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DBU-catalyzed synthesis of novel 2-amino-3-nitrile-4*H*-chromenes

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Abstract: A simple method via the base-catalyzed Michael addition of nitroalkanes to 2-iminochromenes was developed, which leads to the production of highly functionalized 2-amino-3-nitrile-4*H*-chromenes in good yields.

Keywords: base catalyst; iminochromene; Michael addition; nitroalkane.

Dedicated to: This paper is dedicated to Professor Necdet Coşkun on the occasion of his 57th birthday.

1 Introduction

The chromene moiety often appears as an important structural component in both biologically active and natural compounds. It widely occurs in natural alkaloids, flavonoids, tocopherols and anthocyanins [1–4]. Moreover, in recent years, functionalized chromenes have played an increasing role in the field of medicinal chemistry [5–7]. Among different types of chromene systems, 2-amino-4*H*-chromenes are of particular utility as they belong to privileged medicinal scaffolds serving for the generation of small-molecule ligands with highly pronounced spasmolytic, diuretic, anti-coagulant and anti-anaphylactic activities [8–11]. Due to their numerous applications, some catalytic methods have been reported for the synthesis of 2-amino-3-nitrile-4*H*-chromenes [12–16]. However, the general approach for their synthesis is a cascade Michael-cyclization sequence of 2-(*E*)-2-nitrovinylphenols and malononitrile using a variety of catalysts (Fig. 1) [17–20].

In the course of our studies on the asymmetric synthesis of chromene heterocycles [21], we developed a practical 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) catalyzed method for the synthesis of 2-amino-4-(nitroalkyl)-4*H*-chromene-3-carbonitriles. DBU is a well-known catalyst in the Michael addition of nitroalkanes to unsaturated carbonyl compounds [22–26]. However, there is no report on the DBU-catalyzed Michael additions to 2-iminochromenes.

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2 Results and discussion

First, we synthesized and characterized 2-iminochromenes (**1a–g**) according to previously reported methods using the pyrrolidine catalyzed reaction of appropriate aldehydes and malononitrile in methanol [27–31].

Then we investigated a series of base catalysts and solvents for the addition of nitroalkanes to 2-iminochromenes. We selected the addition of nitromethane to **1a** as a test reaction (Table 1).

The catalytic system 20 mol% DBU-MeOH/H_2O was determined as the optimum for this addition reaction. Finally, we assessed the scope of the reaction using nitroalkanes, and various 2-iminochromenes and a series of functionalized 2-amino-3-nitrile-4*H*-chromenes (**2a–g**, **3a–g**) were obtained successfully with good yields (Fig. 2). All of the new 2-amino-3-nitrile-4*H*-chromenes were fully characterized using spectroscopic methods (IR, ^{1}H NMR, ^{13}C NMR, HRMS) while the spectroscopic data of the known compounds were checked with literature data. In the course of the nitroethane addition, the products were obtained as a 1:1 mixture of diastereomers except for **3c** and **3g** which were obtained as only one diastereomer.

We also applied our optimized conditions to the one-pot synthesis of 2-amino-3-nitrile-4*H*-chromenes [32], but the substrate scope was very narrow and the reaction times were very long, up to 24 h (Fig. 3).

3 Conclusions

We have developed a practical method for the synthesis of medicinally privileged 2-amino-3-nitrile-4*H*-chromenes using DBU as a Brønsted base in aqueous media. This catalyst proved to be efficient for the Michael addition of nitroalkanes to electrophilic 2-iminochromenes. A series of highly functionalized 2-amino-3-nitrile-4*H*-chromenes (14 examples) were synthesized successfully using this catalytic system.

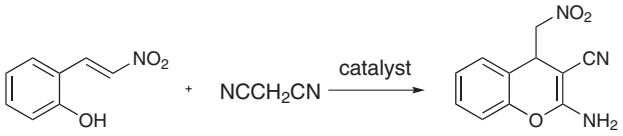
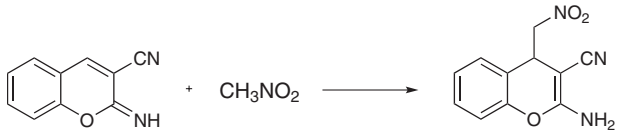


Fig. 1: General method for the synthesis of 2-amino-3-nitrile-4*H*-chromenes.

Table 1: Base-catalyzed Michael addition of nitromethane to **1a**.



1a **2a**

Base catalyst	Solvent	Time (min)[a]	Catalyst loading (%)	Yield (%)[b]
DBU	Toluene	30	10	77
DBU	Methanol	20	10	80
DBU	MeOH:H_2O (5:1)	20	10	82
DBU	MeOH:H_2O (5:1)	10	20	95
DABCO[c]	MeOH:H_2O (5:1)	180	20	81
Et_3N	MeOH:H_2O (5:1)	120	20	76
Piperidine	MeOH:H_2O (5:1)	30	20	88
Pyrrolidine	MeOH:H_2O (5:1)	30	20	89

[a]All reactions were performed at room temperature.
[b]Isolated yield.
[c]DABCO (1,4-diazabicyclo[2.2.2]octane).

4 Experimental section

All reagents were obtained from commercial sources and were used without further purification. Silica gel F_{254} (Merck 5554) precoated plates were used for thin layer chromatography. Infrared spectra were recorded on a NICOLET-IS50 FTIR. ^{1}H NMR and ^{13}C NMR spectra were carried out using a 400 MHz Bruker NMR spectrometer at ambient temperature. HRMS analyses were performed on Agilent 6540 UHD accurate mass Q-TOF LC/MS. Melting points were recorded with an electrothermal digital melting point apparatus. The 2-iminochromenes **1a–g** were synthesized by previously reported methods and characterized using melting point and NMR data [27–31]. Compounds **2a–g**, **3a**, **3b** and **3d** were characterized using melting point and NMR data of previous reports [17–19, 32–34].

4.1 General procedure for the synthesis of 2-iminochromenes (1a–g)

To a solution of aromatic aldehyde (5 mmol) and malononitrile (5 mmol) in MeOH (4 mL) piperidine (30 mol%) was added. The precipitated product was filtered and washed with cold MeOH and dried under vacuum.

4.1.1 2-Imino-2*H*-chromene-3-carbonitrile (1a)

Yellow solid, 86% yield, m.p. 163–165°C (decomp.). – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): $\delta = 7.77$ (s, 1H), 7.53 (td, $J = 1.6$, 8.0 Hz, 1H), 7.39 (dd, $J = 1.6$, 8.0 Hz, 1H), 7.22 (td, $J = 0.8$, 8.0 Hz, 1H), 7.16 (d, $J = 8.4$ Hz, 1H).

4.1.2 2-Imino-8-methoxy-2*H*-chromene-3-carbonitrile (1b)

Pale yellow solid, 82% yield, m.p. 173–174°C. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): $\delta = 8.93$ (s, 1H), 8.32 (s, 1H), 6.92–7.38 (m, 3H), 3.86 (s, 3H). – ^{13}C NMR (75 MHz, [D_6]DMSO, 25°C, TMS): $\delta = 161.91$, 151.41, 146.37, 124.51, 122.82, 118.12, 115.59, 104.78, 55.29.

4.1.3 6-Hydroxy-2-imino-2*H*-chromene-3-carbonitrile (1c)

Dark green-brown solid, 91% yield, m.p. >260°C. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): $\delta = 9.75$ (br s, 1H), 8.61 (s, 1H), 8.31 (s, 1H), 7.04–6.39 (m, 3H). – ^{13}C NMR ([D_6]DMSO, 75 MHz, 25°C, TMS): $\delta = 153.4$, 152.1, 146.9, 146.8, 121.4, 117.5, 116.3, 113.8, 104.1, 23.6.

4.1.4 6-Bromo-2-imino-2*H*-chromene-3-carbonitrile (1d)

Pale yellow solid, 88% yield, m.p. 184°C. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): $\delta = 7.84$–7.83 (br, 1H), 7.71–7.69 (m, 1H), 7.63–7.62 (m, 1H), 7.54 (s, 1H), 7.06–7.05 (br, 1H). – ^{13}C NMR ($CDCl_3$, 75 MHz, 25°C, TMS): $\delta = 152.7$, 143.8, 136.7, 136.5, 131.9, 131.7, 130.9, 117.9, 116.8, 113.8.

4.1.5 6-*tert*-Butyl-2-imino-2*H*-chromene-3-carbonitrile (1e)

Yellow solid, 75% yield, m.p. 129°C. IR (ATR): $\nu = 3302$, 3032, 2952, 2228, 1651, 1616, 1577, 1377, 1209, 1121, 847, 815 cm^{-1}. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): $\delta = 7.69$ (s, 1H), 7.57 (s, 1H), 7.47 (d, $J = 5.6$ Hz, 1H), 6.98 (d, $J = 5.6$ Hz, 1H), 1.25 (s, 9H). – ^{13}C NMR ($CDCl_3$, 75 MHz, 25°C, TMS): $\delta = 154.0$, 152.0, 147.7, 146.1, 131.6, 125.3, 116.7, 115.7, 114.6, 105.1, 34.5, 31.2. – HRMS ((+)-ESI): $m/z = 227.2341$ (calcd. 227.1139 for $C_{14}H_{14}N_2O$, $[M+H]^+$).

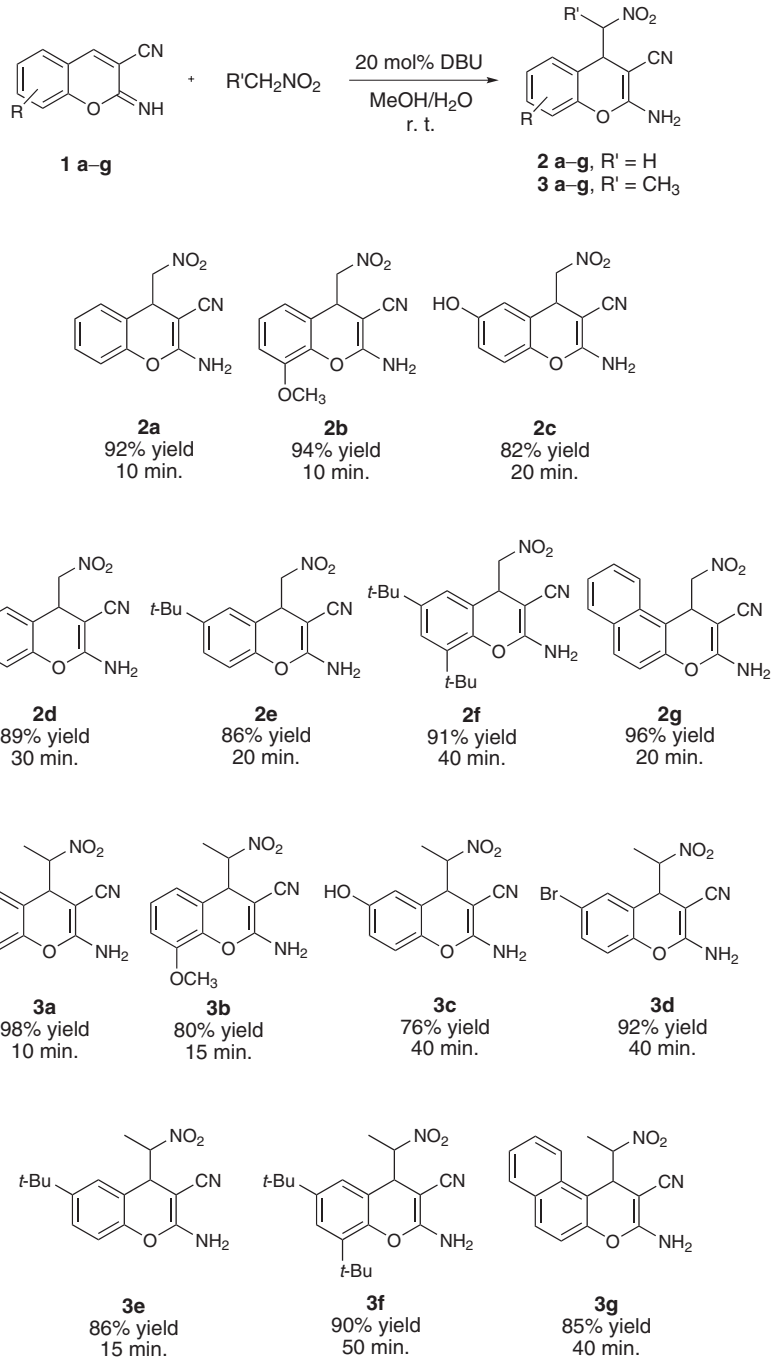


Fig. 2: DBU-catalyzed Michael addition of nitroalkanes to 2-iminochromenes.

4.1.6 6,8-Di-*tert*-butyl-2-imino-2*H*-chromene-3-carbonitrile (1f)

Pale yellow solid, 83% yield, m.p. 156–158°C (decomp.). – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): $\delta = 7.78$ (d, $J = 1.6$ Hz, 1H), 7.61 (bs, 1H), 7.56–7.55 (d, $J = 2.4$ Hz, 1H), 7.19–7.19 (d, $J = 2.4$ Hz, 1H), 1.45 (9H, s), 1.33 (9H, s). – ^{13}C NMR ($CDCl_3$, 75 MHz, 25°C, TMS): $\delta = 162.7$, 150.6, 148.1, 146.9, 137.4, 125.3, 123.7, 118.4, 115.7, 114.6, 35.0, 34.6, 31.2, 29.8.

4.1.7 3-Imino-3*H*-benzo[*f*]chromene-3-carbonitrile (1g)

Dark green solid, 99% yield, m.p. 218–220°C. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): $\delta = 8.48$ (s, 1H), 8.06 (d, $J = 5.1$ Hz, 1H), 7.98 (d, $J = 5.4$ Hz, 1H), 7.86 (d, $J = 4.8$ Hz, 1H), 7.71–7.67 (m, 2H), 7.55 (t, $J = 4.5$ Hz, 1H), 7.24 (s, 1H). – ^{13}C NMR ($CDCl_3$, 75 MHz, 25°C, TMS): $\delta = 154.3$, 141.4, 135.5, 130.1, 129.3, 129.2, 128.9, 126.3, 120.9, 116.2, 114.9, 111.2, 104.2.

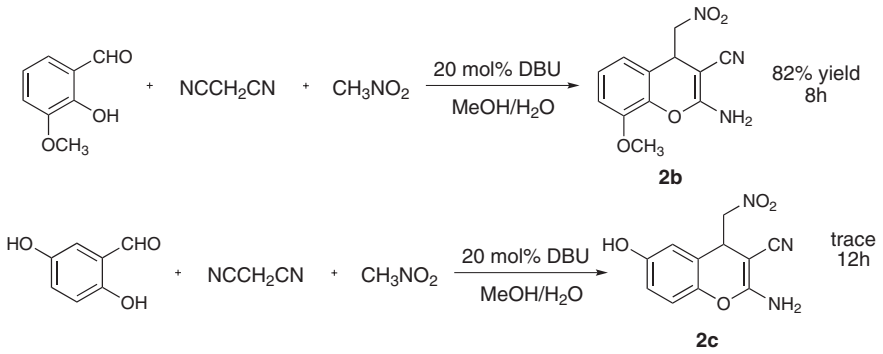


Fig. 3: DBU-catalyzed one-pot synthesis of 2-amino-3-nitrile-4*H*-chromenes.

4.2 General procedure for the Michael addition of nitroalkanes to 2-iminochromenes (2a–g, 3a–g)

The corresponding 2-iminochromene (**1a–g**) (0.30 mmol) was added to the mixture of a 20 mol% DBU and nitromethane (0.90 mmol) in methanol:water (5:1, 5 mL). The resulting suspension was stirred at room temperature until the addition was completed. The solvent was removed under vacuum and the product was extracted with dichloromethane:water. The organic phase was dried with Na_2SO_4, filtered, and dichloromethane fraction was evaporated under vacuum. The crude product was purified with column chromatography (1:3 ethyl acetate:hexane) to give the addition product.

4.2.1 2-Amino-4-(nitromethyl)-4*H*-chromene-3-carbonitrile (2a)

Yellow crystal, 92% yield, m.p. 143–144°C. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 7.47–7.43 (m, 2H), 7.32–7.28 (t, J = 8 Hz, 1H), 7.16–7.14 (d, J = 8 Hz, 1H), 4.93–4.89 (dd, J = 5.2, 12.4 Hz, 1H), 4.81–4.77 (dd, J = 5.2, 12.4 Hz, 1H), 4.45–4.42 (t, J = 5.2 Hz, 1H), 3.44 (s, 2H). – ^{13}C NMR ($CDCl_3$, 600 MHz, 25°C, TMS): δ = 161.7, 149.3, 129.6, 127.9, 125.7, 118.6, 116.9, 109.9, 80.1, 54.2, 34.7.

4.2.2 2-Amino-8-methoxy-4-(nitromethyl)-4*H*-chromene-3-carbonitrile (2b)

Yellow crystal, 94% yield, m.p. 166–167°C. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 7.24–7.19 (t, J = 8 Hz, 1H), 7.14–7.12 (dd, J = 1.2, 8.4 Hz, 1H), 6.98–6.97 (d, J = 7.6 Hz, 1H), 4.88–4.84 (dd, J = 5.2, 12 Hz, 1H), 4.76–4.72 (dd, J = 5.2, 12 Hz, 1H), 4.41–4.38 (t, J = 5.2 Hz, 1H), 3.92 (s, 3H), 3.41 (s, 2H). – ^{13}C NMR ($CDCl_3$, 600 MHz, 25°C, TMS): δ = 161.7, 147.8, 138.9, 125.5, 119.7, 119.0, 118.6, 111.8, 80.1, 56.1, 54.2, 34.9.

4.2.3 2-Amino-6-hydroxy-4-(nitromethyl)-4*H*-chromene-3-carbonitrile (2c)

White crystal, 82% yield, m.p. 165°C (decomp.). – IR (ATR): ν = 3450, 3333, 2190, 1652, 1615, 1580, 1539, 1498, 1427, 1220 cm^{-1}. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 9.45 (s, 1H), 7.01 (s, 2H), 6.87–6.84 (d, J = 8.8 Hz, 1H), 6.71–6.68 (dd, J = 2.8, 8.8 Hz, 1H), 6.65 (d, J = 2.8 Hz, 1H), 4.74–4.69 (dd, J = 5.2, 12.4 Hz, 1H), 4.63–4.58 (dd, J = 5.6, 12.4 Hz, 1H), 4.22–4.19 (t, J = 5.2 Hz, 1H). – ^{13}C NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 162.4, 153.9, 142.1, 120.0, 119.9, 116.8, 115.8, 113.5, 80.7, 49.5, 34.9.

4.2.4 2-Amino-6-bromo-4-(nitromethyl)-4*H*-chromene-3-carbonitrile (2d)

White crystal, 89% yield, m.p. 181–182°C. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 7.70 (d, J = 2.4 Hz, 1H), 7.57–7.54 (dd, J = 2.4, 8.8 Hz, 1H), 7.07–7.05 (d, J = 8.8 Hz, 1H), 4.95–4.91 (dd, J = 5.2, 12.4 Hz, 1H), 4.78–4.74 (dd, J = 4.8, 12.8 Hz, 1H), 4.41–4.39 (t, J = 4.8 Hz, 1H), 3.37 (s, 2H). – ^{13}C NMR ($CDCl_3$, 600 MHz, 25°C, TMS): δ = 161.3, 148.4, 132.7, 130.6, 120.7, 118.6, 118.2, 118.1, 79.6, 34.5, 29.7.

4.2.5 2-Amino-6-*tert*-butyl-4-(nitromethyl)-4*H*-chromene-3-carbonitrile (2e)

White crystal, 86% yield, m.p. 121–123°C. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 7.30 (d, J = 5.6 Hz, 1H), 7.10 (s, 1H), 6.95 (d, J = 5.6 Hz, 1H), 4.99 (bs, 2H), 4.60 (dd, J = 3.2, 8 Hz, 1H), 4.46 (dd, J = 5.2, 8 Hz, 1H), 4.36–4.34

(t, J = 4 Hz, 1H), 1.27 (s, 9H). – ^{13}C NMR ($CDCl_3$, 600 MHz, 25°C, TMS): δ = 162.0, 148.7, 146.9, 126.5, 124.5, 119.0, 117.9, 116.2, 80.5, 53.5, 35.1, 34.4, 31.2.

4.2.6 2-Amino-6,8-di-*tert*-butyl-4-(nitromethyl)-4*H*-chromene-3-carbonitrile (2f)

White crystal, 91% yield, m.p. 115°C. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 7.23 (d, J = 2 Hz, 1H), 7.15 (bs, 3H), 4.68–4.63 (dd, J = 6.4, 12 Hz, 1H), 4.62–4.57 (dd, J = 6, 12 Hz, 1H), 4.25–4.22 (t, J = 6 Hz, 1H), 1.36 (s, 9H), 1.25 (s, 9H). – ^{13}C NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 162.1, 146.1, 145.9, 136.2, 122.9, 122.6, 119.7, 119.6, 81.0, 49.7, 35.5, 34.5, 34.1, 31.0, 29.9.

4.2.7 3-Amino-1-(nitromethyl)-1*H*-benzo[*f*]chromene-2-carbonitrile (2g)

Yellow crystal, 96% yield, m.p. 157–159°C. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 8.09–8.06 (d, J = 8.8 Hz, 1H), 8.00–7.98 (d, J = 8 Hz, 1H), 7.96–7.94 (d, J = 9.2 Hz, 1H), 7.68–7.67 (t, J = 7.2 Hz, 1H), 7.56–7.53 (t, J = 8 Hz, 1H), 7.25–7.23 (m, 3H), 4.99–4.97 (t, J = 4.4 Hz, 1H), 4.75 (d, J = 4.4 Hz, 2H). – ^{13}C NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 162.2, 147.8, 130.6, 129.9, 129.4, 128.7, 127.6, 125.2, 122.2, 119.7, 116.5, 111.9, 79.7, 50.4, 32.4.

4.2.8 2-Amino-4-(nitroethyl)-4*H*-chromene-3-carbonitrile (3a)

Yellow solid, 98% yield, m.p. 159°C (decomp.). – IR (ATR): ν = 3432, 3320, 3199, 2199, 1636, 1539, 1418, 759 cm^{-1}. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 7.36–7.33 (m, 2H), 7.29 (d, J = 4.8 Hz, 1H), 7.25 (bs, 2H), 7.24 (bs, 2H), 7.21–7.15 (m, 3H), 7.08–7.04 (m, 2H), 4.83–4.79 (m, 1H), 4.78–4.75 (m, 1H), 4.25 (d, J = 3.2 Hz, 1H), 4.20 (d, J = 2.8 Hz, 1H), 1.35 (d, J = 4.4 Hz, 3H), 1.21 (d, J = 4.0 Hz, 3H). – ^{13}C NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 163.1, 162.9, 149.8, 149.7, 129.1, 128.4, 128.2, 124.73, 124.70, 120.2, 119.8, 119.7, 119.3, 116.1, 115.9, 87.3, 86.9, 49.1, 48.3, 40.4, 39.9, 39.8, 14.1, 13.5.

4.2.9 2-Amino-8-methoxy-4-(nitroethyl)-4*H*-chromene-3-carbonitrile (3b)

Yellow solid, 80% yield, m.p. 165°C (decomp.). – IR (ATR): ν = 3394, 3055, 2987, 2196, 1651, 1583, 1551, 1265, 736, 703 cm^{-1}. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 7.09–7.05 (m, 2H), 6.89–6.87 (m, 2H), 6.69 (d, J = 5.2 Hz, 1H), 6.53 (d, J = 5.2 Hz, 1H), 5.16 (bs, 2H), 5.12 (bs, 2H), 4.69–4.65 (m, 1H), 4.53–4.49 (m, 1H), 4.38 (d, J = 2.8 Hz, 1H), 4.17 (d, J = 4.0 Hz, 1H), 3.87 (s, 6H), 1.55 (d, J = 4.4 Hz, 3H), 1.33 (d, J = 4.4 Hz, 3H). – ^{13}C NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 162.8, 162.3, 147.6, 147.4, 139.6, 139.3, 125.4, 125.3, 120.8, 119.4, 119.3, 119.2, 119.1, 118.5, 111.8, 111.6, 87.8, 86.1, 55.9, 54.0, 52.6, 40.5, 40.4, 29.6, 14.9, 12.8.

4.2.10 2-Amino-6-hydroxy-4-(nitroethyl)-4*H*-chromene-3-carbonitrile (3c)

Yellow solid, 76% yield, m.p. 115°C (decomp.). – IR (ATR): ν = 3399, 3341, 2958, 2929, 2852, 2181, 1731, 1274, 744 cm^{-1}. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 9.48 (bs, 1H), 7.12 (bs, 2H), 6.87 (d, J = 5.6 Hz, 1H), 6.69 (d, J = 5.6 Hz, 1H), 6.60 (s, 1H), 4.72–4.68 (m, 1H), 4.13 (d, J = 3.2 Hz, 1H), 1.28 (d, J = 4.4 Hz, 3H). – ^{13}C NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 163.5, 153.9, 142.5, 120.5, 116.8, 115.7, 113.7, 86.9, 47.8, 40.3, 28.9, 13.5. – HRMS ((+)-ESI): m/z = 262.1945 (calcd. 262.0783 for $C_{11}H_{11}N_3O_4$, $[M+H]^+$).

4.2.11 2-Amino-6-bromo-4-(nitroethyl)-4*H*-chromene-3-carbonitrile (3d)

White solid, 92% yield, m.p. 179°C (decomp.). – IR (ATR): ν = 3438, 3323, 3276, 3191, 2923, 2855, 2193, 1648, 1598, 1033, 827 cm^{-1}. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 7.54–7.49 (m, 4H), 7.32 (bs, 2H), 7.30 (bs, 2H), 7.04 (d, J = 5.6 Hz, 1H), 7.01 (d, J = 6.0 Hz, 1H), 4.89–4.85 (m, 1H), 4.84–4.81 (m, 1H), 4.31 (d, J = 2.8 Hz, 1H), 4.20 (d, J = 2.0 Hz, 1H), 1.42 (d, J = 4.4 Hz, 3H), 1.29 (d, J = 4.0 Hz, 3H). – ^{13}C NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 162.9, 162.7, 149.13, 149.11, 131.9, 131.7, 130.9, 130.8, 130.7, 122.4, 122.2, 120.2, 119.5, 118.3, 118.1, 116.2, 116.1, 87.5, 86.5, 48.3, 48.13, 48.10, 14.7, 13.4.

4.2.12 2-Amino-6-*tert*-butyl-4-(nitroethyl)-4*H*-chromene-3-carbonitrile (3e)

Yellow solid, 86% yield, m.p. 130–132°C. – IR (ATR): ν = 3479, 3326, 2957, 2905, 2201, 1636, 1545, 1533, 1430, 1386, 1362, 1277, 821 cm^{-1}. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 7.30 (m, 2H), 7.10 (s, 1H), 6.97–6.91 (m, 3H), 5.03 (bs, 2H), 4.99 (bs, 2H), 4.70–4.68 (m, 1H), 4.54–4.49 (m, 1H), 4.38 (d, J = 2.4 Hz, 1H), 4.18 (d, J = 4.4 Hz, 1H), 1.56 (d, J = 4.4 Hz, 3H), 1.31 (d, J = 4.4 Hz, 3H), 1.28 (s, 9H), 1.26

(s, 9H). – ^{13}C NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 162.9, 162.5, 148.7, 148.5, 147.8, 147.6, 126.3, 126.2, 125.0, 124.7, 119.6, 119.2, 118.9, 116.5, 116.0, 115.7, 88.1, 86.2, 54.1, 52.5, 40.7, 40.6, 34.4, 34.3, 31.2, 31.1, 15.0, 12.3. – HRMS ((+)-ESI): *m/z* = 302.2785 (calcd. 302.1460 for $C_{16}H_{19}N_3O_3$, $[M+H]^+$).

4.2.13 2-Amino-6,8-di-*tert*-butyl-4-(nitroethyl)-4*H*-chromene-3-carbonitrile (3f)

Yellow solid, 90% yield, m.p. 161–163°C. – IR (ATR): ν = 3426, 3335, 2958, 2867, 2187, 1669, 1551, 1407, 1171 cm^{-1}. – ^{1}H NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 7.30 (s, 2H), 6.96 (s, 1H), 6.79 (s, 1H), 5.01 (bs, 2H), 4.97 (bs, 2H), 4.68–4.64 (m, 1H), 4.52–4.48 (m, 1H), 4.32 (d, *J* = 2.8 Hz, 1H), 4.14 (d, *J* = 4.4 Hz, 1H), 1.56 (d, *J* = 4.4 Hz, 3H), 1.39 (bs, 18H), 1.32 (d, *J* = 4.4 Hz, 3H), 1.28 (s, 9H), 1.27 (s, 9H). – ^{13}C NMR (400 MHz, $CDCl_3$, 25°C, TMS): δ = 162.7, 162.2, 147.7, 147.5, 146.8, 146.6, 136.9, 136.6, 123.9, 123.8, 123.2, 122.9, 119.8, 119.4, 119.1, 117.4, 88.1, 86.4, 54.5, 53.1, 41.4, 41.3, 34.9, 34.8, 34.6, 34.5, 31.3, 31.2, 30.2, 30.1, 15.1, 12.9. – HRMS ((+)-ESI): *m/z* = 358.3628 (calcd. 358.2086 for $C_{20}H_{27}N_3O_3$, $[M+H]^+$).

4.2.14 3-Amino-1-(nitroethyl)-1*H*-benzo[*f*]chromene-2-carbonitrile (3g)

Yellow solid, 85% yield, m.p. 139°C (decomp.). – IR (ATR): ν = 3332, 3194, 2926, 2193, 1723, 1654, 1586, 1542, 1418, 1236, 739 cm^{-1}. – ^{1}H NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 8.13 (d, *J* = 5.6 Hz, 1H), 8.01 (d, *J* = 5.2 Hz, 1H), 7.99 (d, *J* = 6.0 Hz, 1H), 7.34 (t, *J* = 4.8 Hz, 1H), 7.57 (t, *J* = 5.2 Hz, 1H), 7.39 (bs, 2H), 7.29 (d, *J* = 6.0 Hz, 1H), 5.10 (d, *J* = 1.2 Hz, 1H), 4.93–4.89 (m, 1H), 1.16 (d, *J* = 4.4 Hz, 3H). – ^{13}C NMR (400 MHz, [D_6]DMSO, 25°C, TMS): δ = 163.2, 147.9, 130.7, 130.2, 129.2, 128.8, 127.9, 125.4, 119.5, 116.6, 112.6, 84.1, 47.7, 37.7, 15.9, 11.5. – HRMS ((+)-ESI): *m/z* = 296.2281 (calcd. 296.0991 for $C_{16}H_{13}N_3O_3$, $[M+H]^+$).

5 Supplementary information

^{1}H, ^{13}C NMR and HRMS spectra of all new compounds are given as Supplementary Information available online (https://doi.org/10.1515/znb-2017-0040).

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Graphical synopsis

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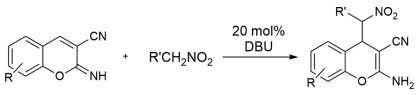
DBU-catalyzed synthesis of novel 2-amino-3-nitrile-4*H*-chromenes



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