72–7.77 (m, 2H, Ar), 7.27–7.16 (m, 4H, Ar), 6.95–7.05 (m, 3H, Ar), 5.35 (s, 1H, ArC$\underline{H}$), 2.68 and 2.57 (AB system, *J* = 17.4 Hz, 2H, CH_a.H_bCMe$_2$), 2.34 (d, *J* = 16.2 Hz, 1H of C$\underline{H}_2$CO), 2.13 (d, *J* = 16.2 Hz, 1H of C$\underline{H}_2$CO), 1.03 (s, 3H, CM$\underline{e}$), 0.85 (s, 3H, CM$\underline{e}$) ppm; ^{13}C NMR (300 MHz, DMSO-d_6): δ = 195.92, 163.90, 158.83, 156.47, 147.64, 140.81, 132.37, 130.24, 129.84, 128.88, 125.47, 117.14, 115.11, 114.96, 113.51, 113.10, 105.08, 50.03, 40.33, 33.43, 31.83, 28.77, 26.14 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3184, 1629, 1593, 1381, 1236; MS (ESI) *m*/*z* Calcd. For $C_{25}H_{21}FO_3$: 388.14 Found: 389. 20 [M^+ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.287 × 10^4 L mol^{-1} cm^{-1}), 337 (0.256 × 10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-9,9-dimethyl-12-(4-nitrophenyl)-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-one (7d, $C_{25}H_{21}NO_5$)

Light yellow solid; Yield = 87%; M.p. 288–290 °C (decom.) (Lit. 288–290 °C)[14d]; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 9.29 (s, 1H, OH), 8.03 (d, *J* = 8.1 Hz, 2H, Ar), 7.70–7.63 (m, 2H, Ar), 7.56–7.53 (d, *J* = 8.4 Hz, 2H, Ar), 7.19 (s, 1H, Ar), 7.14 (d, *J* = 8.7 Hz, 1H, Ar), 7.03 (d, *J* = 8.7 Hz, 1H, Ar), 5.63 (s, 1H, ArC$\underline{H}$), 2.59 (s, 2H, C$\underline{H}_2$CMe$_2$), 2.35 (d, *J* = 16.2 Hz, 1H of C$\underline{H}_2$CO), 2.24 (d, *J* = 16.2 Hz, 1H of C$\underline{H}_2$CO), 1.13 (s, 3H, CM$\underline{e}$), 0.94 (s, 3H, CM$\underline{e}$) ppm; ^{13}C NMR (300 MHz, DMSO-d_6): δ = 195.84, 164.49, 158.07, 151.96, 147.50, 145.68, 132.52, 130.18, 129.31, 125.06, 123.23, 117.94, 113.77, 112.93, 112.13, 104.90, 49.94, 40.32, 34.42, 31.85, 28.74, 26.20 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3196, 1632, 1594, 1382, 1221; MS (ESI): *m*/*z* Calcd. For $C_{25}H_{21}NO_5$: 415.14 Found: 416.14 [M^+ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 328 nm (0.438 × 10^4 L mol^{-1} cm^{-1}), 337 (0.392 × 10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-methoxyphenyl)-9,9-dimethyl-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-one (7e, $C_{26}H_{24}O_4$)

White solid; Yield = 85%; M.p. 282–284 °C (decom.) (Lit. 280–282 °C)[14d]; ^{1}H NMR (300 MHz, $CDCl_3$): δ = 9.24 (s, 1H, OH), 7.64 (dd, ^2J = 1.5 Hz, ^3J = 8.7 Hz, 2H, Ar), 7.33 (s, 1H, Ar), 7.27 (d, *J* = 8.7 Hz, 2H, Ar), 7.11 (d, *J* = 8.7 Hz, 1H, Ar), 7.01 (dd, ^2J =

2.1 Hz, ^3J = 8.7 Hz, 1H, Ar), 6.70 (d, J = 8.7 Hz, 2H, Ar), 5.47 (s, 1H, ArC$\underline{H}$), 3.67 (s, 3H, OC$\underline{H}_3$), 2.56 (s, 2H of C$\underline{H}_2$CMe$_2$), 2.32 (d, J = 16.2 Hz, 1H of CH_2CO), 2.23 (d, J = 16.2 Hz, 1H of C$\underline{H}_2$CO), 1.11 (s, 3H, C$\underline{M}$e), 0.96 (s, 3H, C$\underline{M}$e) ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3190, 1630, 1594, 1380, 1227; ^{13}C NMR (300 MHz, DMSO-d$_6$): δ = 195.93, 163.60, 157.41, 156.33, 147.57, 136.80, 132.46, 130.15, 128.99, 128.57, 125.45, 117.04, 115.68, 113.51, 113.46, 113.42, 105.22, 54.84, 50.09, 40.32, 33.21, 31.83, 28.81, 26.22; MS (ESI): m/z Calcd. For $C_{26}H_{24}O_4$: 400.17 Found: 401.18 [M$^+$ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.254 × 10^4 L mol^{-1} cm^{-1}), 337 (0.221 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Chlorophenyl)-2-hydroxy-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-one (8a, $C_{23}H_{17}ClO_3$)

White solid; Yield = 83%; M.p. >300 °C (Lit. >300 °C)[14d]; ^{1}H NMR (300 MHz, DMSO-d$_6$): δ = 9.73 (s, 1H, OH), 7.67–7.62 (m, 2H, Ar),7.68–7.12 (m, 7H, Ar), 5.25 (s, 1H, ArC$\underline{H}$), 2.69–2.63 (m, 2H, C$\underline{H}_2$), 2.42–2.24 (m, 2H, C$\underline{H}_2$), 1.94–1.89 (m, 1H of C$\underline{H}_2$), 1.76–1.79 (m, 1H of C$\underline{H}_2$) ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3174, 1629, 1595, 1380, 1227, 1196; MS (ESI): m/z Calcd. For $C_{23}H_{17}ClO_3$: 376.09 Found: 377.10 [M$^+$ + H]; 379.10 [M$^+$ + H+2]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.561 × 10^4 L mol^{-1} cm^{-1}), 337 (0.634 × 10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-nitrophenyl)-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-one (8b, $C_{23}H_{17}NO_5$)

Light yellow solid; Yield = 86%; M.p. >300 °C (decom.) (Lit. >300 °C)[14d]; ^{1}H NMR (300 MHz, DMSO-d$_6$): δ = 9.94 (s, 1H, OH), 8.10 (d, J = 8.4 Hz, 2H, Ar), 7.82 (dd, ^2J = 9.0 Hz, , ^3J = 13.2 Hz, 2H, Ar), 7.52 (d, J = 8.4 Hz, 2H), 7.24 (d, J = 8.7 Hz, 2H), 7.12 (s, 1H, Ar), 5.51 (s, 1H, ArC$\underline{H}$), 2.74–2.71 (m, 2H, C$\underline{H}_2$), 2.39–2.32 (m, 2H, C$\underline{H}_2$), 2.01–1.97 (m, 1H of C$\underline{H}_2$), 1.85–1.83 (m, 1H of C$\underline{H}_2$) ppm; ^{13}C NMR (300 MHz, DMSO-d$_6$): δ = 196.20, 166.38, 156.63, 152.22, 147.66, 145.87, 132.28, 130.36, 129.43, 129.38, 125.47, 123.45, 117.26, 114.00, 113.51, 113.30, 104.91, 36.31, 34.38, 26.97, 19.84 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3197, 1630, 1594, 1344, 1228; MS (ESI): m/z Calcd. For $C_{23}H_{17}NO_5$: 387.11 Found: 388.11 [M$^+$ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 325 nm (0.592 × 10^4 L mol^{-1} cm^{-1}), 337 (0.627 × 10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-phenyl-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-one (8c, $C_{23}H_{18}O_3$)

White solid; Yield = 89%; M.p. >300 °C (decom.) (Lit. >300 °C)[14d]; ^{1}H NMR (300 MHz, DMSO-d$_6$): δ = 9.86 (s, 1H, OH), 7.72–7.76 (m, 2H, Ar), 7.25–7.16 (m, 6H, Ar), 7.08–7.04 (m, 1H, Ar), 6.97 (d, J = 9 Hz, 1H, Ar), 5.37 (s, 1H, ArC$\underline{H}$), 2.71–2.69 (m, 2H, C$\underline{H}_2$), 2.41–2.25 (m, 2H, C$\underline{H}_2$), 1.99–1.94 (m, 1H of C$\underline{H}_2$), 1.83–1.79 (m, 1H of C$\underline{H}_2$) ppm; ^{13}C NMR (300 MHz, DMSO-d$_6$): δ = 196.14, 165.76, 156.38, 147.70, 144.97, 132.46, 130.18, 128.70, 128.15, 128.07, 126.13, 125.45, 117.10, 115.45, 114.57, 113.48, 105.13, 36.40, 34.06, 26.90, 19.91 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3200, 1625, 1593, 1382, 1230, 1194; MS (ESI): m/z Calcd. For $C_{23}H_{18}O_3$: 342.13 Found: 343.18 [M$^+$ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 324 nm (0.695 × 10^4 L mol^{-1} cm^{-1}), 337 (0.623 × 10^4 L mol^{-1} cm^{-1}).

12-(4-Trifluoromethylphenyl)-2-hydroxy-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-one (8d, $C_{24}H_{17}F_3O_3$)

White solid; Yield = 88%; M.p. >300 °C (decom.); R_f 0.40 (petroleum ether : EtOAc, 60 : 40 v/v); ^{1}H NMR (300 MHz, DMSO-d$_6$): δ = 9.88 (s, 1H, OH), 7.78–7.73 (m, 2H, Ar), 7.27–7.16 (m, 4H, Ar), 7.05–6.95 (m, 3H, Ar), 5.38 (s, 1H, CH), 2.74–2.70 (m, 2H, CH_2), 2.38–2.31 (m, 2H, CH_2), 2.01–1.96 (m, 1H of C$\underline{H}_2$), 1.85–1.83 (m, 1H of C$\underline{H}_2$) ppm; ^{13}C NMR (300 MHz, DMSO-d$_6$): δ = 196.02, 163.72, 156.32, 148.10, 147.54, 137.25, 132,52, 130.16, 128.57, 125.44, 120.05, 117.06, 115.66, 113.51, 112.23, 111.48, 105.27, 33.54, 31.48, 28.85, 26.14 ppm; IR (KBr) $\nu_{max,}$ cm^{-1} = 3186, 1626, 1594, 1384, 1233; MS (ESI): m/z Calcd. For $C_{24}H_{17}F_3O_3$: 410.11 Found: 411.18 [M$^+$ + H]; Anal. Calcd. for $C_{24}H_{17}F_3O_3$: C, 70.24; H, 4.18; Found: C, 70.28; H, 4.16; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 326 nm (0.539 × 10^4 L mol^{-1} cm^{-1}), 338 (0.487 × 10^4 L mol^{-1} cm^{-1}).

2-Hydroxy-12-(4-methylphenyl)-8,9,10,12-tetrahydrobenzo[*a*]xanthen-11-one (8e, $C_{24}H_{20}O_3$)

White solid; Yield = 84%; M.p. 286–288 °C (decom.) (Lit. 286–288 °C)[14d]; ^{1}H NMR (300 MHz, DMSO-d$_6$): δ = 9.86 (s, 1H, OH), 7.76–7.72 (m, 2H, Ar), 7.20–7.10 (m, 4H, Ar), 7.00–6.94 (m, 3H, Ar); 5.32 (s, 1H, ArC$\underline{H}$), 2.73–2.71 (m, 2H, C$\underline{H}_2$), 2.40–2.24 (m, 2H, C$\underline{H}_2$), 2.16 (s, 3H, ArC$\underline{H}_3$), 2.02–1.96 (m, 1H of C$\underline{H}_2$), 1.84–1.82 (m, 1H of C$\underline{H}_2$); ; ^{13}C NMR (300 MHz, DMSO-d$_6$): δ = 196.15, 165.57, 156.32, 147.62, 142.06, 135.20, 132.46, 130.16, 128.71, 128.61, 127.95, 125.42, 117.05, 115.57, 114.64, 113.47, 105.18, 36.41, 33.62, 26.89, 20.46, 19.94 ppm; IR (KBr) $\nu_{max,}$ cm^{-1}: 3212, 1630, 1596, 1380, 1229, 1196; MS (ESI): m/z Calcd. For $C_{24}H_{20}O_3$: 356.14 Found: 357.18 [M$^+$ + H]; UV (2 × 10^{-4} M solution in DMSO) λ_{max} (ε) = 324 nm (0.428 × 10^4 L mol^{-1} cm^{-1}), 335 (0.318 × 10^4 L mol^{-1} cm^{-1}).

Conclusions

In conclusion, we have developed a simple, one-pot three component facile syntheses of diverse naphthopyranopyrimidines, diazaanthra[2,3-*d*][1,3]dioxole-7,9-dione and tetrahydrobenzo[*a*]xanthen-11-ones in PEG-400 catalyzed by alum. Simple work up procedure, general applicability, ambient conditions and recyclability of the reaction media PEG-400 makes this protocol eco-friendly and distinctly superior to many other methods reported earlier. Moreover, compounds **3a**, **3d**, **3i**, **3j**, **3k**, **3l**, **3o**, **4a**, **4b** and **5b** displayed very good antioxidant activity compared to the standard.

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